REQUIREMENTS FOR THE TECHNOLOGY FLOW QUALIFICATION OF FLEXIBLE HEATERS

ESCC Basic Specification No. 2544009

Issue 1	December 2025

Document Custodian: European Space Agency – see https://escies.org

LEGAL DISCLAIMER AND COPYRIGHT

DOCUMENTATION CHANGE NOTICE

(Refer to https://escies.org for ESCC DCR content)

DCR No.	CHANGE DESCRIPTION

TABLE OF CONTENTS

1 PURPOSE

This specification provides additional information and requirements for the Qualification Approval of Flexible Heater Technology Flows and Components, and their inclusion on the ESCC Qualified Manufacturer's List (QML). It outlines the additional specific requirements for the definition of Technology Flow and its boundaries, the establishment of a Quality Management Programme, the preparation of a Process Capability and Reliability Assessment Programme, an Evaluation Test Programme and Qualification Test Programme, and the performance of an On-site Validation Audit.

This specification shall be read in conjunction with ESCC Basic Specification No. 25400.

This specification does not directly define detailed requirements for a component Manufacturer but instead defines the points which the Manufacturer must address in his Quality Management Programme.

2 APPLICABLE DOCUMENTS

The following documents 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 the Technology Flow certification.

- ESCC Basic Specification No. 20200, Component Manufacturer Evaluation
- ESCC Basic Specification No. 21300, Terms, Definitions, Abbreviations, Symbols and Units.
- ESCC Basic Specification No. 22600, Requirements for the Evaluation of Standard Electronic Components for Space Application
- ESCC Basic Specification No. 22700, Requirements and Guidelines for The Process Identification Document (PID)
- ESCC Basic Specification No. 25400, Requirements for the Technology Flow Qualification of Electronic Components for Space Application.
- ESCC Generic Specification No. 4009, Resistors, Heaters, Flexible.

3 TERMS, DEFINITIONS, ABBREVIATIONS, SYMBOLS AND UNITS

The terms, definitions, abbreviations, symbols and units specified in ESCC Basic Specification No. 21300 shall apply.

4 INTRODUCTION

ESCC Technology Flow qualification is the status granted to a Manufacturer's specified Technology Flow after successful completion of an evaluation, certification and qualification programme as defined in ESCC Basic Specification No. 25400, the relevant parts of ESCC Generic Specification No. 4009 and this specification. It is also the status granted to any component type which is both:

- Manufactured using, and within the boundaries defined for, a qualified Technology Flow.
- Defined by, and meets the requirements of, ESCC Generic Specification No. 4009 and the relevant ESCC Detail Specification.

5 DEFINITION OF TECHNOLOGY FLOW BOUNDARIES

5.1 GENERAL

The Manufacturer shall define the Technology Flow for which certification and qualification is sought, as required by ESCC Basic Specification No. 25400.

This Technology Flow definition shall also form the basis of a Process Identification Document (PID) to be produced by the Manufacturer which shall fulfil all of the requirements of ESCC Basic Specification No. 22700 in terms of content and configuration control. This definition must demonstrate that the Technology Flow and its corresponding boundaries represent a structured, properly controlled and monitored design methodology and manufacturing process for flexible heater technologies.

To meet these requirements, the definition should, as a minimum, address the areas listed in the following paragraphs at least to the extent detailed therein. The definition should cover all elements of the Technology Flow where a change could affect product performance and would therefore need to be reviewed by the Technology Review Board (TRB) before being introduced. Additional information should be supplied whenever necessitated by the particular nature of the technology under approval.

Within the definition of the Technology Flow, five areas are of particular concern:

- The component design and procedures which are closely related to the manufacturing process (see Para. 5.2)
- The design system and procedures used to implement the component design methodology (see Para. 5.3)
- Component manufacture and assembly including materials, technologies and processes applied (see Para. 5.4)
- Inspection and test requirements (see Para. 5.5)
- Traceability (see Para. 5.6)

These areas are addressed in the subsequent paragraphs.

NOTE: When considered necessary and appropriate by the Manufacturer, any information considered as proprietary may be made available to the ESCC Executive on a limited access basis for review only within the Manufacturer's facility.

5.2 COMPONENT DESIGN

The component design is governed by a set of technology specific rules and parameters, commonly called 'Design Rules'. These rules define the construction and composition of all structures foreseen for the design and manufacture of the component in a specific technology.

The description of the design requires the definition of at least the following characteristics:

(a) Physical, thermal and material design rule set which covers the following considerations:

- Heater resistive element (including material, thickness, track width, spacing)
- Heater physical configuration (including the heating area; individual, strip and module types; single- & double-layer types; Physical forming capabilities and limitations)
- Operating and storage temperature ratings
- Flexibility considerations
- Magnetic design
- Coatings, covers, adhesives/tapes, backing foil
- Terminals leads, connecting wires and bridging tabs (including nature and finishing)
- Marking

(b) The electrical rule and parameter set in terms of:

- Maximum power density
- Resistance, insulation resistance and voltage ratings
- Temperature coefficient
- Other electrical and parameters design rules used during conception.

(c) Other relevant parameters or restrictions not covered in the previous points such as the suitability to implement particular component design techniques.

5.3 DESIGN SYSTEM

The design methodology is defined by the design system and all other procedures applied in the design of a component. The design system comprises all software, basic design data and the hardware platform.

Technology Flow Qualification of a design system requires as a minimum:

- The implementation of a configuration control system guaranteeing the traceability of all software and data forming part of the system.
- The application of a quality assurance system addressing at least documentation procedures, acceptance testing prior to system release and the organisation of error reporting and corrective action procedures.

Both systems shall be fully documented, and their application must be evident.

At least the following items shall be covered in the PID:

(a) The design flow-chart including a general description of the design system plus block diagrams representing:
- The software structure of the system.
- The design flow, distinguishing between interactive and automatic actions.
- The data flow within the system, with emphasis on the dynamics of the accumulated design data.

(b) A description of the hardware platform (e.g. workstations, memory requirements, LAN, host computers, etc.).

(c) Software and associated data shall be described in terms of:
- The origin and version of the programme.
- A comprehensive description of its functional scope.
- The programming language and the amount of code.
- The memory requirements.
- Definition of data formats and description languages.
- Definition of programme interfaces.
- A description of the human interface with permitted or required interactivity, and output format.
- All software serving simulation type purposes require a detailed description of the underlying models and their parametric capability.

(d) A description of the configuration control system.

(e) A description of the quality assurance system.

5.4 MANUFACTURE AND ASSEMBLY

The Technology Flow definition shall as a minimum cover the following areas with regards to the manufacture of components within the boundaries of the Technology Flow.

5.4.1 Materials

The Manufacturer shall summarise the procedures for provision of materials used for the manufacture of components. The summaries should include, but not be limited to, the following areas:

- The selection and approval of the materials and vendors used.
- A list of materials used and associated procurement specifications.
- A list of incoming inspection procedures and other documents used to ensure the consistent quality of materials used.
- Procedures for traceability, and control of limited shelf-life items.

5.4.2 Technologies

The Manufacturer shall summarise the basic technologies used for the manufacture and assembly of components. The summaries should include, but not be limited to, the following areas:

- Type of heater (e.g. flexible, rigid, foil, etc.).
- Materials preparation processes.
- Lot definition.
- Assembly process sequence.
- Finishing (e.g. coating, covers, adhesives/tapes, backing foil, marking, etc.).
- Terminals, leads, and connection methods (e.g. type of leads, soldering, crimping, connector types, strain reliefs, and finishing of terminals).

5.4.3 Processes

The Manufacturer shall summarise the processes for the manufacture and assembly of components. They shall also give reference to the documents specifying the processes. The summaries, which shall include a statement on the equipment used, should include, but not be limited to, the following areas:

- Lot formation.
- Physical location of the manufacturing facility.
- Clean room conditions.
- Rework procedures.
- Handling and storage conditions.

5.5 INSPECTION AND TEST

The Manufacturer shall summarise the inspection and test facility characteristics for the manufacture and assembly of components. The test facility characteristics to be covered by the summaries should include, but not be limited to, the following areas:

- Implementation procedures for external visual or other test methods.
- Testing flow.
- Physical location of the test facility.
- Sample plans (quantity and acceptance numbers).
- Test procedures.
- Lot formation.

The Manufacturer shall summarise the inspection and test methods giving references to the documents specifying the methods. The summaries should include, but not be limited to, the following areas:

- Incoming inspection testing
- In-process controls/inspections & acceptance criteria
- Statistical process control (SPC) implementation
- Production control testing
- Customer Source Inspections
- Screening tests and associated electrical tests.
- Qualification testing.
- Periodic testing and Lot Validation Testing.

5.6 TRACEABILITY

The Manufacturer shall summarise his traceability system that allows for traceability from the component to a specific production lot. The summaries should include, but not be limited to, the following areas:

- The use of purchase orders and specifications.
- The use of route sheets and travellers.
- The traceability of materials, test vehicles, and components.

6 QUALITY MANAGEMENT PROGRAMME

As specified in ESCC Basic Specification No. 25400

7 TECHNOLOGY CHARACTERISATION VEHICLES

Test vehicles (TV) which are required for evaluation and qualification, shall be described in the PID. Production shall be to the highest level specified in the PID. The TV should address the following requirements:

- Process and Device Characteristics
  Test vehicles shall enable the verification of all relevant material, process and device parameters.
- Complexity
  The TVs should exercise the functionality of the process Technology Flow and be of a representative complexity.
- Design
  The TVs should be designed to stress the design capabilities of the process. The architecture of the TVs should be designed so that failures can be easily diagnosed.
- Manufacture
  The TVs should be processed on a manufacturing line which is intended to be, or already is, a certified ESCC QML line.

8 PROCESS CAPABILITY AND RELIABILITY ASSESSMENT PLAN AND EVALUATION TEST PLAN

8.1 GENERAL

As part of evaluation, the Manufacturer shall perform tests and analyses on suitable test vehicles. These actions shall be designed to demonstrate, together with any existing information, the capabilities of the total manufacturing process with regard to quality, reliability and producibility, and its suitability for producing space level components. The necessary activities shall be described in either a process capability and reliability assessment plan, and/or an evaluation test plan, which should cover all design, assembly, test and control processes which comprise the total manufacturing process.

As a minimum the plans must generate sufficient information to allow for a process capability demonstration covering:

(a) Component Design.
(b) SPC or in-process monitoring programmes.
(c) Assembly.
(d) Test Vehicle Testing.

8.2 DESIGN

In the plan(s), the Manufacturer should address the methodology for the following areas of component design. The design procedure and tools should be controlled in such a manner that the ensuing component design performs only with limits that have been shown to be reliable for the technology being used, within the constraints of established design rules.

(a) Component design
It shall be demonstrated that all models utilised in the design process are functional, predictable and accurate over the worst-case temperature and electrical extremes. It shall be demonstrated that the procedures used for design are capable of identifying all known design errors.

(b) Performance verification
Testing shall be performed on test vehicles representative of the full range of components covered by the technology flow to verify the performance of the component design is in line with the defined thermal and electrical design goals.

8.3 SPC AND IN-PROCESS MONITORING PROGRAMME

The Manufacturer should have an in-process monitoring system to control key processing steps to ensure device yield and reliability.

The critical operations to be monitored should be determined by the Manufacturer based on his experience and knowledge of his processes. The resulting data should be analysed by appropriate SPC methods to determine control effectiveness.

8.4 ASSEMBLY

The Manufacturer should demonstrate the capability of the component assembly processes by performing a qualification exercise on suitable test vehicles.

8.4.1 Assembly Processes

The Manufacturer should list the assembly processes that are expected to be used in the ESCC QML component assembly and should then qualify these processes by the testing of fully assembled test vehicles in accordance with appropriate tests for the assembly technology used.

The assembly process related tests given in ESCC Basic Specification No. 22600 and the appropriate ancillary Basic Specification and ESCC Generic Specification No. 4009 can be used by the Manufacturer as a guide to suitable qualification tests. Sample sizes should be defined by the TRB.

8.4.2 Construction/Technology Styles

The Manufacturer should document, for ESCC QML products, how the different component physical construction/technology types are qualified. In particular, the Manufacturer should document his criteria for deciding which component types can be treated as similar and show how these are grouped together for qualification and change control purposes. Construction/technology style qualification test methodologies, vehicles and results should be available.

The construction/technology related tests given in ESCC Basic Specification No. 22600 and the appropriate ancillary Basic Specification and ESCC Generic Specification No. 4009, can be used by the Manufacturer as a guide to suitable testing. Sample sizes should be defined by the TRB.

8.5 TEST VEHICLE RELIABILTY TESTING

As part of evaluation, as a minimum, the quantity of suitable test vehicles specified in the Process Capability and Reliability Assessment Programme, or the Evaluation Test Programme shall be subjected to a range of qualification level reliability tests. The related tests given in ESCC Generic Specification No. 4009, can be used by the Manufacturer as a guide to suitable testing. Sample sizes should be defined by the TRB. These test vehicles shall have passed all assembly acceptance criteria prior to testing. The results of these tests will serve as a qualification benchmark for the technology. Failure analysis should be performed on failed TVs to determine each failure category, and action should be proposed and taken for correcting any problems found. The TV reliability data, including failure analysis results, should be prepared in a suitable form for review by the ESCC Executive.

9 ON-SITE VALIDATION AUDIT

9.1 GENERAL

The on-site audit by the ESCC Executive shall be performed in accordance with the requirements of ESCC Basic Specifications No. 20200 and No. 25400 and will cover, as a minimum, the following applicable areas of the Manufacturer's facility:

- Management.
- Quality assurance.
- Design.
- Manufacture.
- Assembly.
- Electrical test.

The on-site validation will be performed only after a satisfactory review of the Manufacturer’s QM plan and self-validation results.

9.2 TECHNOLOGY VALIDATION

A satisfactory review of the following areas during validation by the ESCC Executive, where applicable, is seen as critical for ESCC QML certification and should cover:

- Design procedures.
- Design review procedures.
- Software configuration and configuration management.
- Archival system.
- Test vehicle tests and data.
- SPC and/or In-process monitoring programmes.
- Design rule documentation.
- Clean room procedures.
- Piece part traceability.
- Assembly rework procedures.
- Device traceability and travellers.
- Lot formation (device and inspection).
- Assembly area environmental control.
- Visual inspection.
- Human contamination prevention procedures.
- Equipment calibration and maintenance.
- Training policy and procedures.
- Electrical test procedures.
- Screening procedures.
- Periodic testing procedures.
- Qualification test plan.

10 QUALIFICATION TEST PLAN

10.1 QUALIFICATION TEST VEHICLES

The qualification test programme should define the relevant number of qualification test vehicles to cover the certified Technology Flow which the Manufacturer will produce on the certified manufacturing line. The qualification test vehicles should be of such complexity as to be representative of the ESCC QML components to be supplied by the Manufacturer. Each vehicle should operate and perform in compliance with the device specification and should be suitable for space use and which will not induce additional failures.

10.2 QUALIFICATION TEST PLAN

The qualification test plan should detail the test flow, test limits, test data to be measured, recorded and analysed, test sampling techniques and traceability records. As a baseline, the test flow should be based on the qualification testing specified in ESCC Generic Specification No. 4009 and the electrical measurements should be those given in the appropriate Detail Specification. The qualification test plan must be agreed and approved between the Manufacturer and the ESCC Executive.

10.3 QUALIFICATION TEST REPORT

The Manufacturer should present to the ESCC Executive an analysis of the qualifying data. The aim of this analysis is to show that all process variables are under control and repeatable within the certified technology and that parametric monitor, TV data monitoring is adequate and can be correlated to the process. The ESCC Executive should be notified of any improvements/changes to the certified ESCC QML Technology Flow as a result of evaluation of the qualification test results. The following data, if applicable, should be addressed and retained by the Manufacturer to support the results:

- Thermal Resistance calculation from the design process.
- Test data monitoring.
- Results of each subgroup test conducted, both initial and any resubmission.
- Number of devices tested and rejected.
- Failure mode and mechanism for each rejected device.
- Read and record variables data on all specified electrical parameter measurements.
- Where delta limits are specified, variable data, identified to the component serial number, should be provided for initial and final measurements.
- physical dimensions are checked, the actual dimensions of three randomly selected components should be recorded, except where verification of dimensions by calibrated gauges, overlays, or other comparative dimensions verification devices has been approved.
- For terminal strength testing, the forces at the time of failure and the failure category, or the minimum and maximum readings of the components if no failures occur.

10.4 QUALIFICATION TEST FAILURES

If any particular testing results are not successful, the Manufacturer should perform failure analysis and take any necessary corrective action after consultation with the ESCC Executive. The Manufacturer should notify the ESCC Executive of any decision not to pursue qualification of any material or manufacturing construction technique previously certified. After corrective actions have been implemented, qualification testing should restart.

11 PROCUREMENT

Procurement of components manufactured within the boundaries of the qualified Technology Flow shall be in accordance with the requirements of ESCC Generic Specification No. 4009.