EVALUATION TEST PROGRAMME

FOR

QUARTZ CRYSTALS UNITS

ESCC Basic Specification No. 2263501

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ESA/SCC Basic Specification No. 2263501

space components
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1. INTRODUCTION

1.1 PURPOSE

The purpose of this specification is to establish the procedure to be followed in the evaluation of component capabilities as required for space applications and thereby to anticipate, as far as possible, component behaviour during qualification testing. Therefore, the aim of such testing shall be to overstress specific characteristics of the component concerned with a view to the detection of possible failure modes. Since the behaviour of a crystal depends on the material quality, an initial material analysis shall be performed on the crystal before manufacture. Additionally, a detailed destructive physical analysis shall be performed to detect any design and construction defects which may affect the reliability of the component and to facilitate failure analysis activities.

1.2 SCOPE

This specification covers quartz crystal units as detailed in the ESA/SCC Generic Specifications listed in Para. 2.2 below.

2. APPLICABLE DOCUMENTS

2.1 GENERAL

The following documents (as applicable) form part of, and shall be read in conjunction with, this specification.

2.2 ESA/SCC SPECIFICATIONS

No. 3501 - Generic Specification for Quartz Crystal Units.

No. 20400 - Internal Visual Inspection.

No. 20435 - Internal Visual Inspection of Quartz Crystal Units.

No. 20500 - External Visual Inspection.

No. 20535 - External Visual Inspection of Quartz Crystal Units.

No. 20900 - Radiographic Inspection.

No. 22700 - Requirements and Guidelines for P.I.D.

No. 22900 - Total Dose Steady-State Irradiation Test Method.

Unless otherwise stated herein, reference within the text of this specification to "the Basic, Generic or Detail Specification" shall mean the relevant ESA/SCC Basic, Generic or Detail Specification.

2.3 OTHER (REFERENCE) DOCUMENTS

ESA PSS-01-702, A Thermal Vacuum Test for the Screening of Space Materials.

IEC Publication No. 68, Basic Environmental Testing Procedures.

3. PROCEDURE

Before any manufacturing operations, an analysis of the quartz crystal(s) shall be performed.

Quartz crystal units shall be manufactured as a homogenous lot. These components shall not have been submitted to any screening or burn-in before the test programme, but must have been manufactured in conformity with high reliability practice and an established Process Identification Document (PID) or an identifiable process which shall form the basis for a PID.

The tests specified in the programme shall be performed in the sequence shown in Chart I. All results shall be recorded and failed components submitted to a failure analysis. Probable failure modes and mechanisms shall be determined.

The evaluation test programme shall be performed, under the supervision of the Qualifying Space Agency (QSA) for whom the evaluation of the component concerned is required, by the Manufacturer or at a test laboratory approved by the QSA.

4. TEST PROGRAMME SEQUENCE AND SAMPLE DISTRIBUTION

4.1 GENERAL

The number of components chosen for evaluation testing shall depend upon whether a single component type or a family of parts is evaluated and the number of component types chosen to represent the family.

Not less than 86 specimens shall be used for each test programme.

The component types chosen to represent a family shall cover the range of components to be evaluated and be representative of the different configurations under consideration. They shall also be the most suitable for highlighting those characteristics and parameters that are pertinent to an investigation into failure modes and weaknesses.

The above mentioned quantity shall be submitted to the full evaluation procedure whenever a new technology has been applied to the components concerned, such that there is insufficient experience in their production.

4.2 DETAIL SPECIFICATION(S)

Should a Detail Specification(s) for the device(s) to be evaluated not exist, the Manufacturer shall prepare such a document(s) in accordance with the established ESA/SCC format and submit it to the appropriate QSA for provisional approval. This shall then serve as a basis for the ordering and testing of the relevant components.

4.3 INSPECTION RIGHTS

The QSA reserves the right to inspect at any time the components processed for evaluation purposes. The Manufacturer shall notify the QSA at least 8 working days in advance of the date of internal visual inspection (but see Para. 4.4 below).

4.4 CONTROL DURING FABRICATION

The components shall be procured with reference to an established PID. Internal visual inspections shall be performed on the lot to be tested to the extent that this forms part of the Manufacturer's standard procedures. Progress of the components shall be observed closely and recorded, together with an anlysis of any rejects. A chart showing the numbers in/out and failure cause for each fabrication stage shall be submitted to the QSA.

5. INSPECTION

5.1 GENERAL

The components shall be checked to verify their suitability for the Evaluation Test Programme. Defects or deviations from the established ESA/SCC requirements may invalidate the evaluation.

5.2 QUARTZ CRYSTAL CHARACTERISATION

Before any manufacturing operations, an analysis of the quartz crystal material shall be performed. This analysis shall consist, as minimum, in characterisation of dislocation density and metal-ion inclusion density.

When the Quartz material is delivered according to a quality level, it shall be verified that the material shall conform to the Certificate of Conformity. Rejected materials shall not be used.

5.3 DIMENSIONS (10 Parts)

All devices shall be inspected in accordance with Figure 2 of the Detail Specification and the results recorded together with any non-conformities. Rejected components shall be replaced.

5.4 ELECTRICAL MEASUREMENTS (100%)

These measurements shall be performed in accordance with Table 2 and Table 3 of the Detail Specification. Rejected components shall be replaced.

5.5 EXTERNAL VISUAL INSPECTION (100%)

All devices shall be inspected in accordance with Basic Specification No. 20500 and No. 20535 (as appropriate from Para. 2.2 above). Rejected components shall be replaced.

5.6 RADIOGRAPHIC INSPECTION (100%)

Unless otherwise stated in the Generic and/or Detail Specification, all devices shall be inspected in accordance with Basic Specification No. 20900. Rejected components shall be replaced.

5.7 HERMETICITY (100%)

Unless otherwise stated in the Generic and/or Detail Specifications, fine and gross leak tests shall be performed on all components in accordance with the requirements of the appropriate paragraph in the relevant Generic Specification. Rejected components shall be replaced.

5.8 MARKING AND SERIALISATION (100%)

All components shall be marked and serialised in accordance with the standard procedures of the Manufacturer concerned.

5.9 COMPLETION OF INSPECTION

The completion of inspection shall result in a batch of components that have been verified as to their suitability for the Evaluation Test Programme, i.e. each component has satisfied the requirements of Paragraphs 5.2 to 5.7 above, inclusive.

6. INITIAL ELECTRICAL MEASUREMENTS (100% read and record)

These measurements shall be made according to Table 2 and Table 3 of the Detail Specification. All characteristics shall be recorded against serial numbers.

7. EVALUATION TEST PROGRAMME

7.1 GENERAL

The evaluation tests shall be performed as specified in Chart I. The components shall be randomly divided into 3 groups and their associated subgroups in the proportions indicated in Chart I. When a family of components is under investigation, the variations within that family must be represented in each group/subgroup. The Group 2 tests shall be completed and the results analysed before the Group 3 tests are commenced.

All failed components shall be analysed. The depth of analysis shall depend on the circumstances in which failure occurred and on whether useful information may be gained. As a minimum, the failure mode shall be determined in each case. Components not failing catastrophically, i.e. those displaying out-of-tolerance electrical parameters, shall not be removed from the test sequence, but monitored to observe degradation trends.

7.2 GROUP 1 - CONTROL GROUP

This group shall be retained for comparison purposes. Parts shall be stored at ambient temperature. Whenever electrical measurements are made on any devices under test, these devices shall also be measured.

7.3 GROUP 2 - MECHANICAL/ENVIRONMENTAL GROUP

7.3.1 General

This group shall be randomly divided into four subgroups in the proportions indicated in Chart I. Unless otherwise stated, general precision on resonance frequency measurements shall be $5\ 10^{-9}$.

7.3.2 Thermal Shock Step Stress

(a) **Procedure**

This test shall be performed for 50 thermal shocks in accordance with Para. 9.15 of ESA/SCC Generic Specification No. 3501.

(b) **Sequence and Measurements**

Electrical measurements shall be performed as follows:

- Initial: Table 2 of the Detail Specification.
- After 10, 100, 200, 500 cycles : Resonance Frequency.
- Final Measurements : Table 2 of the Detail Specification.

Variations on resonance frquency shall be calculated and plotted on graphic.

(c) **Final Inspection** : Hermeticity (see Para. 5.7).

7.3.3 Sinusoidal Vibration Step Stress

(a) **Procedure**

5 components with the thickest plate shall be tested in accordance with Para. 9.4 of ESA/SCC Generic Specification No. 3501, with the following exceptions.

The sequence shall be as follows:

- 20g, 30g and 50g with 2 cycles in each axis.
- 50g with 4 additional cycles in each axis.

(b) **Measurements**

Electrical measurements shall be performed as follows:

- Initial : Table 2 of the Detail Specification.
- Intermediate : Resonance Frequency
- Final Measurements : Table 2 of the Detail Specification.

Variations on resonance frquency shall be calculated and plotted on graphic.

7.3.4 Mechanical Shock Step Stress

(a) **Procedure**

5 components with the thickest plate shall be tested in accordance with Para. 9.3 of ESA/SCC Generic Specification No. 3501, with the following exceptions.

The sequence shall be as follows:

- 50g ½sinus 6ms.
- 100g ½sinus 6ms.
- 1500g ½sinus 0.5ms.
- 2000g ½sinus 0.1ms.

(b) **Measurements**

Electrical measurements shall be performed as follows:

- Initial : Table 2 of the Detail Specification.
- Intermediate : Resonance Frequency
- Final Measurements : Table 2 of the Detail Specification.

Variations on resonance frquency shall be calculated and plotted on graphic.

7.3.5 Accelerated Damp Heat

(a) **Procedure**
The crystals units shall be subjected to test 'Ca' of IEC Publication No. 68-2-3, severity 21 days and 56 days.

(b) **Measurements**

Electrical measurements shall be performed as follows:

- Intermediate : Resonance Frequency.
- Final Measurements : In accordance with Table 2 of the Detail Specification.
- After Damp Heat, the specimens shall be visually examined.

7.3.6 Irradiation Step Stress

Left intentionally blank.

7.3.7 Residual Gas Analysis

Residual Gas Analysis shall be performed on 4 components.

7.3.8 Construction Analysis

The purpose of this analysis, consisting of a series of examinations and evaluations, is to examine the construction of a device and to assess potential reliability hazards.

It shall also be used to evaluate the amount of degradation after tests as specified in Chart I. A full description of each type of component shall be made, with photographs to highlight the functional elements. The description shall include, but not be limited to, the component type, method of construction, materials and finishes and sealing techniques.

An analysis by SEM (Scanning Electron Microscope) shall be made to inspect metallisation of the electrodes and other details. A photographic record shall be made.

An angle analysis shall be performed to verify the orientation of the mechanical holding against quartz crystal direction.

It shall be performed on any quartz crystal units of interest from any subgroup, with a minimum of 4 components to be analysed.

7.4 GROUP 3 - ASSEMBLY CAPABILITY GROUP

7.4.1 General

This group shall be randomly divided into subgroups as indicated in Chart I. Unless otherwise specified, general precision on resonance frequency measurements shall be $5\ 10^{-9}$.

7.4.2 Resistance to Soldering Heat

(a) **Procedure**

The test "Ta" of IEC Publication No. 68-2-20, using Method 1 shall be performed.

(b) **Test Conditions:** The components shall be submitted to the following sequence:

Step	Temperature (°C)	Exposure Time (sec)
1	+260	10
2	+260	30
3	+260	60
4	+260	90
5	+260	120

(c) **Measurements**

Electrical measurements shall be performed as follows:

- Initial : Table 2 of the Detail Specification.
- Intermediate : Resonance Frequency and Resistance.
- Final Measurements : Table 4 of the Detail Specification.
- After the immersion, the specimens shall be visually examined.

Variations on Resonance Frequency shall be calculated.

7.4.3 Solderability

(a) **Procedure**

The components shall be mounted as follows:

- The solder shall be either preformed or a paste and be silver-bearing (2% eutectic Sn/Pb together with a non-active flux).
- The components shall be placed across the metallised land area of the substrate in such a manner that contact is made between terminals and substrate land area.
- The substrate shall be placed in a or on a suitable heat transfer unit (hot plate - tunnel oven) of which the temperature is maintained at +215 to +260°C until the solder melts and reflows as a homogeneous solder band, but for no longer than the maximum soldering time as defined in Table 1(b) of the Detail Specification.

(b) **Adhesion**

A force of 20N shall be applied normal to the line joining the terminations and in a plane parallel to the substrate, for a duration of 10 seconds.

At the conclusion of the test the components shall be visually inspected.

(c) **Measurements**

Electrical measurements shall be performed as follows:

- Initial : Table 2 of the Detail Specification.
- Final Measurements : Table 2 of the Detail Specification.

Variations on resonance frequency shall be calculated.

7.4.4 Robustness of Terminations

The crystal units shall be subjected to tests defined in Para. 9.16 of Generic Specification No. 3501.

7.4.5 Failure Analysis

All failed components shall be analysed. The depth of analysis shall depend upon the circumstances in which failure occurred and upon whether useful information may be gained. As a minimum, the failure mode shall be determined in each case. Components not failing catastrophically, i.e. those displaying out-of-tolerance electrical parameters, shall not be removed from the test sequence but shall be monitored to observe degradation trends.

7.5 GROUP 4 - MEASUREMENTS IN TEST OSCILLATOR GROUP

7.5.1 General

15 parts of AT cut and 15 parts of SC cut, equally distributed in 3 sublots for Accelerated Life Test. They shall be in oscillation during this step and measured automatically once a day during this test. The precision on resonance frequency measurements shall be $5\ 10^{-9}$. For the following tests, they shall be mounted in an OCXO and precision of measurements shall suit to the request.

7.5.2 Ageing

The components shall be put in an oven regulated at indicated temperature, and they shall be continously in oscillation mode.

Electrical measurements shall be performed as follows:

- Initial : Table 2 of the Detail Specification.
- Intermediate : Resonance Frequency. The resonators shall be measured automatically once a day during this test or at the following intermediate points: 0h, 96h, 168h, 500h and 1000h.
- Final Measurements : Table 2 of the Detail Specification.

Variations on resonance frequency shall be calculated and plotted on graphics.

7.5.3 Accelerometric Sensitivity

The crystal unit shall be regulated at temperature T_{PT} at drive level P_O in a test oscillator maintained under laboratory conditions and shall be placed as the sensitivity shall be determined in the axes X, Y and Z of the resonator (see Figure 2 of the Detail Specification).

Then it shall be submitted to the 2G-tipover method. The method is based on the turning over of the oscillator. The oscillator is placed on a table so that the Z axis of the crystal unit is vertical, a first measurement of frequency is performed F(+g). The oscillator is then turned upside down slowly and a second measurement is performed F(-g) after frequency stabilisation.

For n tipover, the Accelerometry Sensitivity on the Z axis is:

$$ASz = \frac{\sum_{i=1}^{n} \left| F_{i(+g)} - F_{i(-g)} \right| / F_0}{2 * n} \quad \text{(in } 10^{-10}/\text{g)}$$

Do the same for ASx and ASy, and calculate the modulus of the accelerometric sensitivity as:

$$AS = \sqrt{ASx^2 + ASy^2 + ASz^2}$$

A minimum of 5 tipovers shall be performed by axis.

7.5.4 Barometric Sensitivity

The crystal unit shall be regulated at temperature T_{PT} at drive level P_0 in a test oscillator maintained under laboratory conditions and introduced in a test chamber.

The frequency shall be measured after stabilisation in the following sequence:

1 bar (F_0), 2 mbar $(F\ P_{Min})$, 2 bars $(F\ P_{Max})$ and 1 bar.

The Barometric Sensitivity is obtained by:

$$BS = \frac{\left| F(P_{Max}) - F(P_{Min}) \right| / F_0}{P_{Max} - P_{Min}} \quad \text{(in } 10^{-10}\text{/Bar)}$$

7.5.5 Magnetic Sensitivity

The crystal unit shall be regulated at temperature T_{PT} at drive level P_O out of the test oscillator and placed in 3 axis Helmoltz coils as the sensitivity shall be determined in the axis X, Y and Z of Figure 2. The frequency shall be measured after frequency stabilisation for the successive magnetic fields:

0 (F_0), +B, 0, −B and 0 Gauss, in which B shall be measured and be successively 1, 2, 4 and 10 Gauss.

The Magnetic Sensitivity on the X axis is:

$$MSx = \frac{\sum_{i=1}^{4} \left| F_i - F_{i-1} \right| / F_0}{4 * B} \quad \text{(in } 10^{-12}\text{/Gauss)}$$

The Magnetic Sensitivity shall be plotted against magnetic field level on each axis.

8. DATA DOCUMENTATION

8.1 GENERAL REQUIREMENTS

An evaluation test report shall be established. All data shall be recorded against serial numbers and Quartz Crystal material. All data shall be conformed to each request of the relevant test paragraph. This shall comprise of the following:-

(a) Cover sheet.

(b) List of equipment (testing and measuring).

(c) Data from evaluation test programme (Chart I).

(d) Residual Gas Analysis (Para. 7.3.7), Construction Analysis (Para. 7.3.8), Quartz Crystal Characterisation (Para. 5.2) and Failure Analysis (Para. 7.4.5).

(e) Summary of results and conclusions.

8.2 COVER SHEET(S)

The cover sheet of the evaluation test report shall include as a minimum:-

(a) Reference to this document, including issue and date.

(b) Component type and number.

(c) Lot identification and Quartz Crystal material.

(d) Manufacturer's/test house's name and address.

(e) Location of the manufacturing plant/test house.

(f) Signature on behalf of the Manufacturer/test house.

(g) Total number of pages of the evaluation test report.

8.3 LIST OF EQUIPMENT USED

A list of equipment used for tests and measurements shall be included in the evaluation test report. Where applicable, this list shall contain the inventory number, Manufacturer type number, serial number etc. This list shall indicate for which tests such equipment was used.

8.4 DATA FROM EVALUATION TEST PROGRAMME (CHART I)

All data shall be recorded against serial numbers and Quartz Crystal material. All data shall be conformed to each request of the relevant test paragraph.

8.5 DATA FROM RESIDUAL GAS ANALYSIS, CONSTRUCTION ANALYSIS, QUARTZ CHARACTERISATION AND FAILURE ANALYSIS

All data shall be recorded against serial numbers and Quartz Crystal material. All data shall be confirmed to each request of the relevant test paragraph. This shall include specific requests as photographs, etc ...

8.6 SUMMARY OF RESULTS AND CONCLUSIONS

The above shall be briefly reviewed, indicating the success or otherwise of the Evaluation Test Programme. Any remarks with regard to the PID, the Detail Specification and the qualification test programme shall be outlined.

CHART I - EVALUATION TEST PROGRAMME

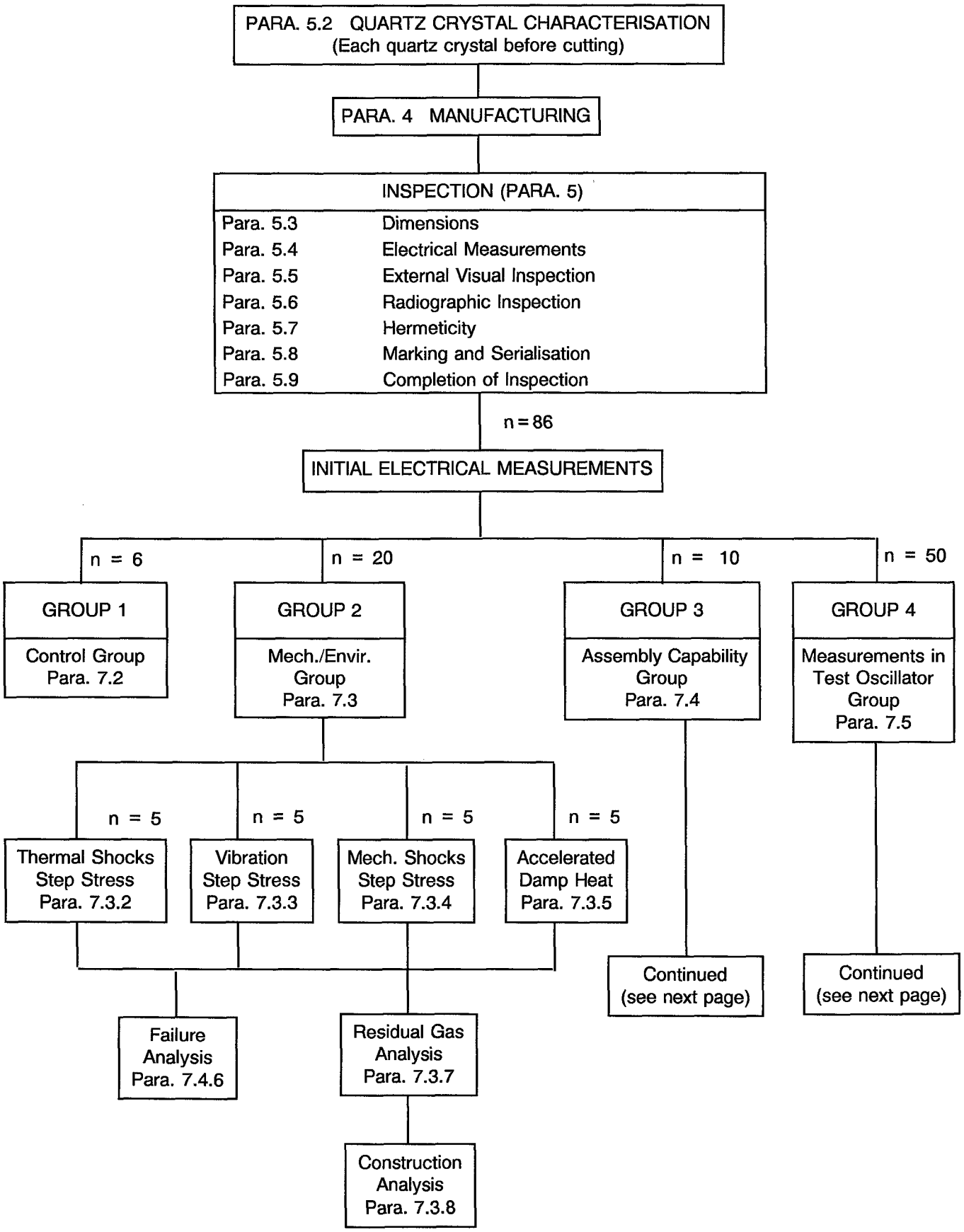
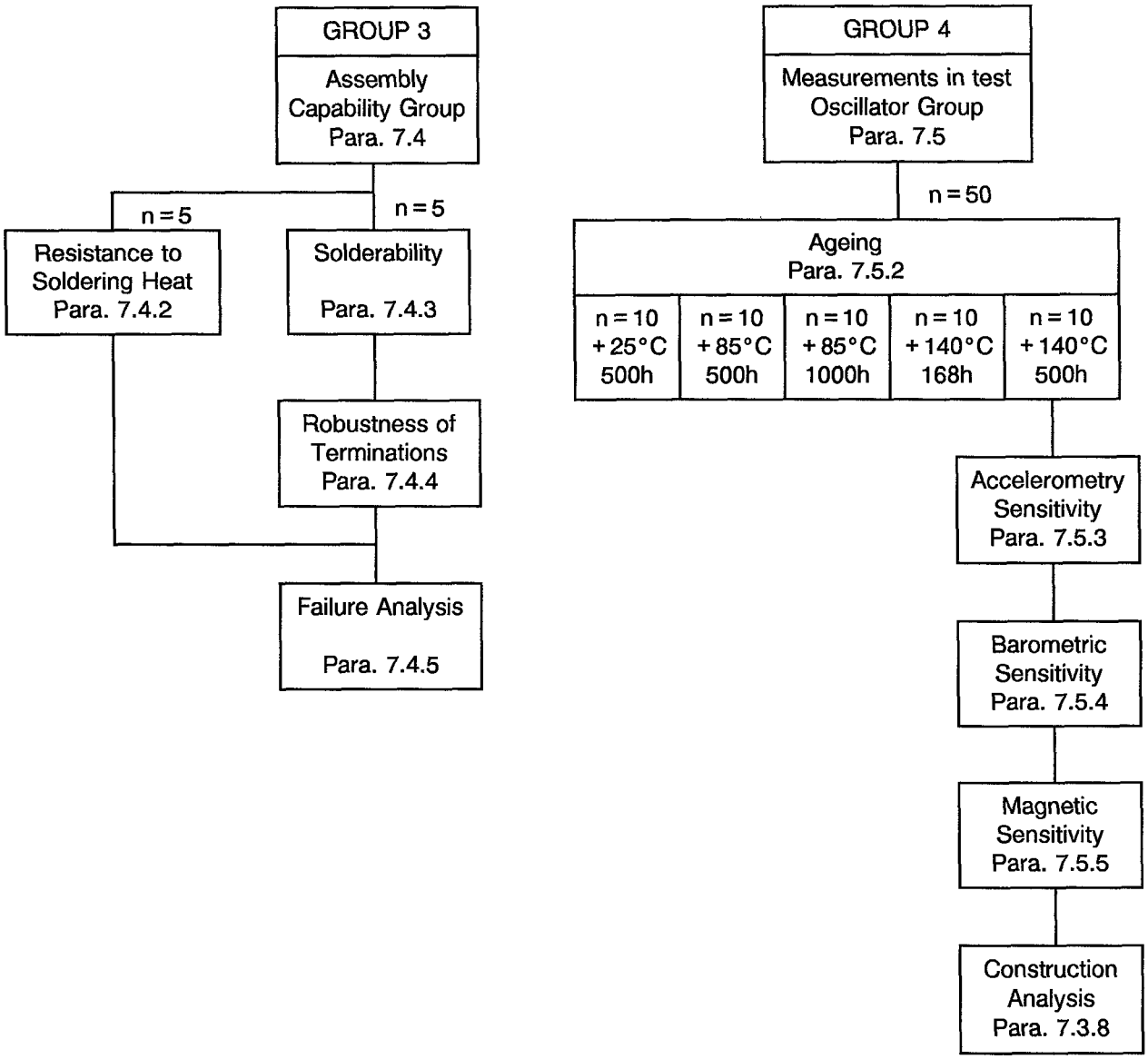


CHART I - EVALUATION TEST PROGRAMME (CONTINUED)



NOTES

1. Group 1: Parts shall be stored at ambient temperature.
2. Group 2: For Vibrations and Shocks: 2 parts of the thinnest plate, 2 parts of the thickest plate and 2 parts of intermediate thickness.
   For Irradiation: Each Quartz Crystal Sample shall be submitted to irradiation sequence and shall be examined at end of the sequences. AT cut and SC cut shall be equally distributed.
3. Group 3: No Comment.
4. Group 4: 15 parts of AT cut and 5 parts of SC cut, equally distributed in 3 sublots for Accelerated Life Test.

TABLE 1 - TEST METHOD, MEASUREMENTS AND INSPECTIONS AT INTERMEDIATE POINTS AND ON COMPLETION OF TESTS

GROUP 2 - MECHANICAL/ENVIRONMENTAL GROUP

TEST	TEST METHOD	TEST CONDITIONS	MEASUREMENTS	REMARKS
Thermal Shock Step Stress	Para. 7.3.2 Step 1 : 5 cycles Step 2 : 10 cycles Step 3 : 15 cycles Step 4 : 25 cycles Step 5 : 50 cycles	Para. 9.15 of 3501 −55°C, +125°C −55°C, +125°C −55°C, +125°C −55°C, +125°C −55°C, +125°C	Initial : Table 2 f_r f_r f_r f_r f_r Final : Table 2 Hermeticity	Graph Δf/f Δf/f calculation Δf/f calculation Δf/f calculation Δf/f calculation Δf/f calculation
Vibration Step Stress	Para. 7.3.3 Step 1 : 30g Step 2 : 40g Step 3 : 50g Step 4 : 60g Step 5 : 70g Step 6 : 80g	Para. 9.4 of 3501	Initial : Table 2 f_r f_r f_r f_r f_r Final : Table 2	Graph Δf/f Δf/f calculation Δf/f calculation Δf/f calculation Δf/f calculation Δf/f calculation
Mech. Shock Step Stress	Para. 7.3.4 Step 1 : 100g Step 2 : 120g Step 3 : 140g Step 4 : 160g Step 5 : 180g Step 6 : 200g	Para. 9.3 of 3501	Initial : Table 2 f_r f_r f_r f_r f_r f_r Final : Table 2	Graph Δf/f Δf/f calculation Δf/f calculation Δf/f calculation Δf/f calculation Δf/f calculation Δf/f calculation
Accelerated Damp Heat	Para. 7.3.5	Para. 9.14.4 of 3501	Initial : Table 2 Final : Table 2	
Irradiation Step Stress	Para. 7.3.6 5.0 krad/h | 25 krad/h 1.0 krad | 5 krad 3.0 krad | 10 krad 5.0 krad | 25 krad 10 krad | 50 krad 25 krad | 100 krad 300 krad 500 krad 1000 krad	ESA/SCC 22900	Initial : Table 2 and 3 f_r f_r f_r f_r f_r f_r f_r f_r Final : Table 2 and 3	Graph Δf/f Δf/f calculation Δf/f calculation Δf/f calculation Δf/f calculation Δf/f calculation Δf/f calculation Δf/f calculation Δf/f calculation
Quartz Crystal Characterisation	Para. 5.2			
Residual Gas Analysis	Para. 7.3.7			
Construction Analysis	Para. 7.3.8			
Failure Analysis	Para. 7.4.5			

TABLE 1 - TEST METHOD, MEASUREMENTS AND INSPECTIONS AT INTERMEDIATE POINTS AND ON COMPLETION OF TESTS (CONTINUED)

GROUP 3 - ASSEMBLY CAPABILITY GROUP

TEST	TEST METHOD	TEST CONDITIONS	MEASUREMENTS	REMARKS
Resistance to Soldering Heat	Para. 7.4.2 Step 1 : 10s Step 2 : 30s Step 3 : 60s Step 4 : 90s Step 5 : 120s	IEC 68-2-20 +260°C	Initial : Table 2 Initial : Table 2 Initial : Table 2 Initial : Table 2 Initial : Table 2 Initial : Table 2 Final : Table 2	
Solderability	Para. 7.4.3	Para. 7.4.3 Adhesion 20N	Initial : Table 2 Final : Table 2	Δf/f calculation
Robustness of Terminations	Para. 7.4.4	Para. 9.16 of 3501		
Failure Analysis	Para. 7.4.5			

GROUP 4 - MEASUREMENTS IN TEST OSCILLATOR

TEST	TEST METHOD	TEST CONDITIONS	MEASUREMENTS	REMARKS
Ageing	Para. 7.5.2	Para. 7.5.2 85°C 500h 105°C 500h 125°C 500h	Initial : Table 2 f_r/each day Final : Table 2	Graphs Δf/f Δf/f calculation Δf/f calculation Δf/f calculation
Accelerometry Sensitivity	Para. 7.5.3	Para. 7.5.3	Initial : f_r Intermediate : f_r Final : f_r	Δf/f calculation Δf/f calculation Δf/f calculation
Barometric Sensitivity	Para. 7.5.4	Para. 7.5.4	Initial : f_r Intermediate : f_r Final : f_r	Δf/f calculation Δf/f calculation Δf/f calculation
Magnetic Sensitivity	Para. 7.5.5	Para. 7.5.5	Initial : f_r Intermediate : f_r Final : f_r	Δf/f calculation Δf/f calculation Δf/f calculation
Construction Analysis	Para. 7.3.8			