

Mechanical Reliability Testing

Preface

MAXMAC evaluates ion modules through combined temperature/vibration, mechanical shock and free-fall testing. This note brings the three methods together with their fixture arrangements, process records, functional checks and physical observations.

The same six sample identifiers, 65#-70#, are retained across the three mechanical tests. Each test received a Pass judgment. The record documents normal function and current, normal appearance and structure, and post-drop LIN, ion-output and shake-check results. Subsequent internal inspection covered samples 69# and 70#.

Program at a Glance

Test	Recorded program	Result
Combined temperature / vibration	X, Y, Z; 8 h per axis; -40 to +85 °C; modes 3.1 / 3.2	Pass
Mechanical shock	500 m/s ² ; 6 ms half-sine; ±X, ±Y, ±Z; 10 pulses per direction; mode 3.2	Pass
Free fall	1.00 ± 0.05 m; two opposite-direction drops per sample; mode 1.1	Pass

Table 1 Overview of the three completed mechanical tests.

Tests and Follow-up Checks

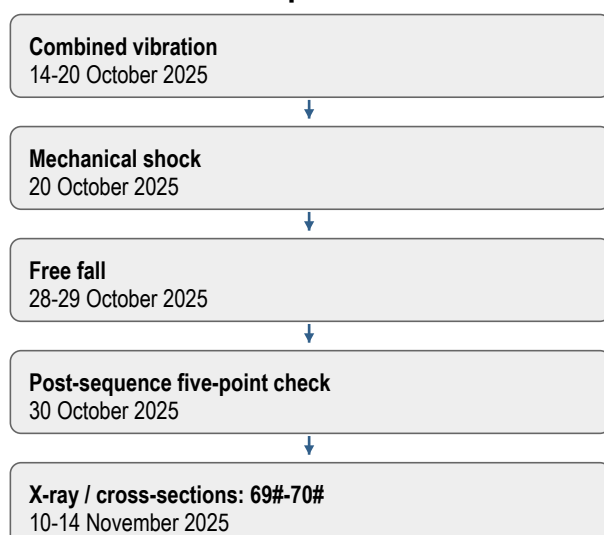


Figure 1 Mechanical stages and subsequent checks in the sample-group record.

Vibration and shock use a rigid fixture connection and connector routing matching the installed arrangement. The free-fall test uses assigned opposite directions for each sample.

Original Axis Definition

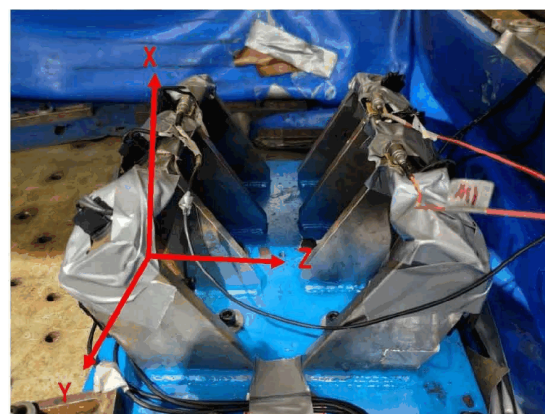


Figure 2 Original fixture photograph defining X, Y and Z directions.

What Is Checked

Function: working current, communication and ion generation.

Physical condition: appearance, structure and signs of loosened parts.

After free fall: recorded current, LIN, ion output, visual inspection and shake check for all six samples.

Combined Vibration: Temperature Program and Setup

Programmed Temperature Sequence for Each Axis

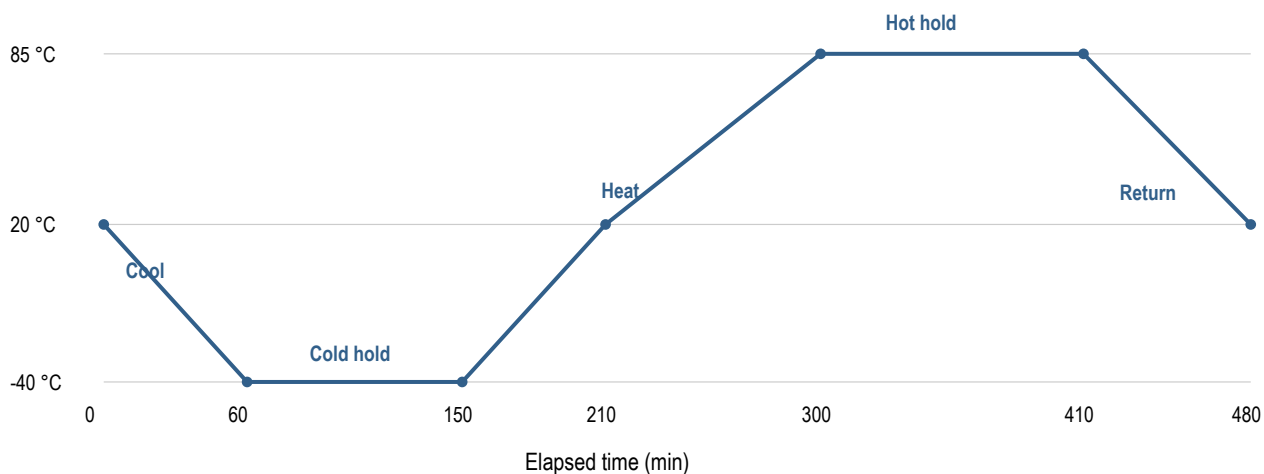


Figure 3 Programmed profile reconstructed from the recorded time-temperature nodes on source p. 50.

Cold hold: 150 – 60 = 90 min. **Hot hold:** 410 – 300 = 110 min.
Per axis: 480 min = 8 h. **Three axes:** 3 × 8 h = 24 h.

Applied Random-Vibration Spectrum

Frequency (Hz)	PSD ((m/s ²) ² /Hz)
5	0.884
10	20
55	6.5
180	0.25
300	0.25
360	0.14
1,000	0.14
2,000	0.14

Table 2 Applied spectrum from the third-party execution record, source p. 50.

Effective acceleration: 30.8 m/s².
Axis sequence: X → Y → Z.
Operating modes: 3.1 / 3.2.

Fixture and Control Sensors

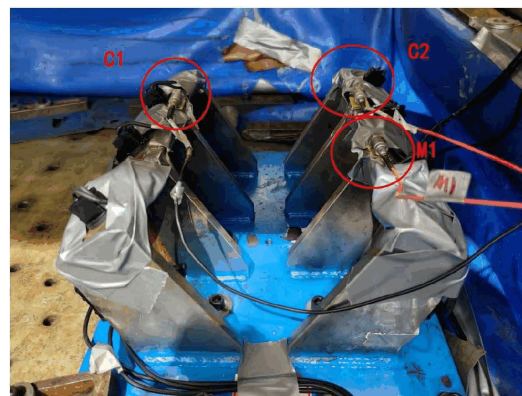


Figure 4 Control points C1/C2 and monitoring point M1 in the original photograph. Control uses the average of two points at the sample/fixture connections.

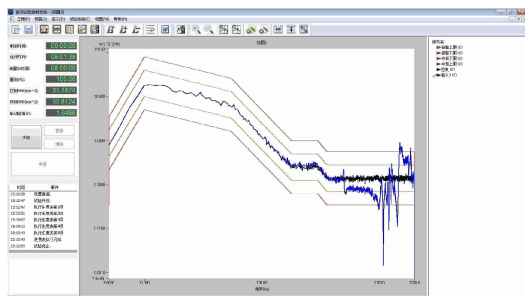
The module, mounting plate and test table form a rigid assembly. Connector routing follows the installed arrangement. The programmed temperature sequence accompanies each axis test.

Recorded observations: normal current with no obvious change during testing; no abnormality in appearance or structure afterward. Overall result: **Pass**.

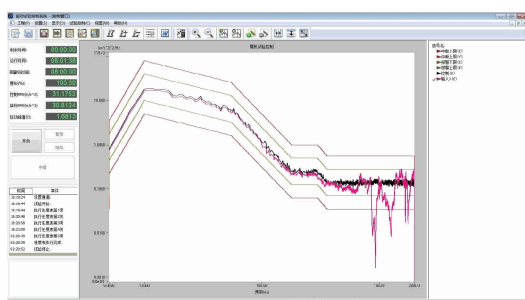
Three-Axis Vibration Records and Function Monitoring

Vibration Spectrum

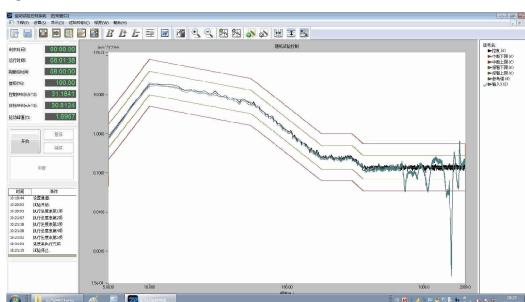
X axis



Y axis

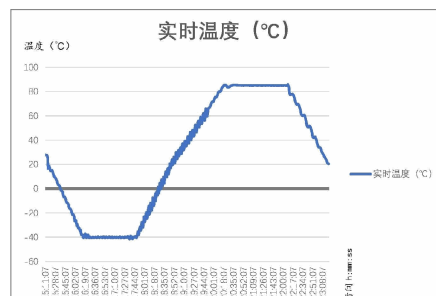


Z axis

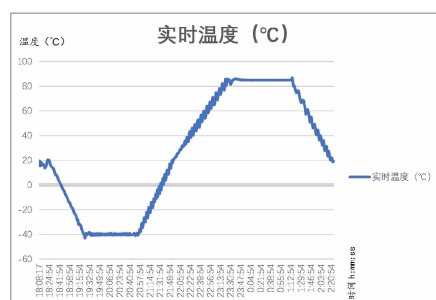


Recorded Temperature

X axis



Y axis



Z axis

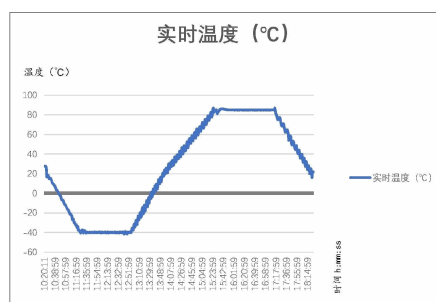
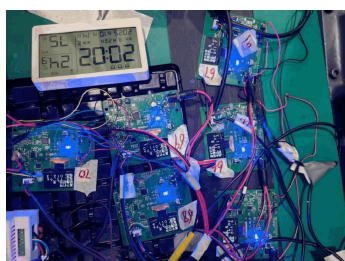
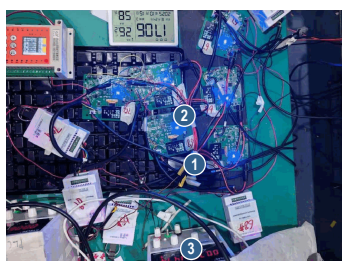


Figure 5 Original X-, Y- and Z-axis spectrum/temperature pairs, source pp. 55, 57 and 59.

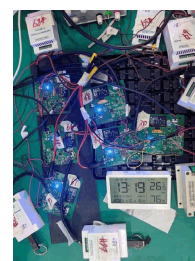
Function Monitoring during Each Axis Test



X-axis monitoring



Y-axis monitoring



Z-axis monitoring

Figure 6 Original monitoring photographs, source pp. 56, 58 and 60. Connected module interfaces and monitoring boards remain in place during the recorded axis tests. The source reports normal current with no obvious change.

Y-axis photo: 1 sample connections; 2 monitoring boards; 3 supply equipment.

Mechanical Shock: Conditions and Six-Direction Records

Shock Conditions

Parameter	Specified condition
Waveform	Half-sine
Peak acceleration	500 m/s ²
Pulse duration	6 ms
Directions	±X, ±Y, ±Z
Pulses	10 per direction
Operating mode	3.2

Per sample: $6 \times 10 = 60$ pulses.

Mounting and Sensor Arrangement

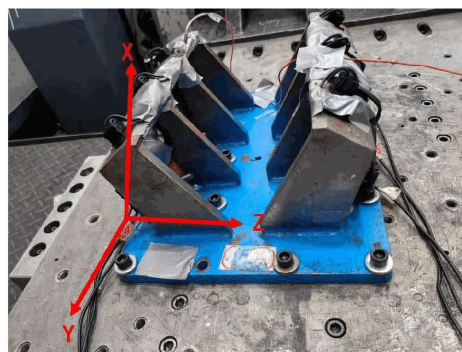


Figure 7 Original mounting arrangement. Modules are fixed to the fixture; the control sensor is near the mounting feet. Connector routing follows the installed arrangement.

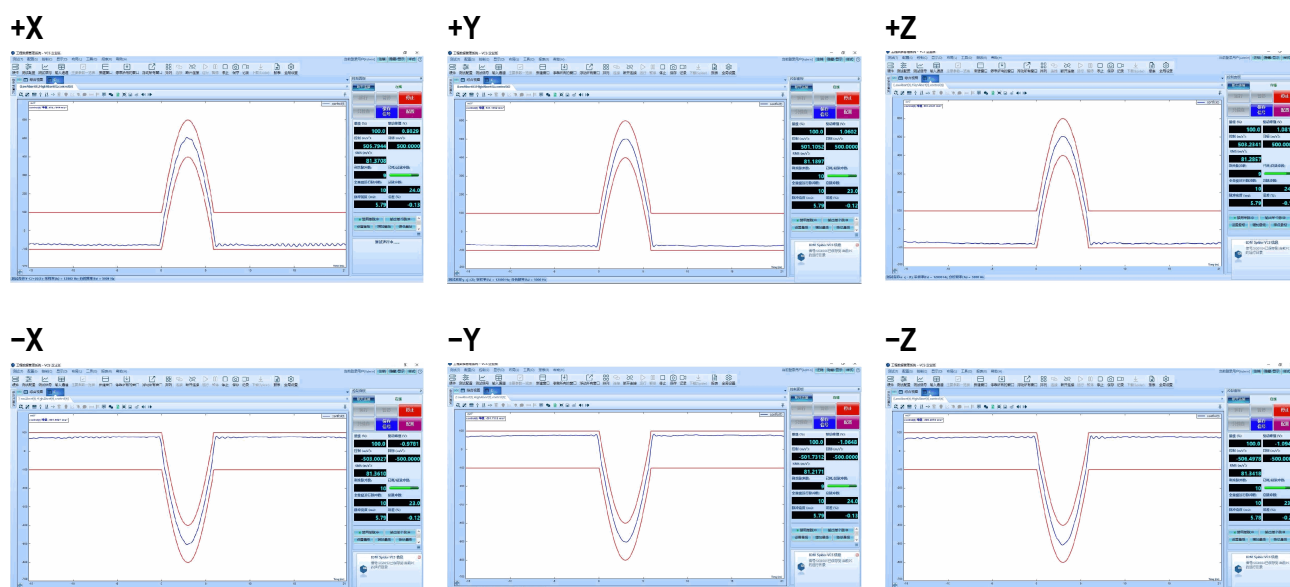


Figure 8 Original pulse records for all six directions, source pp. 69-73.

Monitoring during Shock

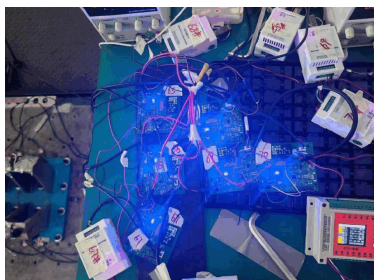


Figure 9 Original connected monitoring arrangement.

Recorded Observations

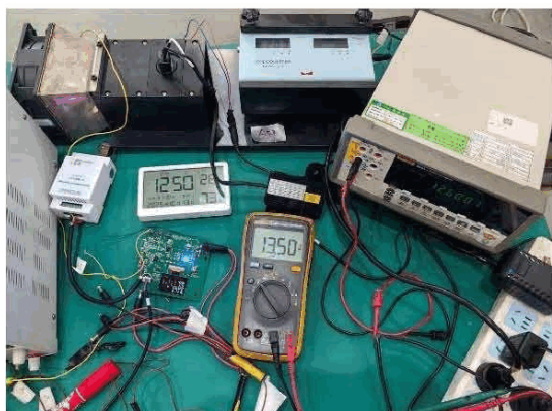
The photograph retains the sample-interface connections and functional monitoring boards used during shock testing. The report records **normal current with no obvious change**. After the test, appearance and structure showed no abnormality. The test was judged **Pass**.

Post-shock functional photographs for all six samples are indexed on the following page.

Sample 65#: Functional Checks across the Test Sequence

These original photographs follow sample 65# through the mechanical stages. They retain the supply/electrical instruments, ion counter and connected functional monitoring arrangement.

Before vibration



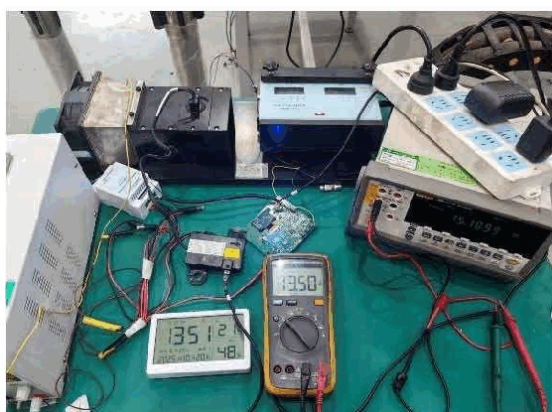
Source p. 53.

After vibration



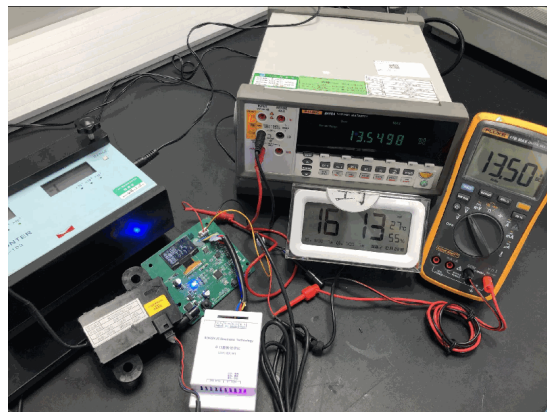
Source p. 60.

After mechanical shock



Source p. 74.

After free fall



Source p. 82.

Figure 10 The same sample at four recorded functional checkpoints.

Six-Sample Functional Photograph Index

Sample	Before vibration	After vibration	After shock	After free fall
65#	p. 53	p. 60	p. 74	p. 82
66#	p. 53	p. 60	p. 74	p. 82
67#	p. 53	p. 60	p. 74	p. 82
68#	p. 53	p. 60	p. 74	p. 82
69#	p. 53	p. 61	p. 74	p. 83
70#	p. 53	p. 61	p. 74	p. 83

Table 3 Source-page index linking each sample to its functional photographs.

Free-Fall Test and Direction Allocation

Drop Conditions

Parameter	Specified condition
Drop height	1.00 ± 0.05 m
Drops per sample	2; opposite directions on one assigned axis
Surface	Concrete floor or steel plate
Operating mode	1.1
Samples	6 modules; 65#-70#
Equipment	CZ-315Q single-wing drop tester

Recorded Sample Directions

Sample	Drop directions
65#	+Z / -Z
66#	+Y / -Y
67#	+Z / -Z
68#	+X / -X
69#	+Y / -Y
70#	+X / -X

Table 4 Original direction allocation, source p. 77.

Recorded program:

6 samples × 2 drops = **12 drops**.

Each sample is visually inspected and shaken to check for loose parts or abnormal movement. Function is checked after dropping.

Original Height Setting



Figure 11 Original 1 m height-setting photograph.

Original Orientation Photographs



+X



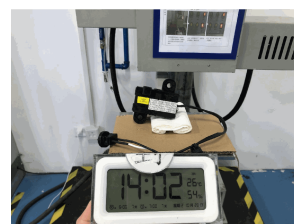
-X



+Y



-Y



+Z



-Z

Figure 12 Original photographs of the six orientations used across the sample group.

Physical and Functional Observations

For every sample, the visual inspection found **no visible damage**. The shake check found **no detached parts or abnormal movement**. Post-test function met **Class A**; the recorded result states no hidden damage.

After dropping, all six samples passed working-current, LIN communication and ion-output checks. Individual current readings are listed on the following page.

Free-Fall Results and Post-Sequence Verification

After free fall, all six working-current readings met ≤ 100 mA. LIN was OK; every sample recorded ion-counter over-range above 20 million ions/cm³. Appearance and shake checks were normal.

Sample	Before: current (mA)	After: current (mA)	LIN / ion output	Appearance / shake
65#	12.6476	13.5498	All pass	Normal / normal
66#	12.3205	12.4135	All pass	Normal / normal
67#	12.5587	13.2110	All pass	Normal / normal
68#	12.3714	12.7491	All pass	Normal / normal
69#	12.3478	12.9856	All pass	Normal / normal
70#	12.9290	12.8280	All pass	Normal / normal

Table 5 Original current readings and results, source pp. 76-77. Post-drop range: 12.4135-13.5498 mA.

All Six Samples after Free Fall



Sample 65#



Sample 66#



Sample 67#



Sample 68#



Sample 69#



Sample 70#

Figure 13 Original post-drop sample photographs, source pp. 81-82.

Follow-up Functional Verification

The sample group completed the **post-sequence five-point check on 30 October 2025**. Samples 65#-70# met the Class A requirement; the source records Pass on pp. 84-85.

Subsequent Internal Inspection

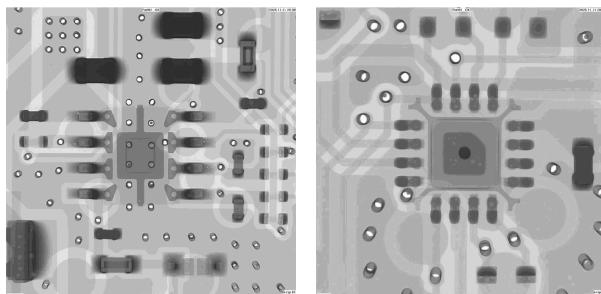
Samples 69# and 70# were inspected by X-ray and cross-section on **10-14 November 2025**, after completion of the Leg5 sequence and the post-sequence functional check. The internal-inspection results follow on page 8.

Post-Sequence Internal Inspection: X-ray and Cross-sections

The Leg5 record proceeds through initial five-point checks, rapid temperature change, combined vibration, shock, free fall and final five-point checks. The subsequent internal inspection covers **69# and 70#**, at two specified locations per board. The inspection was judged **Pass**.

Original X-ray Images

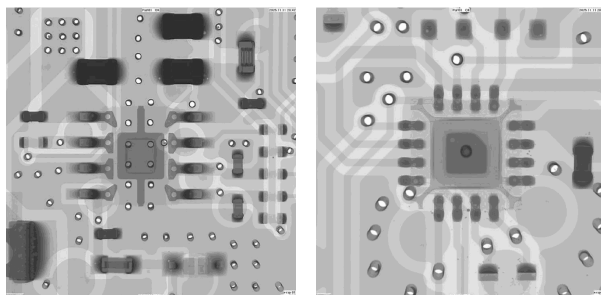
Sample 69#



Position 1

Position 2

Sample 70#



Position 1

Position 2

Figure 14 Original X-ray images of both locations on both boards.

Inspection Locations and Method

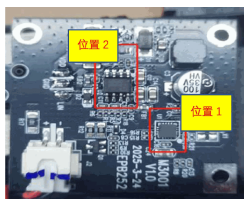
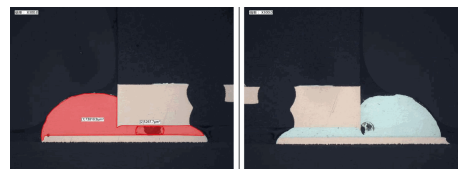


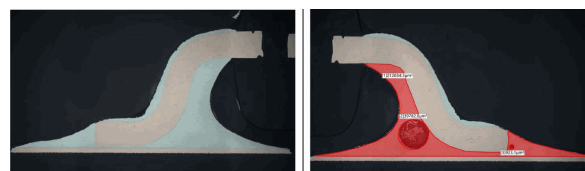
Figure 15 Original board location photograph.

Original Cross-section Details

Sample 69#

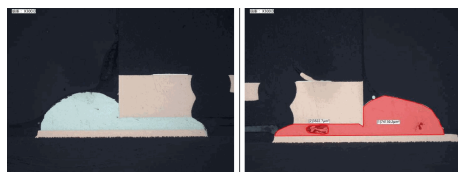


Position 1

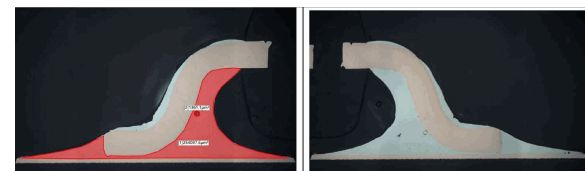


Position 2

Sample 70#



Position 1



Position 2

Figure 16 Microscopic detail views, retaining the original overlays and measurement marks.

X-ray: phoenix micromex neo 160. Cross-sections: mounting, grinding, polishing and VHX-7000 microscopy under IPC-TM-650-2.1.1F.

Sample	Position 1: void ratio	Position 2: void ratio	Recorded observation
69#	6.7%	16.1%	No solder-joint cracks or obvious abnormalities.
70#	4.9%	0.5%	No solder-joint cracks or obvious abnormalities.

Table 6 Cross-section results, source p. 100. Inspection report: SZA03-25113084-QC-01FR1.

Test basis and records: Q/MAT 5502-2023: vibration 10.3 (Leg5 pp. 45-62); shock 10.4.2 (pp. 63-75); free fall 10.8 / IEC 60068-2-32 as cited (pp. 76-83); internal inspection 6.3 (pp. 94-104). Vibration/shock: Suzhou Changling Testing Technology Co., Ltd.; free fall/five-point checks: MAXMAC laboratory; internal inspection: Guangdong Weipu Standard Technology Co., Ltd. Revision 1.1: 26 October 2026.