

Qualification of press-fit connector for space-flight applications, feedback and Design improvements

3rd Space Passive Component Days (SPCD), International Symposium

9-12 October 2018

ESA/ESTEC, Noordwijk, The Netherlands

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SHORT ABSTRACT

The burgeoning demand for the incorporation of disruptive technologies into space industry clearly requires fast and reliable procedures for the space-qualification of these innovative components. This also entails a close collaboration between the manufacturing and qualification laboratories not only to determine the reliability but also to analyse the root causes of eventually present fails, which is the first step for the development of enhanced and qualified products. Hence the present communication reports on the qualification procedure conducted by ALTER Technology of a first generation of press-fit connectors developed by Positronic for spacecraft applications.

INTRODUCTION

The NewSpace concept together with the demand for the incorporation of new fabrication approaches and devices into space applications require for fast and reliable evaluation/qualification processes adapted to the specific system design and the characteristics and requirements of the indented applications. One of the concepts that is emerging in the space technology is press-fit connection. Such automatic or semiautomatic mounting methods are extensively present in the electronic industry since they simplify assembly and inspection processes. In fact, they provide shorter time and lower costs for installation (assembly + inspection) in comparison to manual soldering and it homogenises the system performance regardless the operator skills. However, soldering of PCB connectors remains as one of the ultimate task that is manually performed during the assembly of PCBs for space. In this regard press-fit contact technology is the only solder-less alternative for the full- or semi-automatic mounting of connectors onto printed circuit boards that ensures a reliable electro-mechanical connection. Motivated by these features Positronic (manufacturer) and ALTER Technology (testing laboratory) initiated the qualification process to determine the suitability for space applications of a representative set of different types of commercial press-fit compliant-connectors.

SYSTEM DESCRIPTION

Press-fit connectors can be classified in two main groups: rigid and compliant-connectors. As indicated elsewhere [1] the repeatable connection, and gas-tight and non-destructive character make low-force compliant connection the one with better performance for space applications.

Figure 1 illustrates the working concept of compliant press-fit connectors and shows the used pressing tool. Press-fit connectors are based on a deformable tail that is inserted into a plated through hole (PTH) slightly narrower than the insertion pin. In compliant connectors the insertion tail elastically deforms during the insertion process. This significantly

reduces the stress induced onto the PCB holes, in contrast with the rigid systems, while the it sustains a permanent contact-spring-force that provides reliable electrical and mechanical connection.

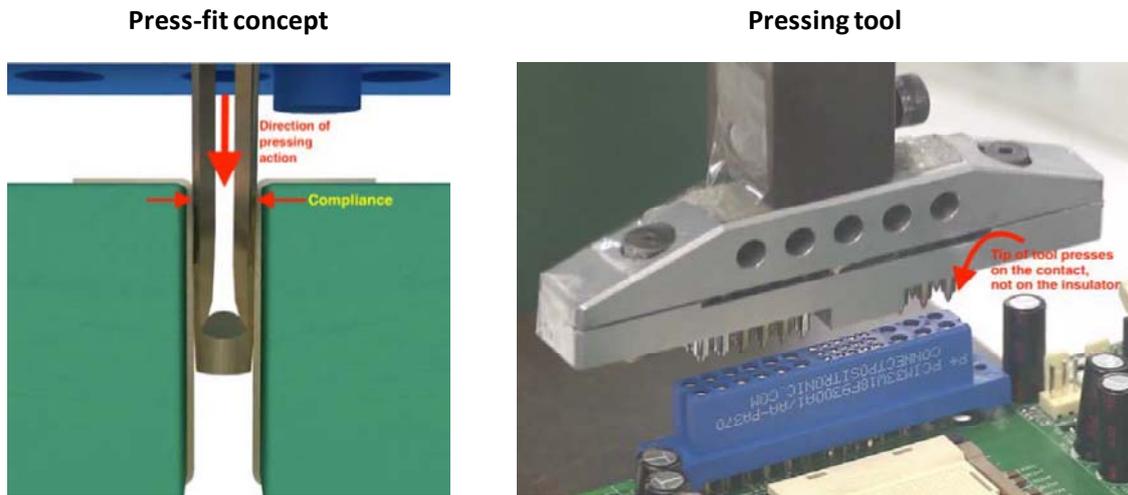


Figure 1: Design and working principle of compliance press-fit connectors

The present communication reports in detail about the qualification process of different types of press-fit connectors developed by Positronic. The studied test vehicles comprise three types of D-sub connectors that differ in the pins density and size and the intended applications (Table 1).

Table 1: Connector characteristics

| Denomination | Pin size | Number of pins | Intended applications | Quantity |
|------------------|----------|----------------|-----------------------|--------------------------|
| High density | 22 | 75 | Signal communication | 3 PCBs with 2 connectors |
| Standard density | 20 | 50 | Low power supply | 3 PCBs with 2 connectors |
| Combo-D | 8 | 5 | High power supply | 3 PCBs with 2 connectors |

Figure 2 gathers the connector photographs taken during the qualification process, and the insets shows the “eye on the needle” design of the implemented insertion pins. As the figure shows the connectors are mounted in pairs on polyimide space-grade PCB. The PCBs include 4 Cu layers of 2.4 mm of thickness and Electroless Nickel Immersion Gold (ENIG) PTHs with a gold coating of 5 μm of thickness. In the case of high-density and standard-density systems the analysed connectors are constructed in both vertical and right-angle configurations.

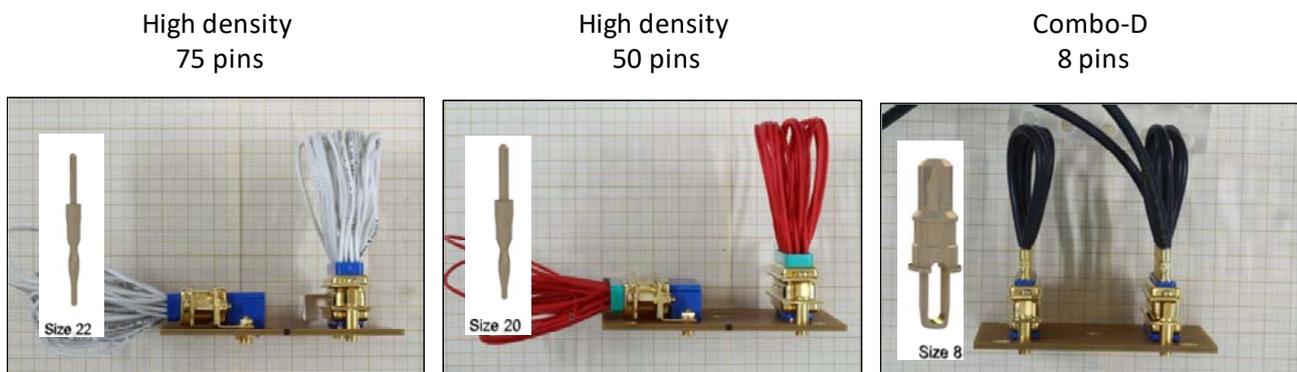


Figure 2: Photographs and pin designs of the analyzed press-fit connectors.

QUALIFICATION PROGRAMME

Traditionally through-hole PCB connections for space systems involve soldering processes. Hence ESA has defined specific requirements [2, 3] to ensure the quality of soldering connections for space application. Amongst others, these specifications state the verification program to apply on any space PCB component. This includes demanding vibration and thermal test and cross-section μ -inspection processes. Inspired by these guidelines, the press-fit connectors herein studied are submitted to the following test plan conceived to thoroughly assess the suitability of press-fit technology for space-flight applications. As with the ESA specification for soldering connections [2,3], the used qualification programme described in Figure 3 consists of different environmental test (vibration and temperature cycling), as well as electrical and visual verifications conducted after each environmental test, and a final detailed internal μ -inspection to evaluate the integrity of the connectors after such aggressive environmental treatments.

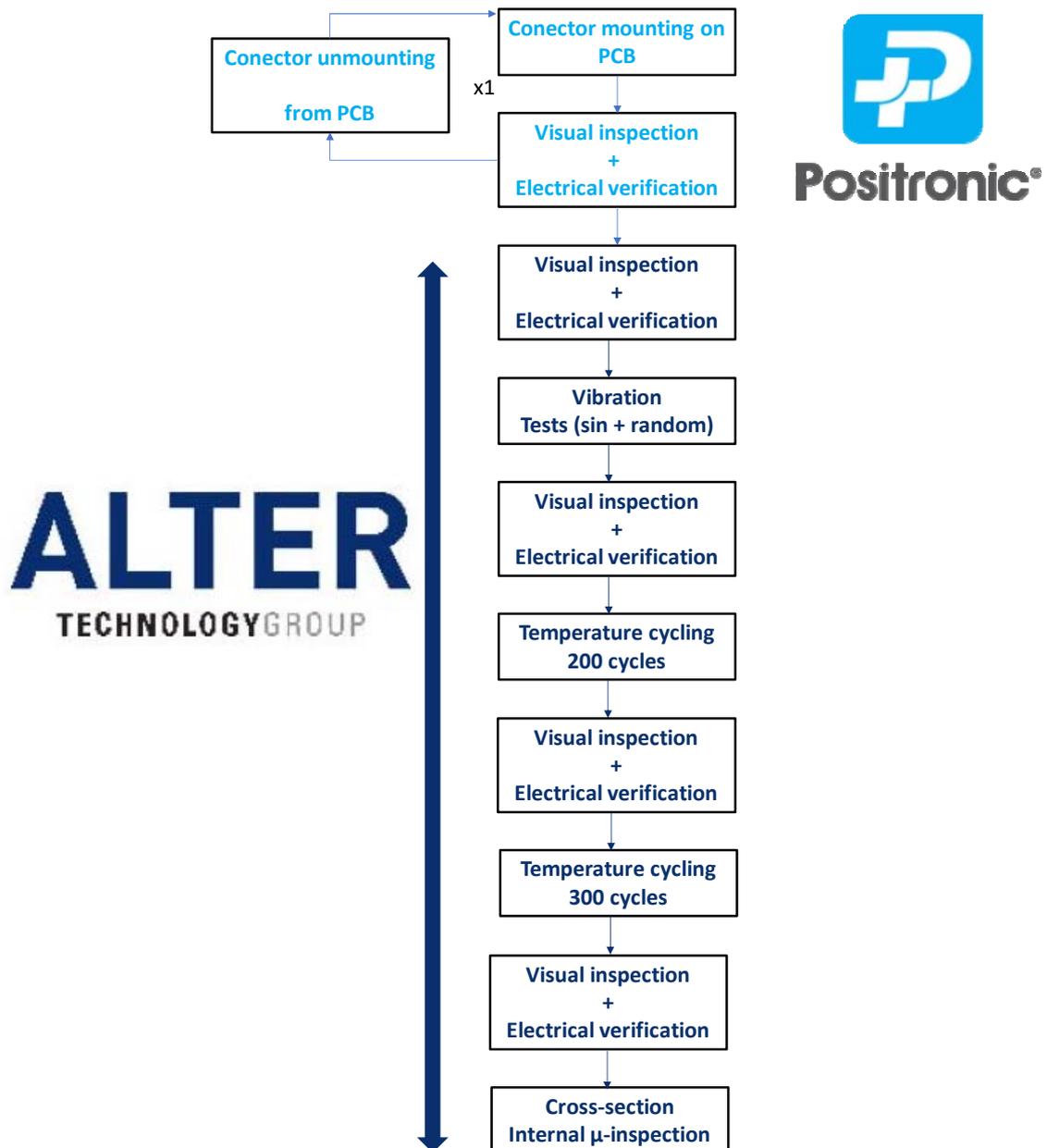


Figure 3: Test flow of the verification process.

In this verification plan it is worth noticing the fact that the connectors are electrically characterized after each treatment, which is an additional requirement in comparison to ESA verification program. This provision is included in the test plan to early detect potential fails that otherwise would not be identified until the program completion. This improves the decision flow and will potentially assist failure analyses, if they are required. It is also remarkable the mounting and unmounting loop specifically conceived for low-insertion-force press-fit connectors that are designed to be reworked (re-mounted) at least once.

As it is indicated in Table 2 these tests are conducted under the premises and conditions stated at the ESA specifications or under more strict conditions. For instance, during vibration test the connectors are electrically monitored to detect electrical micro-cuts longer than 1 μ s, which is not an ESA requirement.

Table 2: Test methods and conditions.

| Test / inspection | Specification |
|---------------------------------|--|
| Visual inspection | ESCC 20500 |
| Electrical characterization | DENG-008-1 Rev. B § 7 (customer procedure) |
| Vibration | ECSS Q ST 70 08C § 13 (sine + random) Additional provision μ -cuts $\geq 1 \mu$ s are not allowed |
| Temperature Cycling | DENG-008-1 Rev. B Par. 14 (-55 °C to +100 °C similar to ECSS Q ST 70 08C) |
| Cross-section μ -inspection | DENG-008-1 Rev. B |

ENVIROMENTAL TEST

Vibration

Vibration test were performed on 3 orthogonal axes as it is illustrated in the Figure 4. Thanks to Daisy Chain design of the used test vehicles the electrical continuity along each pin is easily monitored by means of a single oscilloscope.

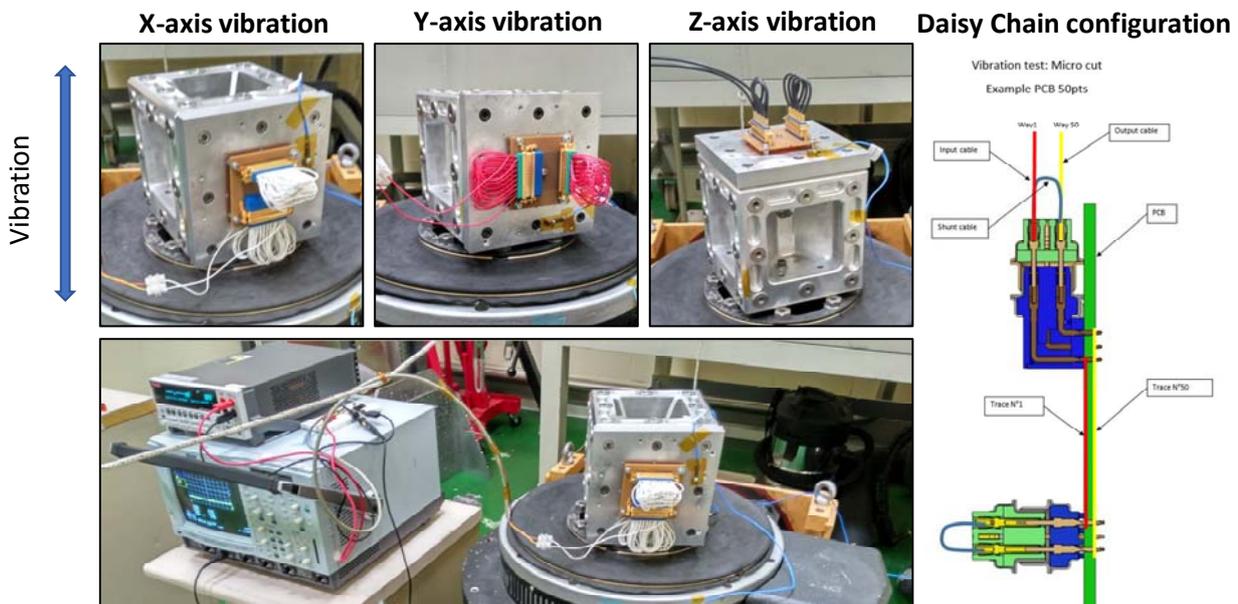


Figure 4: Vibration set-up.

As indicated by ESA specification the boards are submitted to random and sine-sweep vibration tests according to the vibration profiles described in Table 3 and Table 4 for three orthogonal axes. These conditions are conceived to ensure that the system withstand normal terrestrial conditions and the vibrational g-loads imposed by space flight. During the test the vibration conditions were monitored by a nearby accelerometer whose signal is included in Figure 5 and Figure 6 for two representative examples.

Before and after each vibration testing a low-level sine survey is performed (ESA provision in [2]) in order to identify any potential modification induced in the natural frequencies of the tested item. This verification did not reveal any change for all the conducted test. On the other hand, no electrical cut longer than 1 μ s was detected during this test which indicates the good performance of the analysed systems under such hard conditions.

Table 3: Sine-sweep vibration conditions

| Frequency Range (Hz) | Acceleration (g) | Sweep Rate (oct/min) |
|---|------------------|----------------------|
| 42 to 100 | 20 | 1 |
| 100 to 2000 | 15 | 1 |
| Duration: 1 cycle up from 42 Hz to 2000 Hz (3 axes). | | |

Table 4: Random vibration conditions

| PERPENDICULAR TO PCB | | PARALLEL TO PCB | |
|-------------------------------|----------------------|-------------------------------|------------------------|
| Frequency Range (Hz) | PSD Level | Frequency Range (Hz) | PSD Level |
| 20 to 100 | +6 dB/oct | 20 to 100 | +3 dB/oct |
| 100 to 500 | 1 g ² /Hz | 100 to 800 | 0.5 g ² /Hz |
| 500 to 2000 | -6 dB/oct | 800 to 2000 | -3 dB/oct |
| Global GRMS = 28.5 | | Global GRMS = 27.1 | |
| Duration: 5 minutes per axis. | | Duration: 5 minutes per axis. | |

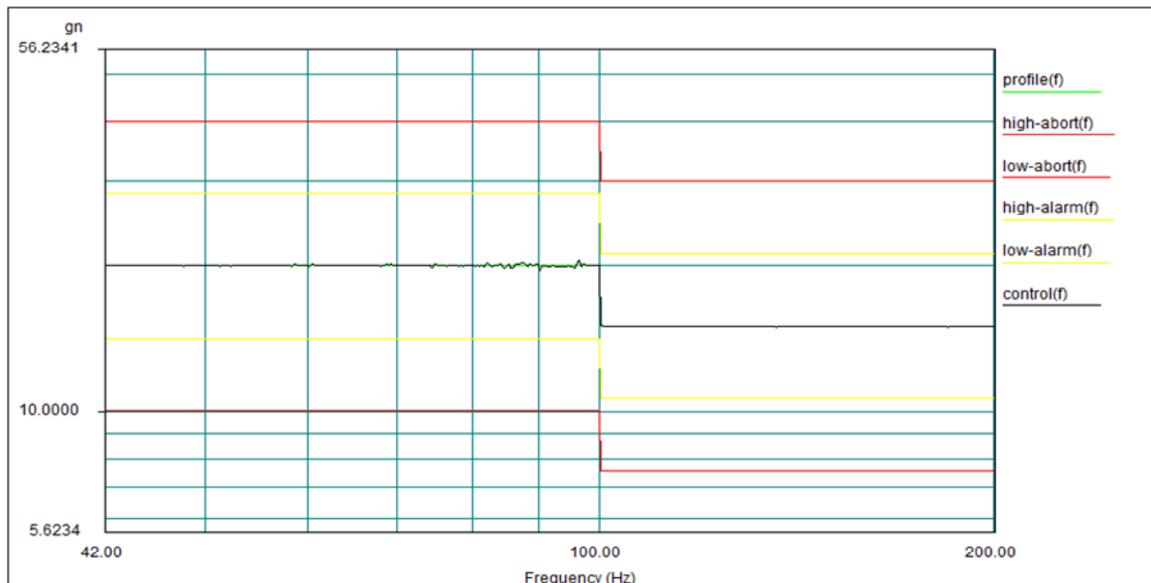


Figure 5: Sine sweep vibration profile

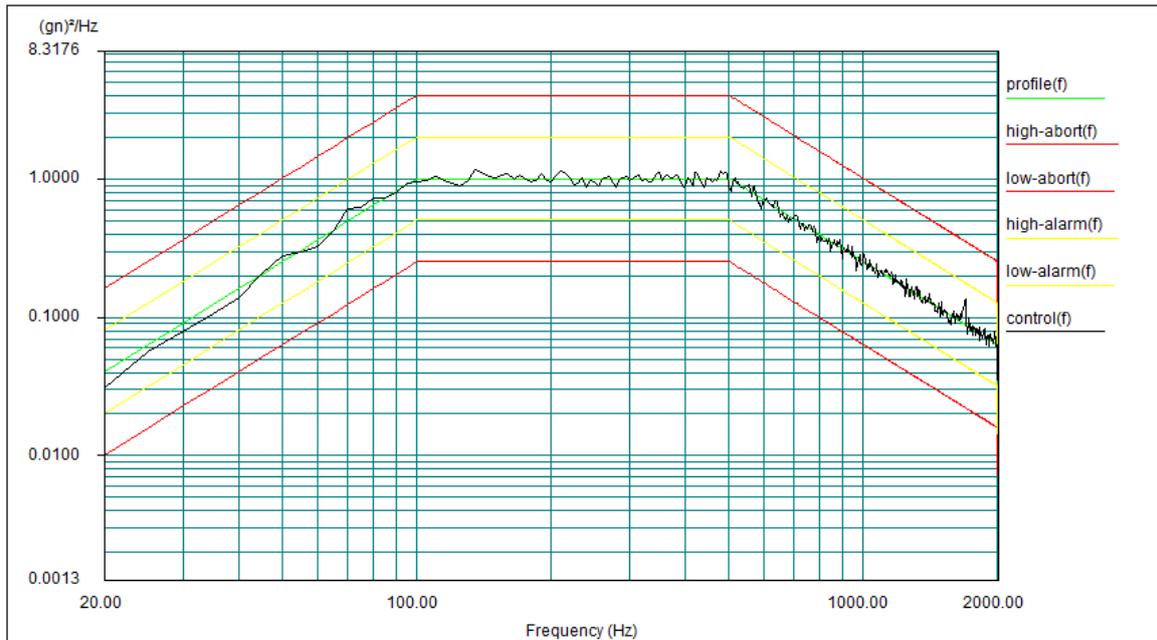


Figure 6: Random vibration profile applied on the Y axis (parallel to PCB condition).

Temperature cycling.

This test is conceived to ensure the resistance of the connectors under extreme high and low temperatures and to such temperature changes. In this test the environmental temperature is cycled in an air circulating climatic chamber. The reference hot and cold temperatures were $-55\text{ }^{\circ}\text{C}$ and $+100\text{ }^{\circ}\text{C}$ respectively, with a dwell time of 15 min at each extreme temperature. In a first run the connectors were submitted to 200 cycles and after electrical verification 300 additional cycles were conducted until to reach a total amount of 500 cycles. To ensure that the system surface reach and maintain the required temperature the surface temperature of each PCB was monitored with a thermocouple attached to the specimen surface. According to these temperature readings, for all the cycles and analysed connectors, at the plateau regions the PCB surface temperature was maintained between $-55\text{ }^{\circ}\text{C}$ and $-60\text{ }^{\circ}\text{C}$ (cold conditions) and $100\text{ }^{\circ}\text{C}$ and $105\text{ }^{\circ}\text{C}$ (hot conditions). Figure 7 shows as example the thermocouple readings during ten representative cycles.

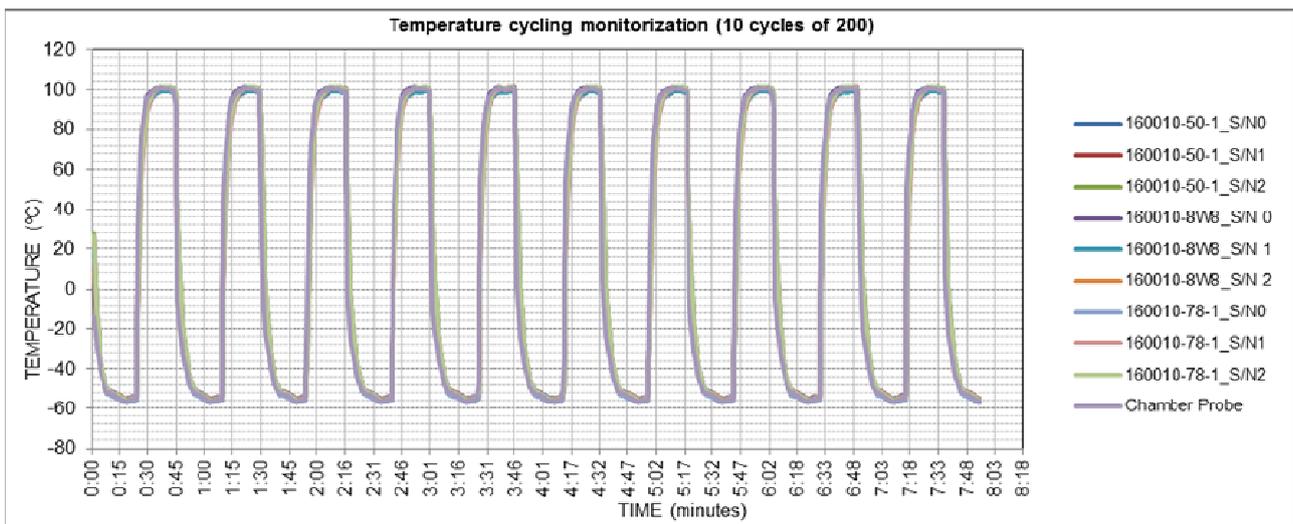


Figure 7: Example of 10 temperature cycles.

INSPECTION AND VERIFICATION MEASUREMENTS

Visual inspection

All the connectors were visually inspected at their reception and after each environmental test. The external visual inspection was performed according to the provision of ESA specification [4] with a binocular. The aim of these inspections is detecting potential rejections causes and any damage or modification induced by the previously described environmental treatments.

For most of inspected connectors and PCB no noticeable deviations were observed. Only in one case it was reported the presence of small marks near the PTH. Special attention was paid to these features after each environmental test. The inspections conducted after each environmental test did not reveal any evolution of these features or the development of additional deviations in the rest of specimens.

Electrical verification.

The press-fit approach is a valid connection method as long as the contact resistance does not affect the system performance. Therefore, this parameter was assessed at each stage of the verification plan. Contact resistance measurements were performed for all the connectors included in Table 1. As it is illustrated in the picture in Figure 8 the contact resistance was measured between the PTH and the insertion pin. In the case of standard-density and high-density connectors 10 pins were analysed for each connector, whereas in the case of Combo-D the measurements were conducted on 8 pins. Individual measurements recoded for single pins were used to calculate the average contact resistance of each connector. Figure 8 gathers the average contact resistance calculated at the beginning and at the completion of the environmental tests. In these graphs the error bars are calculated from the dispersion of data of the resistance values registered at the single pins. No differences of statistical relevance are found between the contact resistance before and after the last environmental test. According to this data the contact resistance is not affected by the imposed environmental conditions. Nonetheless a slight increase is eventually observed in the contact resistance of Combo D connectors after vibration. This increase, that is not considered cause of rejection, disappears in the next electrical verifications (Figure 9) a phenomenon that is under discussion.

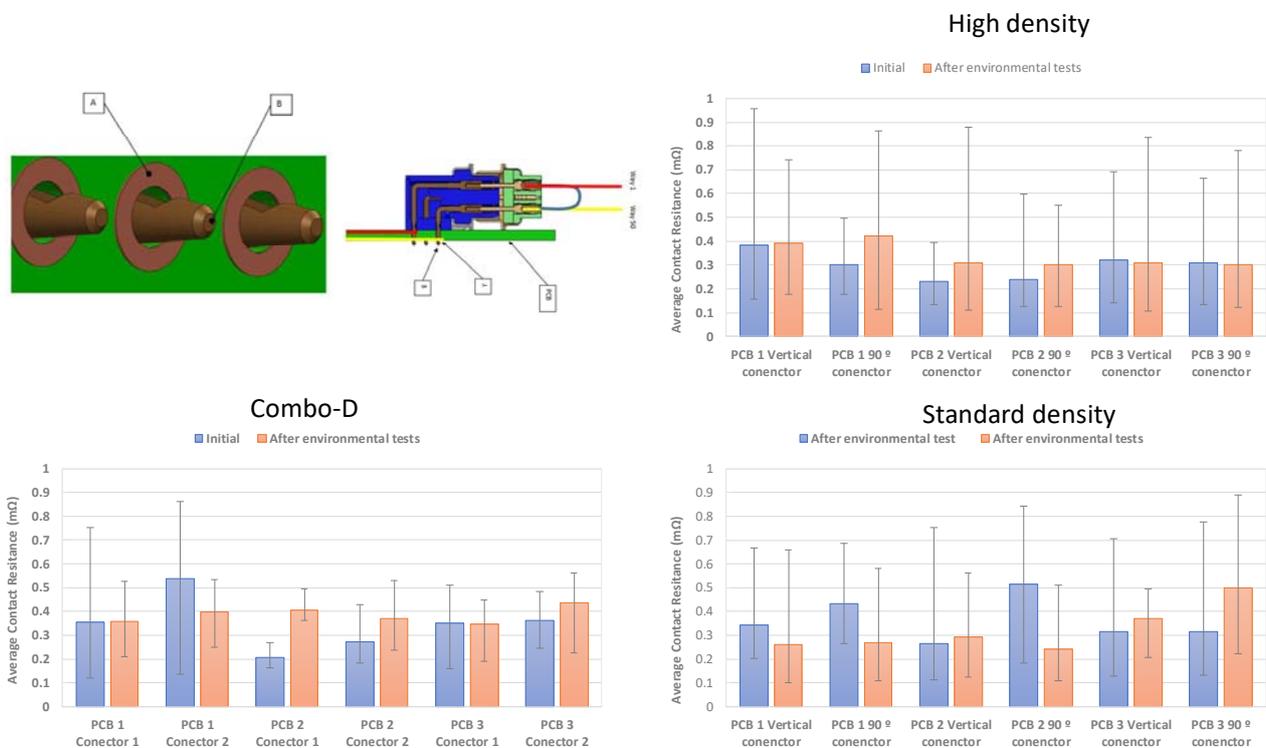


Figure 8. Contact resistance measurements.

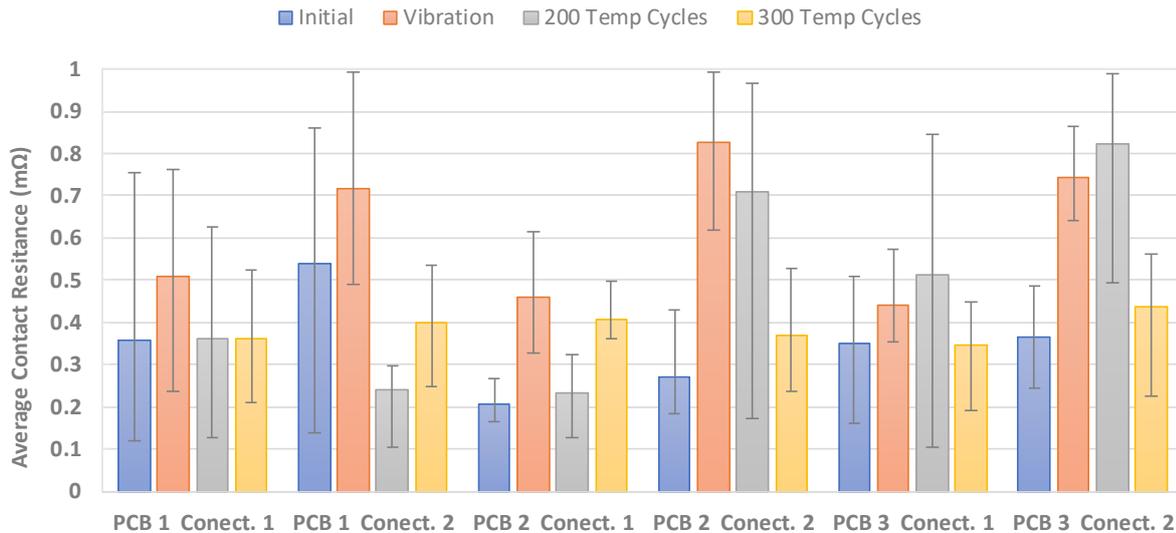


Figure 9: Evolution of the contact resistance in Combo-D conectros

Cross section μ -inspection.

Before μ -inspection the samples are cross-sectioned according to the following procedure.

1. The board is cut around the periphery of the target connector using a linear high-precision wire saw. This operation is conducted at low speed and taking the precautions required to minimize vibrations.
2. The separated piece is placed in a mounting mould appropriate to the size of the device and embedded into epoxy resin.
3. After curing, the embedded sample is labelled for traceability and grinded to reach the plane of interest.
4. Once the inspection plane is reached the connector cross-section is polished to expose a high-quality surface.

At this point is worth remarking that the combination of materials (sandpapers and diamonds suspensions) used and the gridding and polishing parameters have been selected to optimize different characteristics of the process such as: the uniformity, the cleanliness and quality of the resulting cross-section. In this regards Alter Technology recently presented an oral communication to the EMPS Workshop about the key parameters to obtain high-quality cross-section cuts.[5]

For these analyses one PBCs of each type was inspected. Since standard-density and high-density connectors comprise vertical and right-angle connectors, in these connectors three planes were inspected whereas in the case of the Combo-D two cuts were analysed.

Standard and High density connectors.

Standard and high-density connectors do not present any feature causing rejection of disconformity. Figure 10 illustrates this point showing one of the cut inspected in the case of a vertical high-density connector. These inspections show that crimped wires in the male connectors present a good contact and that they are deformed by crimping tool as required (image non-show). Good contact is also observed in the male-to-female interface. No cracks, voids, separation, peeling, flaking, contamination, corrosion, foreign nor displaced materials or any other deviations were observed at these areas.

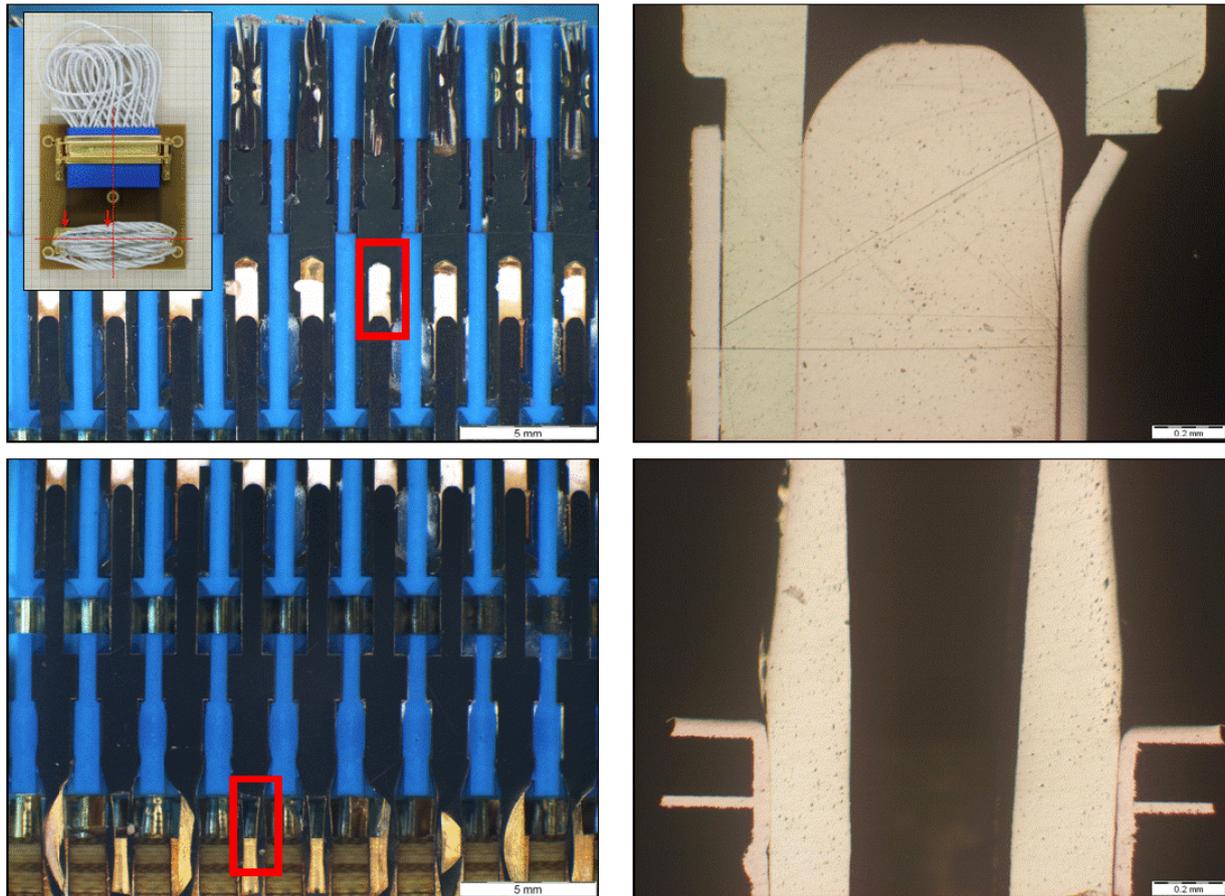


Figure 10: Cross section of a vertical high-density connector. The inset at the top left corner indicates the inspection plane.

Combo-D connectors worst case observed.

In the case of the inspected Combo-D connector an important deviation is observed. As Figure 11 shows, cracks are visible at base of the pin insert of the press-fit connection and at the PCB resin area. The tentative explanation for the formation of these cracks is the tension accumulated at the pin inserted into PTH. As it can be observed in Figure 11, the pin connector is very deformed, which may cause cracks in the metal base. Likewise, pressure exerted by the pin on PCB could cause cracks on the board.

Although no criteria for rejection is specified in the applicable test methods, these two cracks are considered as causes for rejection since reliability risk is present. Cracks in the pin insert can potentially evolve to completely break the metal pin, which may affect to electrical connection between contact and PCB. In the case of the PCB cracks, if moisture penetrates, a high temperature may cause a pop-corn effect, damaging adjacent metallization.

No more deviations were observed. Crimped wires in the male connectors show good connection and they are deformed by crimping tool as required. Good contact is observed in the male-to-female interface. No cracks, voids, separation, peeling, flaking, contamination, corrosion, foreign or displaced materials or any other deviations were observed at these areas.

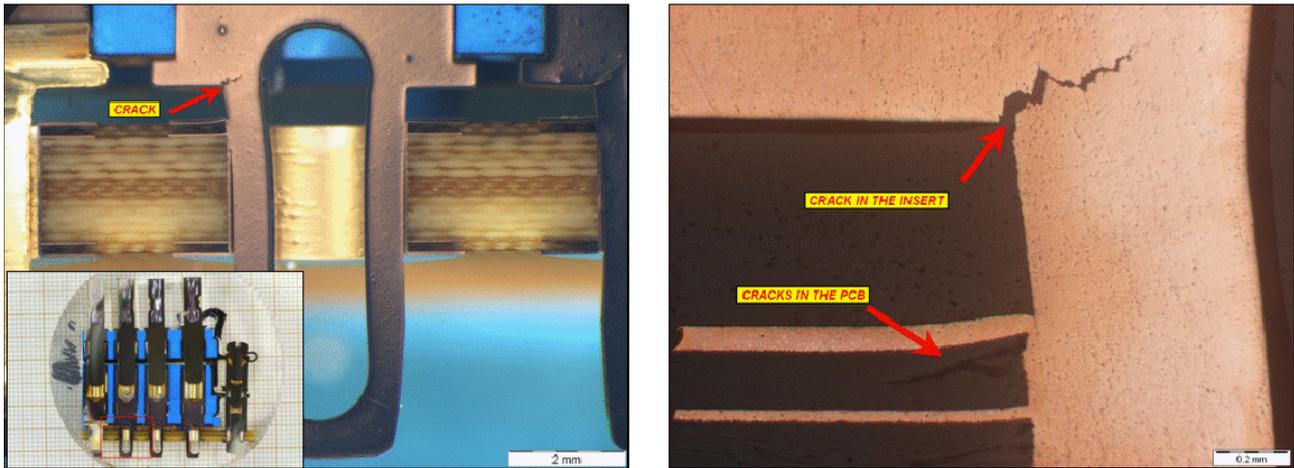


Figure 11: Worst case observed. Crack in connectors Combo-D

CONCLUSIONS:

Within the activities for the space qualification of press-fit connector a set of Sub-D connectors developed by Positronic has been analysed in detail. To this purpose, the selected connectors have been submitted to a complete and stick set of environmental tests and electrical and visual inspections including cross-section μ -inspection. Two of the three types of analysed connectors successfully passed these hard tests and demonstrated high reliability and assembly consistency. The third type presented internal cracks as μ -inspection revealed and further improvements are required. Motivated by the positive results Positronic continues the qualification of the press-fit technology at the same time that is implementing more robust designs to fix the observed deviations in the case of Combo-D connectors.

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