How to qualify press-fit contacts for space flight applications

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1- INTRODUCTION

The fast-growing space industry is constantly under pressure to deliver its services with more and more emphasis on cost and lead-time reduction. In this context, reducing electronic components assembly and control times while improving the ability to repair costly systems becomes a priority axis of development.
During the last few years, as a niche high-performance connector manufacturer, Positronic has strived to introduce low-force, compliant press-fit technology to space flight applications as it addresses this evolutionary trend while being already widespread across the aeronautics industry and therefore a mature technology.

Press-fit terminated contacts present several benefits, notably eliminating the need for solder processes while keeping the option of being removable, replaceable, repairable. The ulterior challenge was to identify tests relevant to the new features and assess the products' performance limits to this regard.

A consortium between the CNES, Positronic and Alter Technology with advisory support from Thales Alenia Space and Airbus D&S, leaned on ESCC3401 and NF-EN 60352-5 to constitute a rigorous test program to serve as foundation to acceptance of press-fit technology for space-flight applications.

In this document, we shall detailed the outline of the test sequence designed and adapted specifically to press-fit technology as well as performance criteria that future users shall expect from these two distinct connector series employing low-force, compliant press-fit terminations in straight and 90º configurations.

2- PRESS-FIT TECHNOLOGY

What Is Press-Fit Technology?

To understand why the press-fit connectors needs few specific tests, it's important to explore the basics of press-fit technology and the difference with the most traditional PCB contact termination the soldering.
This process can be done automatically, with the wave solder or by hand using a iron. In both case, the envionrement (humidity, temperature) have an impact on the quality of the solder.

For the space applications, the solder control, often hard to do and to control, is a major issue which has been resolve from the 60's with the solderlees technology: the pressfit method.

The principle of the pressfit is to design an elastic tail contact, on his diameter which, when it is inserted by force on the rigid PCB, warps to ensure a perfect fit on the PCB via.

The choice of the material and the design of the tail must be carefully defined to ensure the performances and the durability of the connection.

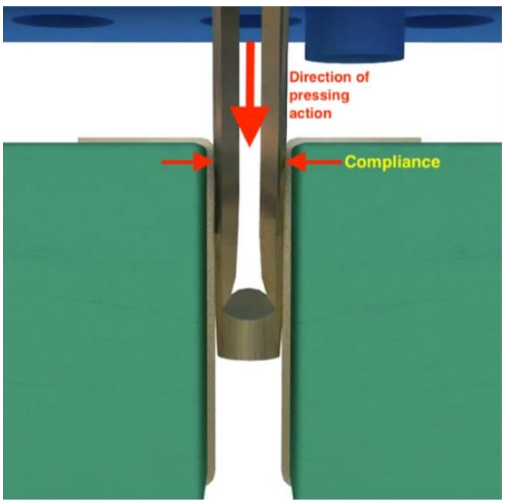


Fig. 1: Action of compliant contact design

Fig. 2: Positronic connector equipped with compliant low-force pressfit contacts.

Technologies

First of all, this is important to understand that there are different technologies available to achieve this solderless pressfit process.
There are two main designs in today's markets:

- Rigid/solid press-fit:
  First technology proposed by the connector manufacturers, the tail, as indicated by his name, is not elastic. This is cheaper to machining complex contact and the PCB is damaged during the insertion. Moreover, the connections are more sensible to the shocks and vibrations due to the micro crack created on the PCB during the insertion.

- Compliant press-fit:
  On this design the tail is elastic. The beam is deformed and does not damage the PCB. It is also created a gas-tight seal. This is the goal of the connection: remove any space and gas between the contact and the PCB. With this gas-tight seal, the oxidation, fretting corrosion or many other concerns can be reduced or eliminated.

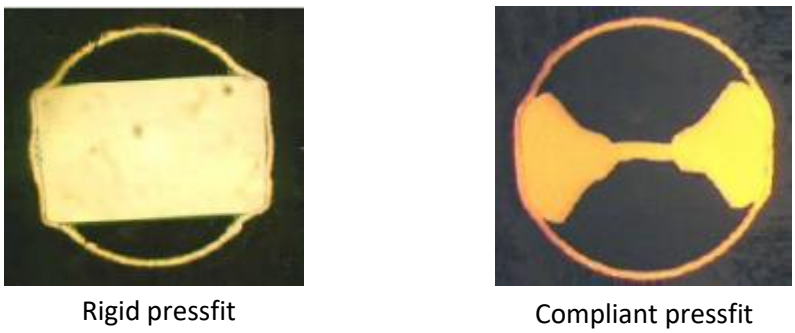


Fig. 3: cross-section of rigid and compliant pressfit contacts

Positronic solution

Positronic takes compliant press-fit technology one step further with its bi-spring power press-fit terminations offering one-piece machined contact from tip to tail. Some manufacturers make a solid machined mating face and a stamped press termination.

These two parts technologies are crimped, and the joint is hidden in the insulator.

The one-piece contact proposed by Positronic increases reliability. All size contacts, straight and 90º, manufactured by Positronic are one-piece construction at Auch in France.

Fig. 4: Positronic France turning shop

3- BENEFITS AND DISADVANTAGES

Of course, this pressfit technology has many benefits but also few disadvantages.
The goal of this qualification program is to determine which benefits must be guarantee for the end-user and which disadvantage not acceptable.

Benefits

- Simple, clean, robust, and highly reliable interconnections, even in high vibration and thermal cycling environment.
- Highly repeatable in connection impedance
- Applicable to one or both side of PCB
- Large thickness of PCB acceptability
- Easily repaired or replaced contacts or connectors
- Does not damage the plated through hole
- Creates a gas-tight connection between contact and plated hole
- Process without any heat or cleaning
- Avoid of high reflow heat, minimizing thermal stress on the PCB and damage plastic connector body.
- Available for mass production
- Control reduced avoiding X-rays i.e.

Quality impact

This quality benefits have been related in various documentations.
Press-fit is mechanically more stable and gas-tight connections are more secure than soldered connections, with a failure in time (FIT) tested at up to 30 times better than soldered connections.

Table 3 Failure rates for various contact technologies Siemens Norm SN 29500-5 / Edition 2004-06 Part 5

Process	Conductor diameter in mm²	Failure rate λref in FIT1)	Notes: Standards/guidelines
Solder manual automatic	_	0.5 0.03	IPC 6102), class 2
Wire bonding for hybrid circuits Al Au		0.1 0.1	28 µm / wedge bond 25 µm / ball bond
Winding	0.05 to 0.5	0.002	DIN EN 60352 – 1 / IEC 60352 – 1 CORR1
Crimping manual automatic	0.05 to 300	0.25	DIN EN 60352 – 2 / IEC 60352 – 2 A 1+2
Clips	0.1 to 0.5	0.02	DIN 41611 – 4
PressFIT	0.3 to 2	0.005	IEC 60352 – 5
Insulation piercing connectors	0.05 to 1	0.25	IEC 60352 – 3 / IEC 60352 – 4
Screws	0.5 to 16	0.5	DIN EN 60999 – 1
Terminals (spring force)	0.5 to 16	0.5	DIN EN 60999 – 1

1) 1 FIT = 1 x 10-9 1/h; (one failure per 109 component hours)
2) Acceptance conditions for printed circuit boards

Extract from the Siemens Norm SN 29500-5 / Edition 2004-06

Disadvantages of press-fit technology

- Specific PCB tolerances and dimensions
- Connector removal maximum admitted up to two times
- Specific tooling needed to press-in
- Specific tooling might be needed to press-out
- Press-in and press out may damage the pin through hole barrel
- Connector price is slightly higher than the price of a connector with solder terminations

4- WHICH PERFORMANCES MUST BE SCREENED?

By defining the advantages, the working group could determine which level of performance must be verified and guarantee.
Vice and versa, the disadvantages of this technology impose to test the connector to avoid any decrease of the performances.

The working group used the ESCC3401 standard as guide.

This specification defines the general requirements for the qualification approval, procurement, including lot acceptance, and delivery of mating pairs of Connectors, Electrical, Non-Filtered, Circular and Rectangular, hermetic or non-hermetic, with removable or non-removable contacts, for space application

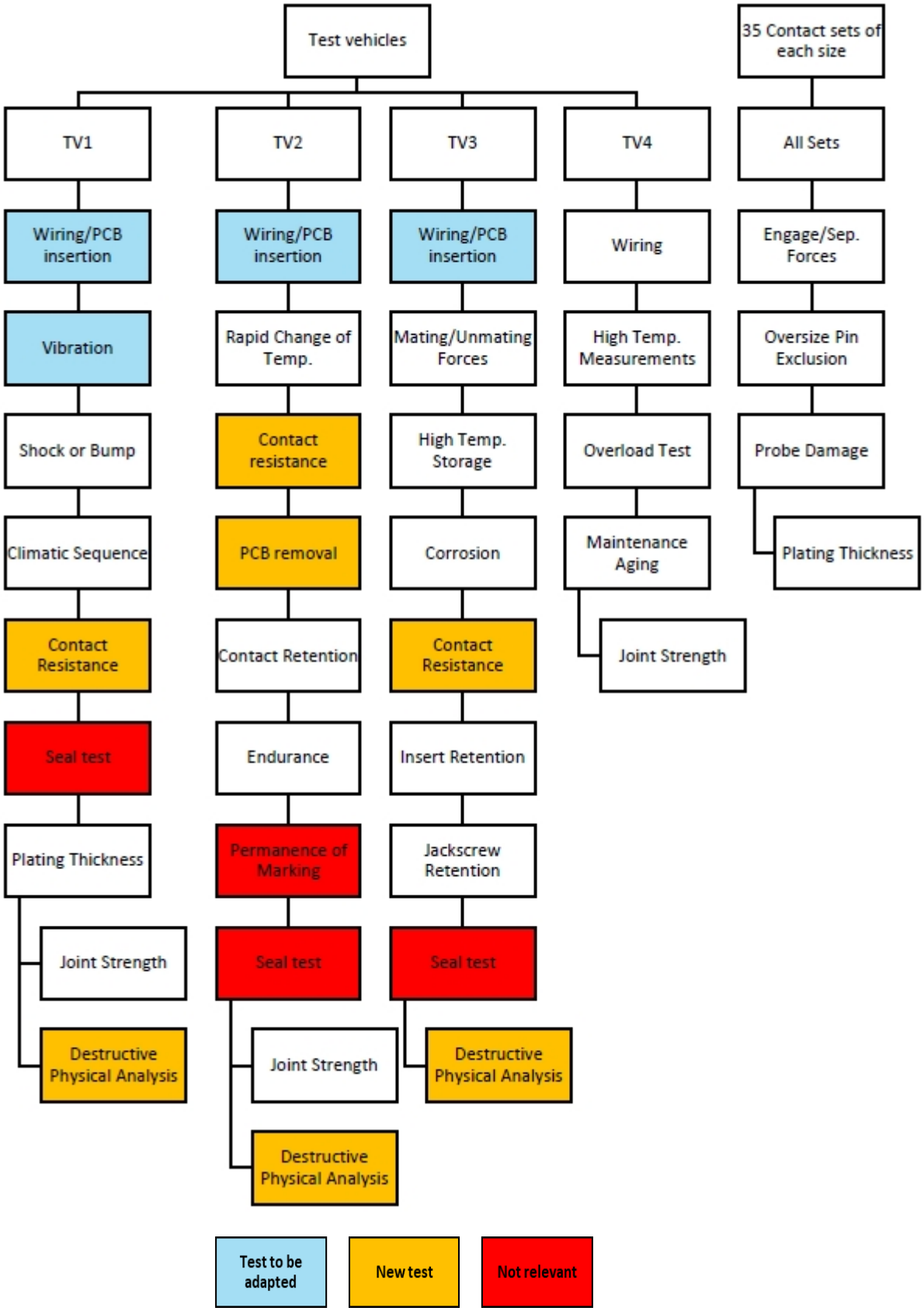
Thus, the test program has been adapted to ensure the reliability of:

- Design
  - Compatibility with space quality PCB, and qualified manufacturer process.
- Environment
  - Capability to support the environment
- Electrical characteristics
  - Performances on stable environment
  - Performances under stress
- Mechanical deformation
  - Durability
  - Reliability
  - Process of installation and reparation

5- IMPACT ON THE ESCC 3401

The range of connectors being qualified is however limited, making some of these tests irrelevant or not applicable, also the introduction of the press-fit terminations makes it necessary to add or modify some of these tests.

The adapted qualification path would be as follows:



All these changes are detailed further in this document.

8.31.1 Random Vibration
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MIL-STD-202, Test Method 214. Unless otherwise specified, the following conditions shall apply:

- Random Vibration Test Curve:

Envelope: Grms = 38.5	
20 to 60 Hz	+6dB/Octave
60 to 400 Hz	$2g^2$/Hz
400 to 800 Hz	-6dB/Octave
800 to 1000 Hz	$0.5g^2$/Hz
1000 to 2000 Hz	-6dB/Octave

- Duration: 180s in each of the 3 mutually perpendicular axes.
- Electrical continuity shall be monitored continuously during the test. No discontinuities > 1µs are allowed.
- Data Points:
  On completion of testing, the test vehicles shall be visually inspected. There shall be no evidence of damage or loosening of parts. VSWR and Insertion Loss shall be measured at T_{amb} = +22 ±3°C as specified in Intermediate and End-Point Electrical Measurements in the

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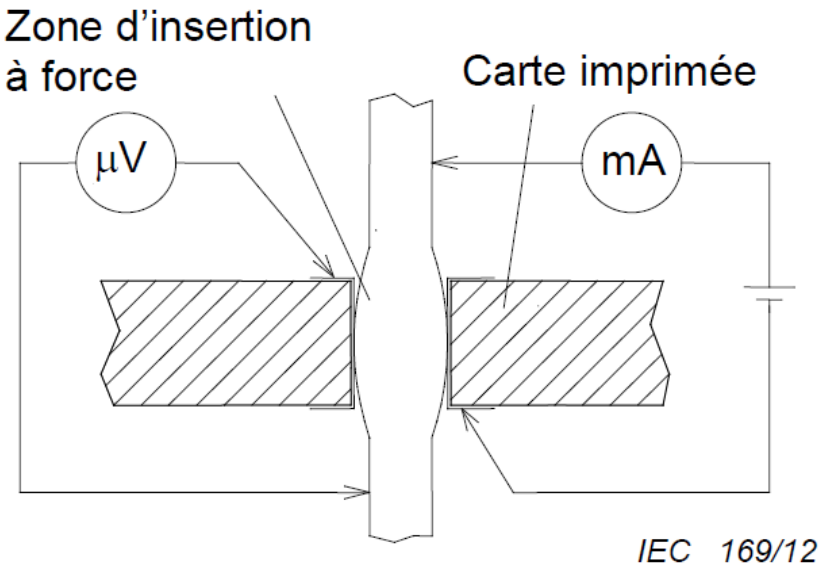
8.31.2 Sine Vibration

MIL-STD-202, Test Method 204. Unless otherwise specified, the following conditions shall apply:

- Sweep Frequency: 5-100-5Hz. For the entire frequency range of 5 to 100Hz and return to 5Hz, the slope rate shall be 2 Octaves per minute maximum.
- Total number of Cycles: 9 (3 times in each of the 3 mutually perpendicular axes).
- Vibration Amplitude:
  - 5Hz to 26Hz: 11mm (peak)
  - 26Hz to 100Hz: 30g
- Data Points:
  On completion of testing, the test vehicles shall be visually inspected. There shall be no evidence of damage or loosening of parts. VSWR and Insertion Loss shall be measured at T_{amb} = +22 ±3°C as specified in Intermediate and End-Point Electrical Measurements in the Detail Specification.

For paths 1, 2 and 3, after conditioning, test vehicles' contact resistance between the contact and PCB shall be measured as per NF EN 60352-5, §5.2.3.1.



To be done on 10% of all connector's contacts or 5 contacts, whichever is more.
The connectors shall be unmated as some test configurations will lead to having all the contacts connected in series, which could lower the resistance measured.
The maximum change of contact resistance after conditioning shall be less than 0.5mΩ.

DESTRUCTIVE PHYSICAL ANALYSIS (DPA)

At the end of path 1, 2 and 3, while the crimped connectors shall be submitted to the Joint Strength test (except for Path 3), the press-fit connectors which shall be still seated on the PCB, shall be micro-sectioned in the transverse direction. DPA shall be performed as per ESCC21001.

PCB REMOVAL

During qualification path 2, after the rapid change of temperature conditioning, press-fit connectors shall be removed from the PCB with the appropriate tools. This in order to proceed with the remaining tests in this path.