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Press-fit Connectors in Spaceflight Applications - Drivers and Challenges

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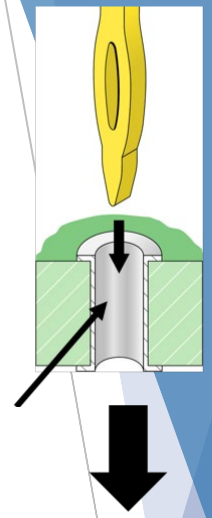
Code 300

Agenda

1. Overview, introduction
2. Drivers for press-fit connectors
3. Qualification tests
4. Emerging designs
5. Eye-of-the-needle fabrication styles
6. Sample qualification test plan
7. Press-fit guidance in NASA-STD-8739.11 (proposed draft)

Overview

- Higher Densities ► Smaller Size ► Lower Contact Normal Force
- Contact interfaces:
  - ➢ Separable Interfaces
  - ➢ Permanent Interfaces
    - – Mechanical
    - – Metallurgical

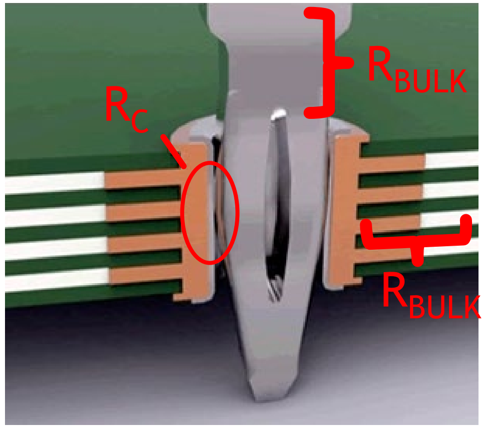


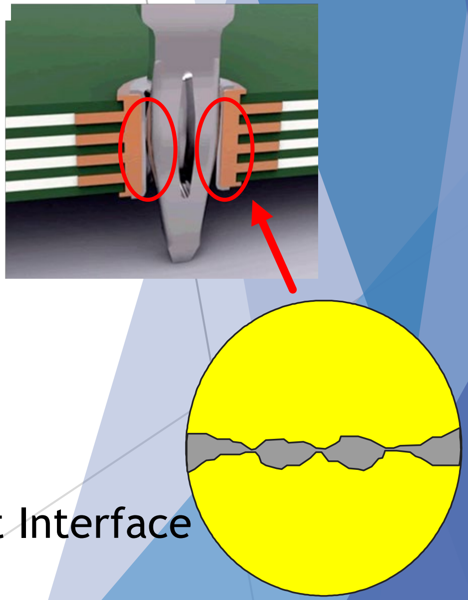
Hole finish

Three sources of resistances:

- Separable interface resistance
- Bulk resistances of the contacts
- Resistance of permanent connections

$$R_O = 2R_{P.C.} + 2R_{BULK} + R_C$$





Contact Interface

1. Baek, Yeon-Jin, et al. "Impact of Thermal Cycling on Cu Press-Fit Connector Pin Interconnect Mechanical Stability." *Journal of Electronic Materials* 50.8 (2021): 4991-4998.
2. Sood, Bhanu, and Michael Pecht. "Testing." Electrical Connectors: Design, Manufacture, Test, and Selection (2020): 173-196.
3. IEC 60352-5:2020, Solderless connections - Part 5: Press-in connections - General requirements, test methods and practical guidance

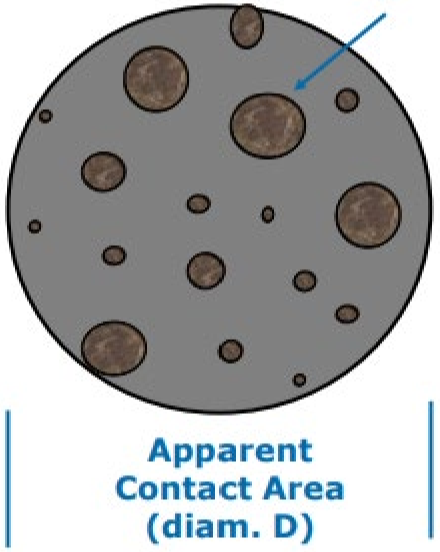
Contact Physics

Primary Concern: Contact Constriction Resistance (Rc)

1950's, R. Holm Asperity model: Actual contact area is directly proportional to applied load

- Assumes plastic deformation

1960's Greenwood & Williamson confirm plastic deformation



$$R = \frac{\rho}{D} + \frac{\rho}{nd}$$

$$\Updownarrow$$

$$R \approx \rho\sqrt{H/F}$$

n number of asperities
d average asperity diameter

Stable n and d → Stable Rc

Reduced Stability

- Reduction in Normal Force (F)
- Formation of Non-conductive Films

Reliability: Testing

Which Test Methods?

Degradation Mechanism ► Test Method

- Reduced Normal Force ► Stress Relaxation ► Heat Aging
- Non-conductive Films ► Corrosion ►
  - Noble platings – Mixed Flowing Gas (MFG)
  - Non-noble plating – microMotion Drivers: Temperature Cycling, Vibration
- Change in Surface Properties ► Plating Wear ► microMotion Drivers

Which Test Conditions?

Application Stress Levels ► Test Stress Levels

Application Lifetime ► Test Duration

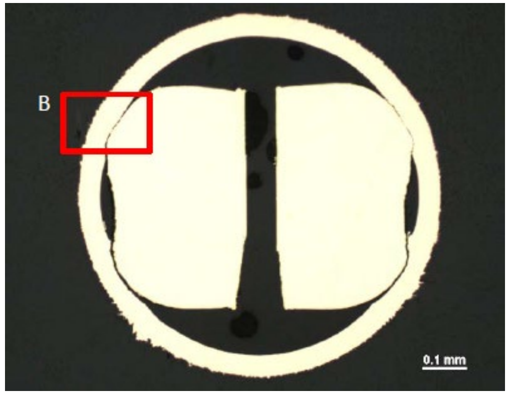
Correlation Between Test Conditions and Application?

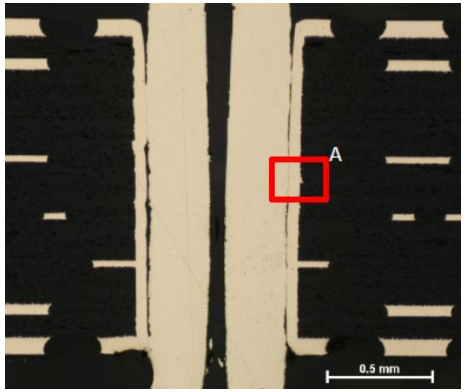
Why Press-fit Connectors?

- For convenience, or a necessity
- Installation & external inspection can be fast
- Desired connector is not available with solder tails
- Installing a header or stacking connector where soldering is not conducive to the PWB assembly flow
- Dense connector footprints not favorable to hand or oven soldering
- High PWB layer counts can make any thru-hole soldering difficult
- Avoid solder's high resistivity, as data speeds approach 6-8 Gb/sec
  - Eutectic 63Sn/37Pb: 12% IACS
  - SAC305 96.5Sn/3Ag/0.5Cu: 13% IACS
  - Sn95 95Sn/5Ag: 12.5% IACS

Terminated Press-Fit Test Approaches

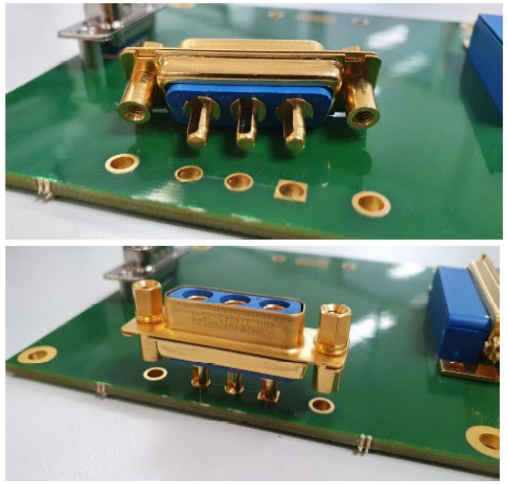
- Whether the connector is used for high data-rate applications or not, it's recommended to adhere to the same Low Level Contact Resistance (LLCR) benchmark: 1.0mΩ from plated-thru hole (PTH) to compliant pin. Perform pre and post environmental tests. Depending on the wafered high-speed connector design, the motherboard PTH to daughtercard PTH path can be as high as 80mΩ.
- Perform High Accelerated Thermal Shock (HATS ™) after press-fit pin installation onto a panel test coupon, while monitoring DC resistance in the PTH interface. HATS is not traditionally performed in this manner.
  - 20C – 200C in air
  - Selecting soak temperatures near a glass transition temperature (T_g) range of any material can help identify unreliable conditions. Avoid over-testing.
  - Ramp time: 6 minutes
  - Can be performed by the printed wiring board supplier but the end user should assure a correct connector attachment
- Perform cross-sections

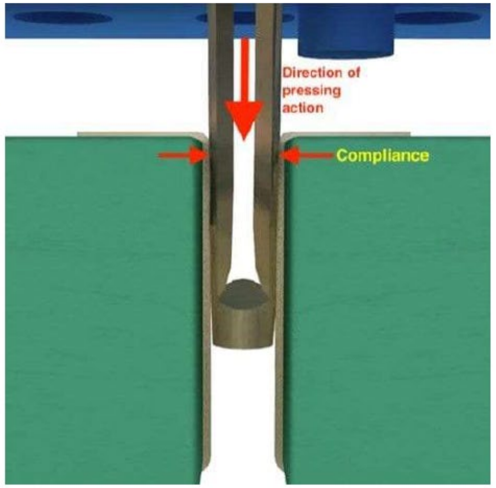


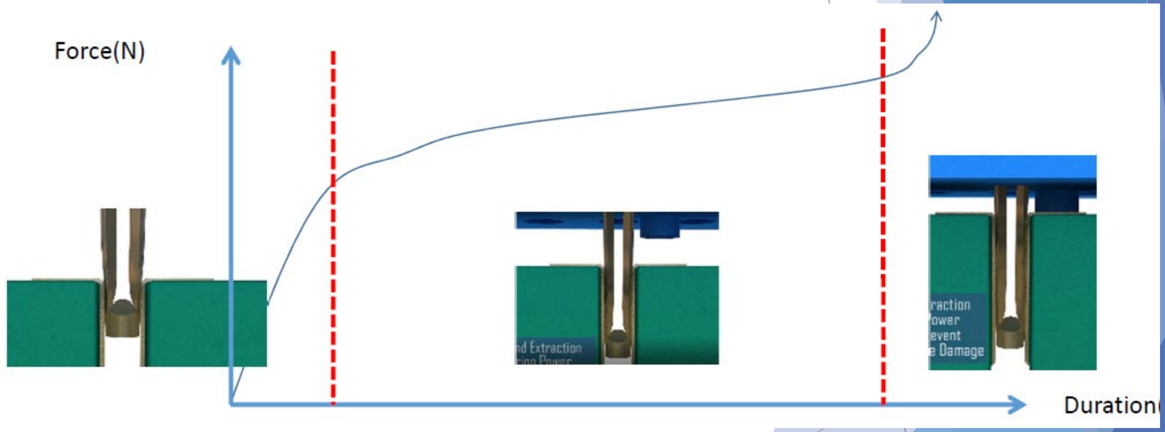


Emerging Press-Fit Design Approaches Low Insertion Force

- Low insertion force – PTH diameter enlarged to enable compliant pin deflection and gold-on-gold burnishing similar to a machined pin & socket, DC resistance target is 1.0mΩ
- Individual maximum, initial insertion forces; a press is still required
  - #22 & #20: 400 grams #18: 600 grams #16: 800 grams #12: 1.6 kilograms

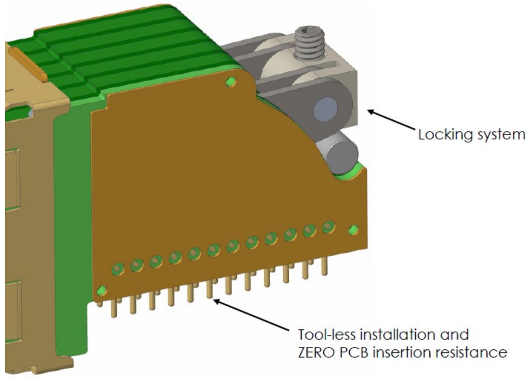


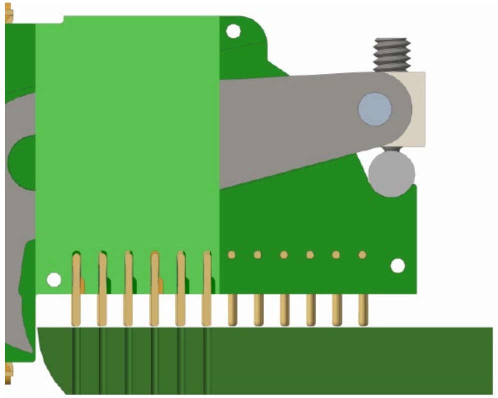


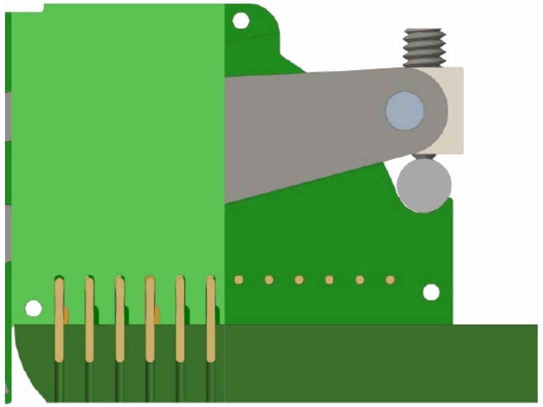


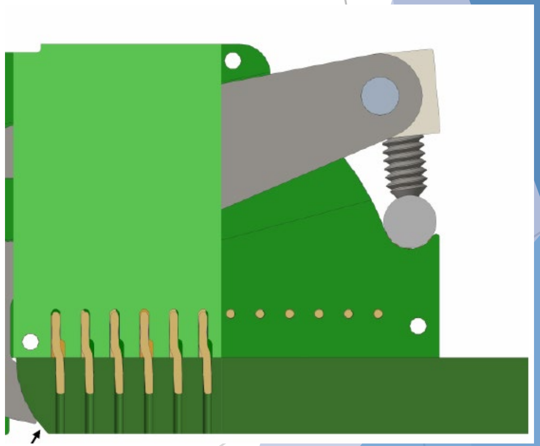
Emerging Press-Fit Design Approaches
No Insertion Force

- Gold-plated pins are 0.40mm (16 mils) diameter, 1.6mm -2.0mm pitch, free insertion into gold PTH’s, no wiping, for straight & right-angle terminations
- Controlled pressure activated by the screw shifts the connector housing just enough to deform the pin within its elastic deformation range and provide gas-tight asperity areas in two regions.









Emerging Press-fit Approach Insulation Displacement

- UR polyurethane coating placed in the PTH. Inserted press-fit pin cuts through to the PTH plating.
- The intention is to keep the asperity areas in an anaerobic region
- The following single component polyurethanes should provide a consistent coat thickness:
  - HumiSeal 1A33 (oxygen cure) has been evaluated by one PWB vendor, in HASL PTH’s and SnPb compliant pins.
  - Cured thickness 1-3mm
  - Per pin pushout retention forces remained consistent: 650 grams mean over three mating cycles to simulate connector replacement
  - No appreciable change in DC resistance
  - Dymax 9771 under consideration for gold-on-gold; longer pot life during application; light & moisture cure; 0.2mm cured thickness; Shore hardness D72
- Life testing still needs to be conducted
- The rest of the PWB can be coated and staked with a polyurethane of choice

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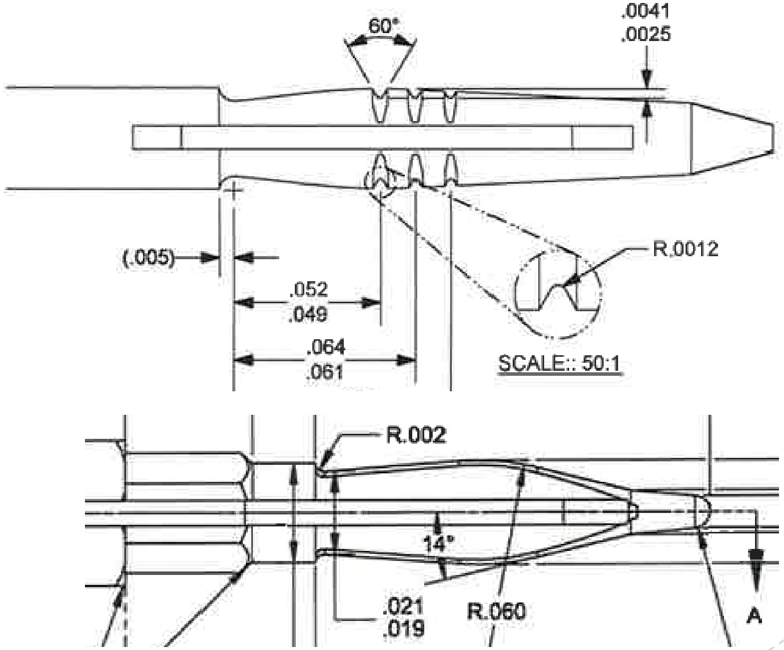
Eye Design– Machined

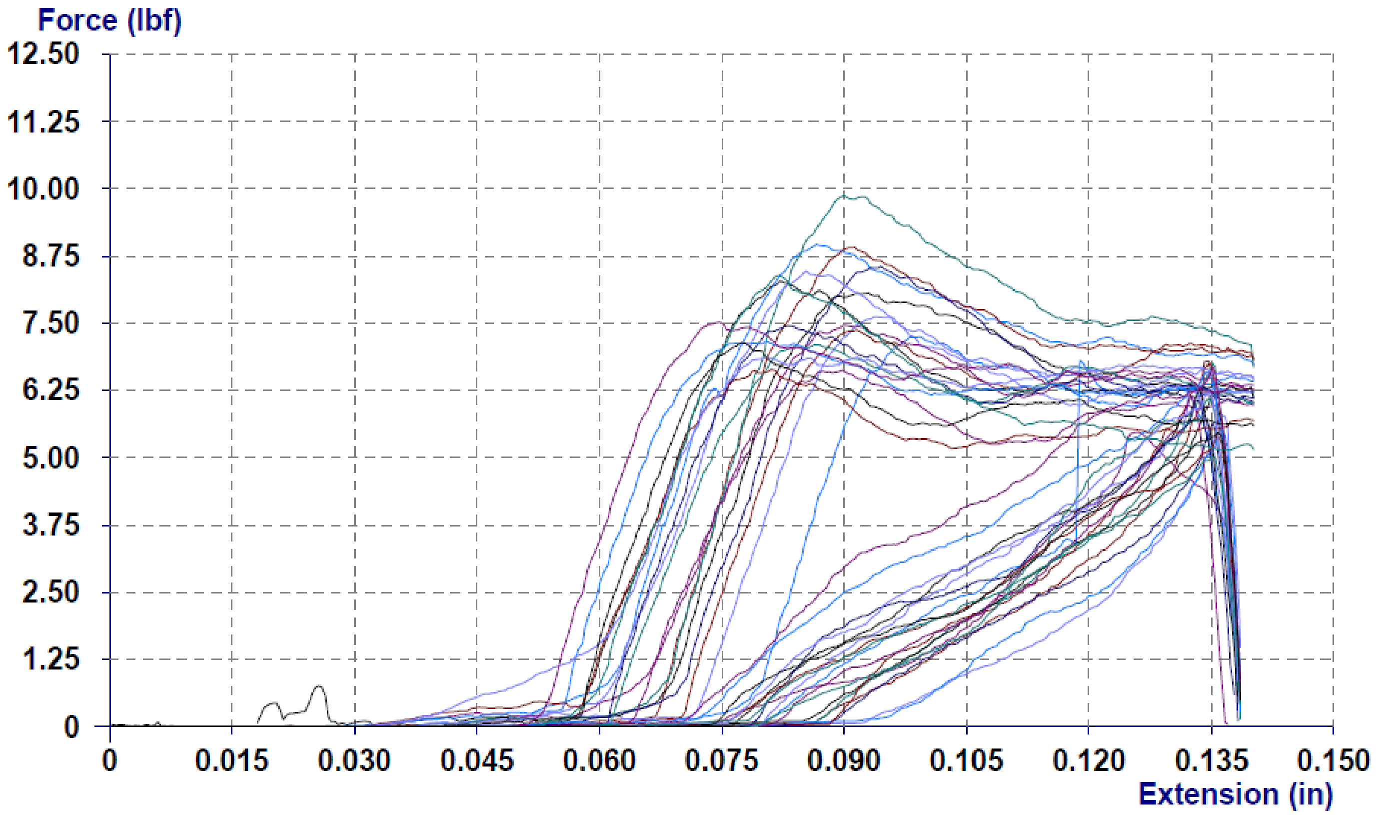
- Machined eye-of-the-needle, for a highly controlled surface profile or dimension control is desired. More expensive than stamped. Available on high-speed VITA connectors
- Elastic eye deformation still needs to be studied. This manufacturer recommends an ENIG PTH.



Machined Eye Insertion/Extraction Example

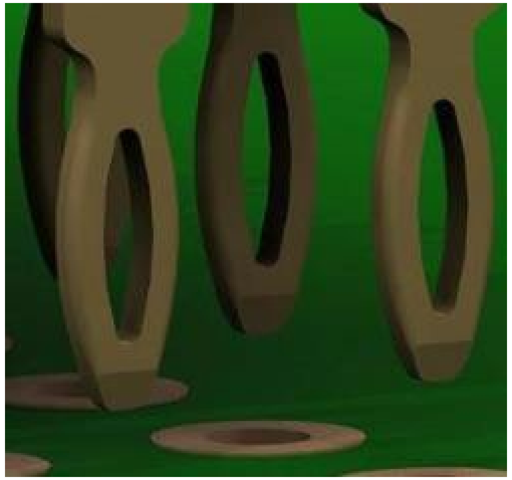
Gold Eye Pin into ENIG – First Insertion

- Mean insertion: 7.8 pounds (3.5 kilograms)
- Mean extraction: 6.1 pounds (2.8 kilograms)



Eye Design – Stamped

- Precision metal stamping – Single-stage shearing then sometimes followed by coining or compression embossing (metal is compressed and squeezed in some locations to form the desired three-dimensional shape)
- Whatever processes are used, the brass cannot creep to an out-of-spec shape
- Does a stamped eye lead to a reliable or favorable pin/socket system?



Press-Fit Technology for space-flight applications[1] – 1/2

- The test vehicles passed the test sequence up to thermal cycling (steps 1 to 16).
- The repeated insertion and removal operations did not induce damage in the PTH (no burrs, no chip).
- Vibration testing showed acceptable results, no damage observed.

Stage	Operation	Details
1	Mount the connector on the PCB	Press-in all connector
2	Visual inspection	Look for burrs, particles, damages
3	Remove the connector	Press-out 2 over 3 of connectors
4	Visual inspection	PCB barrel and contact termination
5	Mount the connector on the PCB	Press-in all connectors removed
6	Visual inspection	Look for burrs, particles, damages
7	Remove the connector	Press-out 1 over 2 of the removed connectors
8	Visual inspection	PCB barrel and contact termination
9	Mount the connector on the PCB	Press-in all connectors removed
10	Visual inspection	Look for burrs, particles, damages
12	Electrical tests	Low level contact resistance
13	Vibrations	Sine and Random
14	Visual inspection	Look for burrs, particles, damages
15	Electrical tests	Low level contact resistance
16	Thermal cycle	200 cycles -55°C/+100°C, sloop 10°/min max
17	Visual inspection	Look for burrs, particles, damages
18	Electrical tests	Low level contact resistance
19	Thermal cycle	300 cycles -55°C/+100°C, sloop 10°/min max
20	Visual inspection	Look for burrs, particles, damages
21	Electrical tests	Low level contact resistance
22	PCB Micro section	Destructive physical analysis

Table 3: Outline of evaluation test plan.

1 - Dr. Jean Baptiste Sauveplane, Gaby Cristian Mindreci, "Connector Press-Fit Technology for space-flight applications", Proceeding to Space Passive Component Days 2016, available online https://www.spcd.space/past-events.php?pastEvent=2016.

Press-Fit Technology for space-flight applications[1] – 2/2

- Selected connectors submitted to a complete set of environmental, electrical tests, and visual inspections including cross-sections.
- Two of the three types of analyzed connectors successfully passed these tests and demonstrated durability and assembly consistency.
- The third type presented internal cracks.
  - Cracks are visible at base of the pin insert of the press-fit connection and within the PCB PTH and dielectric area.
  - Tentative explanation for the formation of these cracks is the residual stress as the pin inserted into PTH.
- Vendor continues the qualification of the press-fit technology, implementing more robust designs to fix the observed deviations in the case of Combo-D connectors.

1 - Qualification of press-fit connector for space-flight applications, feedback and Design improvements - ESA/ESTEC, Noordwijk (The Netherlands) 2018-10-12, Aparicio et. al.

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 ≥ 1 μs 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

oved
ease.

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 g2/Hz	100 to 800	0.5 g2/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.	

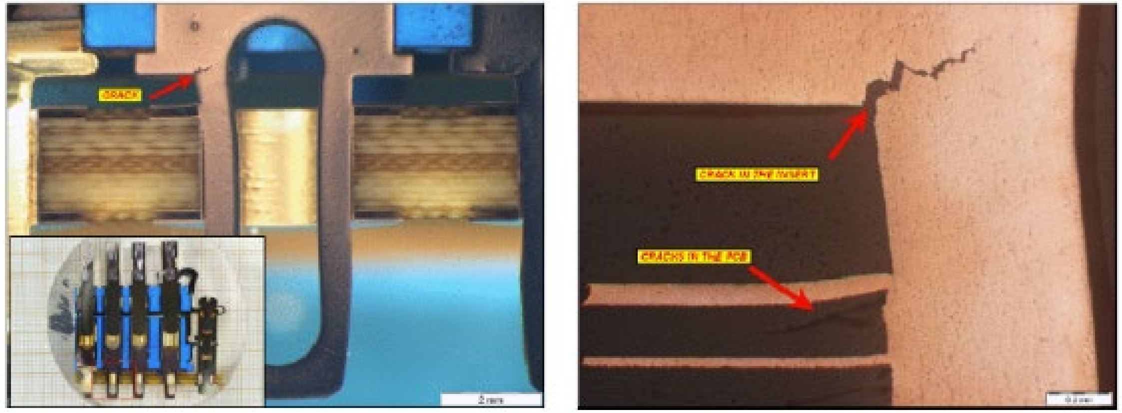


Figure 11: Worst case observed. Crack in connectors Combo-D

NASA-STD 8739.11 Proposed Language

There is no standardized method of terminating process for "compliant press fit" connectors. The compliant pin connectors were developed mainly for commercial applications and rely exclusively on connector compliant pin contact tails with plated through holes on printed circuit boards and no soldering involved. Their successful use is also dependent on the design, materials and processes used to produce the boards and used to terminate the connectors; connector level qualification cannot account for these variables. Connectors that were developed specifically to be soldered, the performance depends on the board manufacturer's ability to follow the plated through hole dimensions as recommended by the compliant press fit connector manufacturer.

The use of compliant press fit printed wiring board terminations on connectors shall require project or program approval. The project or program approval process will involve review of submitted specification, testing and qualification data. Compliant press fit connectors and printed circuit board interconnects shall be designed and qualified together as a system to a pre-defined specification. The following factors must be addressed in the specification:

1. *Compliant press fit connector materials and construction*
2. *Printed circuit board plated through hole design and materials*
3. *Compliant press fit tail insertion, assembly process, and retention forces*
4. *Screening and Qualification testing*
5. *Rework and repair*

NASA STD 8739.11 Rationale

- Press-fit connectors are strongly preferred in today's designs because the smaller press-fit pins require smaller diameter holes which require smaller pads
  - allows more routing real-estate without taking exceptions to specs.
- The lack of solder for a press-fit connection also makes the conductive path more predictable
  - Advantageous for high-speed digital design
  - impedance discontinuities can be minimized as the signal moves from the printed circuit board to the connector.
- Touch-up during manufacturing is also reduced and streamlines the assembly process.

Summary

- Press-fit technology has matured as its adoption has increased within high availability applications such as medical devices and avionics.
- Press-fit connectors are preferred in high density (smaller diameter holes, smaller pads, more routing real-estate).
- The lack of solder for a press-fit connection makes the conductive path more predictable for high-speed digital design and impedance discontinuities can be minimized as the signal moves from the printed circuit board to the connector.
- Inclusion of press-fits in upcoming NASA-STD-8739.11 will open the door for a broader review of press-fits for NASA missions.

Acknowledgements

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Q&A

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