

Reliability of PressFIT Connections

PressFIT is a force fitting easy connection technology, which provides a higher reliability to meet the trends to higher temperatures and new applications for power semiconductor modules. This technology is well-known as a highly reliable connection for several years in the industry, in telecommunications and in automotive designs. Infineon modify common reliability test procedures for power modules and PressFIT connections.

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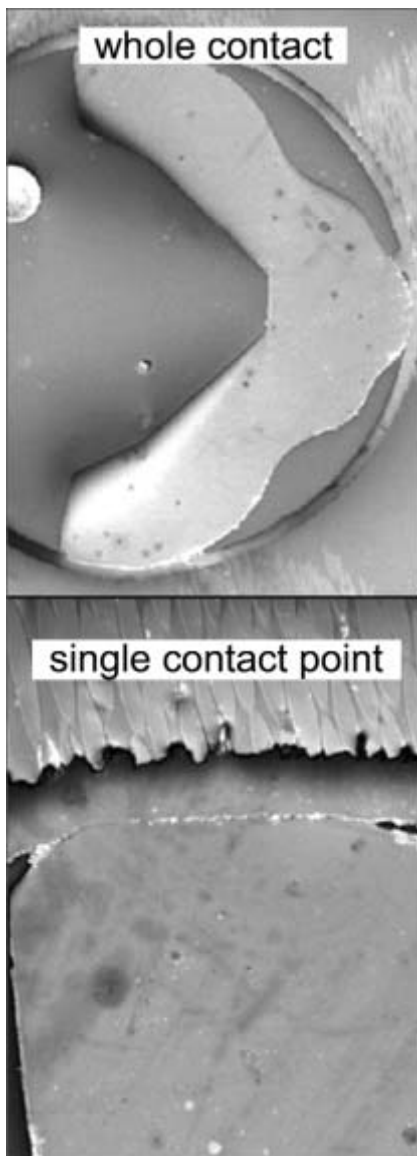


Figure 1: SEM micrograph from a cross section of well merged surfaces in a force fitting connection (here Easy PressFIT)

Force fitting connections

If two contact faces fitted together, there are only a few spots which are really connected (metal to metal) – also for polished surfaces. The minimum radius of such a contact is typically 10 μ m. In force fitting technologies like PressFIT, there is always a necessary plastic deformation on these really effective contact points within the contact zone, due to the high contact pressure that occurs since the macroscopic contact force concentrates on a small microscopic contact area. That means the two faces will be merged (Figure 1).

Thus, the effective contact zone will be increased and - that is the most important thing – a gas tight contact zone is generated, which is very robust against corrosive environments. A schematic drawing of this is shown in Figure 2.

The connection principle is the well known cold welding effect which dedicated for permanent contacts, where the requirements regarding reliability are often much higher [2].

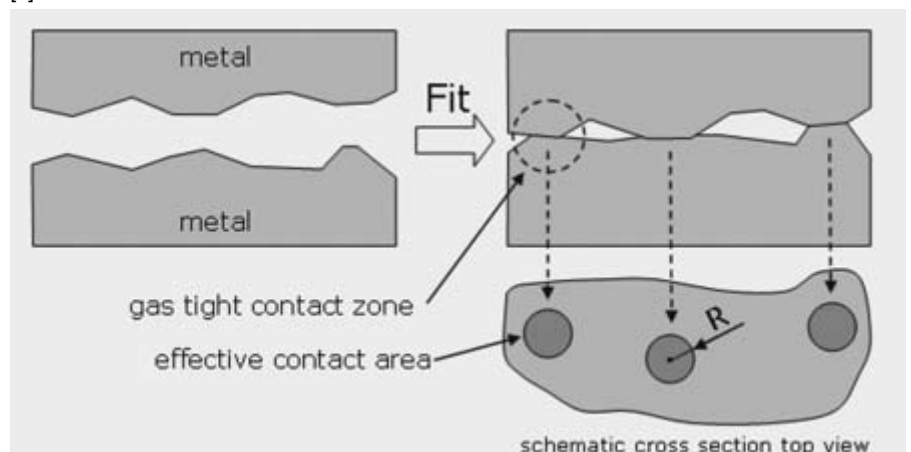


Figure 2: Principle of PressFIT connection [2]

Common subjects for connections

Overlays

On every surface there are existing overlays out of corrosions, organic waste (e.g. fat) and other contamination and oxide layers. The oxide layers are generating the most problems. To prevent such problems is to provide a surface out of noble metals. These surfaces are only leading to corrosion layers with a thickness of 2nm.

On all base metals, there can appear corrosion overlays in a thickness from 5nm up to more than 100nm. To build a good contact and to keep this alive, there are two mechanisms working:

The first is the so called "fritting". This is the effect, where by electrical breakdown at voltages above typical 20mV (depending on overlay thickness) most corrosion will be burned away. The disadvantage is that for voltages below the 20mV limit (for signals, measurement voltages), fritting does not occur and the contact resistance increases.

A second way is to make sure that such disturbing overlays are destroyed during the contact formation process. This happens by the use of PressFIT. No noble metal surface is needed, equal which signal has to transfer.

Fretting corrosion

In every design, there are ongoing movements during lifetime, due to vibrations or displacements from thermal cycles.

If the surface of the connectors is plated with a noble metal, there will be no contact problem. But, due to the friction, the lifetime of the plating (for noble metals mostly a flash of <0.1µm gold) is limited so that sometimes the problem is only shifted to a later date.

By the PressFIT technology with the high holding forces the actual movements are expected to be negligible. The movements within a contact system are generally under 10µm. The result is, that there is no relevant change of the contact resistance measurable over system lifetime, consequently the PressFIT contact is never expected to be the limiting factor.

If there are movements above the 10µm, the connector resistance increases to a few ohms quickly, in most cases (Figure 3) [2].

While a periodic displacement >10µm, resulting from periodically overcome of the holding force, will lead to contact degeneration for PressFIT contacts in the way described above, a limited number of long-range displacements are tolerated by the PressFIT contact system.

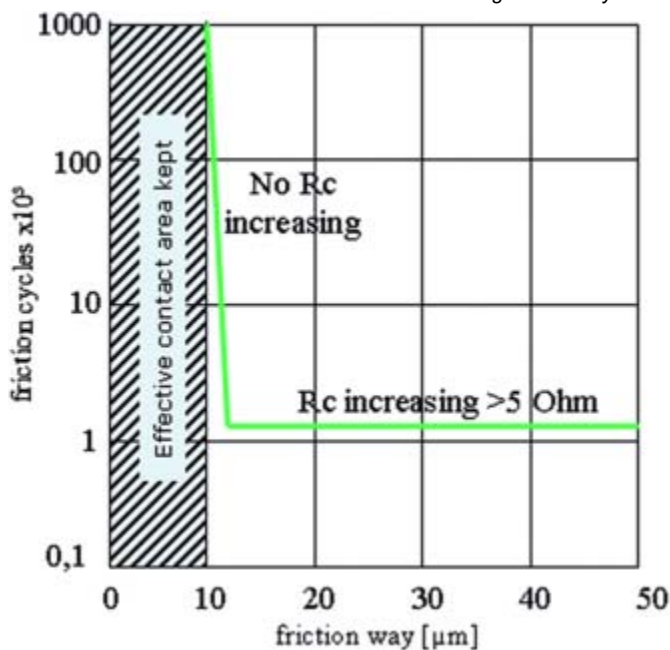


Figure 3: Relation of friction and resistance

The effect is that the high contact force is able to generate new, gas tight contact zones after a movement. That means also, the contact can compensate some displacements resulting from mounting displacements due to tolerances.

PressFIT connections for power modules

Econo & Easy PressFIT

Due to providing large enough force to remove corrosion layers and guarantee sufficiently high holding forces, providing enough flexibility not to destroy the contacted PCB, tolerating manufacturing tolerances for conventional PCB holes (vias), and providing sufficiently large current capability two PressFIT designs with flexible force fitting

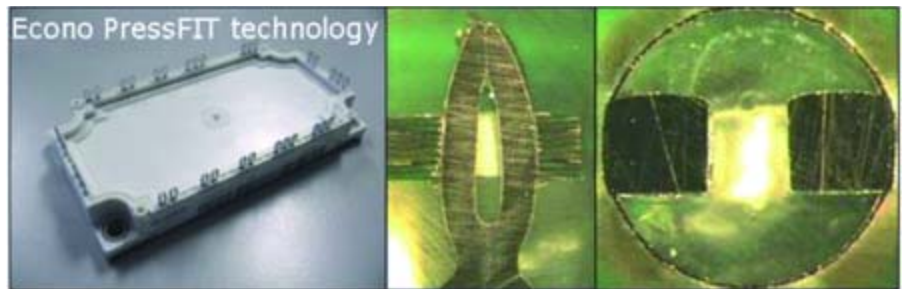


Figure 4: EconoPIM PressFIT

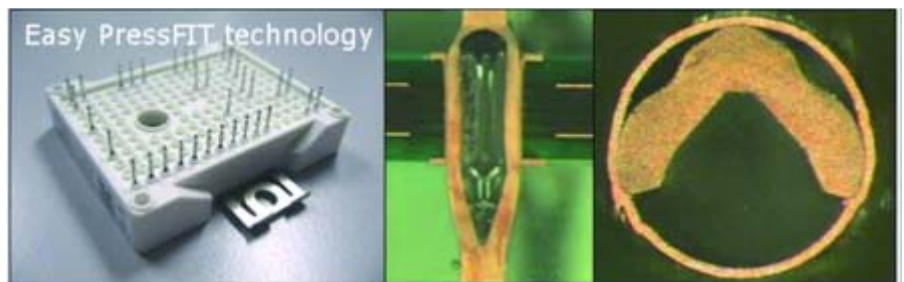


Figure 5: EasyPIM PressFIT

geometries have been developed (Fig.4 and Fig.5). The Econo and the Easy modules, providing current carrying capabilities to max. 50A/pin and 25A/pin [1] [3].

Test	Boundaries	Requirement	Amount
Microsections of contact	min. hole	No damages	6 contacts min hole
Press-in and push out forces	min. hole max. hole	The minimum and maximum push-outforce shall be specified by the manufacturer	7 contacts min hole 7 contacts max hole
Climatic sequence (contact resistance after different serial tests)			
TST	-40°C to +125°C, exposure time= 30min, 10 cycles	No relevant change of resistance	100 contacts min hole 100 contacts max hole
Damp cycling	16h dry heat 120°C, 5 cycles: damp heat (12h, 25°C; 85%-93% and 55°C; 85-93%) -> 2h cold -40°C	standard: 85°C resistance	Serial test! 2x 100 contacts have to pass all 4 tests in series!
Dry heat	120°C, 1000h	No relevant change of resistance	
Flowing mixed gas corrosion	4-components-mixed gas; 240h: SO2: 0,2ppm H2S: 0,01ppm NO2: 0,2ppm CO: 0,01ppm	No relevant change of resistance	

* Example of Easy PressFIT

Figure 6: Contact qualification acc. to IEC 60532-5 adjusted to power module needs

The Econo and Easy PressFIT are based upon the same principles for force-fitting connections. Both are built with a copper alloy and have a surface plating of pure tin.

Reliability of PressFIT connections for power modules

Standard reliability tests to release a new PressFIT design – with enhanced conditions

The PressFIT technology is qualified according the IEC standard 60352-5 (Figure 6) [4]. All the tests have to be made with standardized PCB's (with minimum and maximum hole diameters) and especially the climatic sequence is a quite challenging test.

For the required suitability for power modules, the temperatures in the single components of the climatic sequence have been increased. [4].

The temperatures in the Temperature Shock Test (TST), damp cycling and the dry heat test have been increased (Figure 6). This value even lies significantly above the common maximum temperature for standard PCB's of 105°C.

All the qualifications have been passed, without any failure and without any noticeable contact degradations.

As shown in Figure 7, the contact resistance of the PressFIT contact is even decreased after the climatic sequence test (minimum hole diameter of 1.04mm). This is the well known effect described above, resulting from re-crystallisation and the further merging of the contact partners.

Standard reliability tests to release a power module – with enhanced conditions

For power modules, there is also a well established standard accepted, according to the IEC 60749 [6] (Figure 9). In addition, some further tests became usual regarding the influence of the environment of the modules, according to the IEC 60068-2 Part 43 and 52 (Figure 9) [7] [8].

All the reliability standard tests for modules are made without a PCB and now by the improved tests a PCB were used.

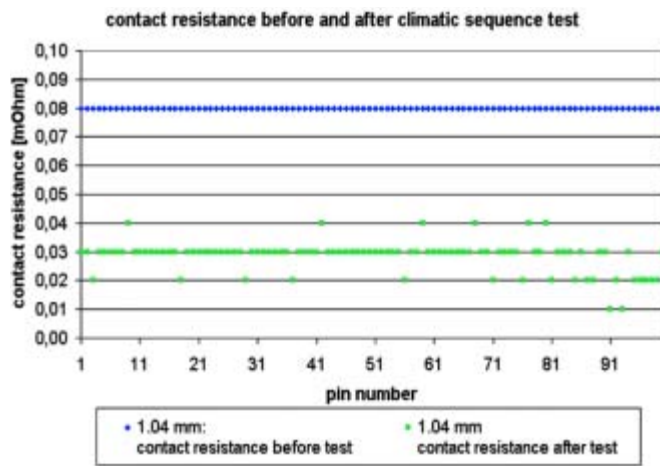


Figure 7: Contact resistance after a climatic sequence

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In the H3TRB (high humidity, high temperature, reverse bias), TST (thermal shock test) and the vibration test, an additional online resistance measurement was realised. The voltage was adjusted at ~1.3mV (1.2mV to 1.4mV, depending on temperature in test and corresponding electric conductivity) and the current was set to 1A. As described above, these low values are important to eliminate fringing effects, which could blur small changes of the contact resistance. The resistance value of 1.3mOhm belongs to the whole test setup and consists of two contact resistances and a small circuit path (Figure 8).

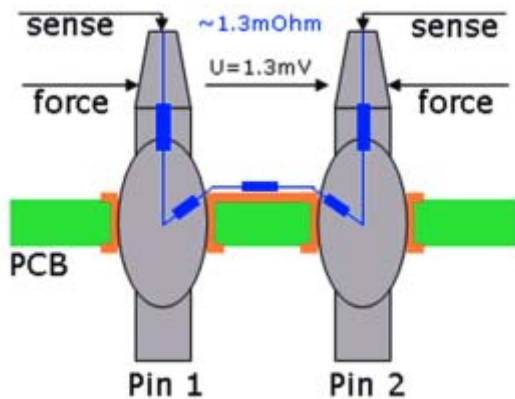


Figure 8: schematic drawing of the online resistance observation setup.

For the power cycling test ("minutes"), the temperature was not only adjusted to the maximum chip temperature but also to a maximum PCB temperature of ~105°C.

Module Qualification acc. to IEC 60749			
Test	Boundaries	Requirement	Amount
H3TRB	1000h; 85°C; 85%RH; Vce 80V; on PCB with online resistance observation*	No relevant change resist. after 1000h	standard: Without PCB & without R-online observ.
TST	-40°C to +125°C; 50 cycles; on PCB with online resistance observation*	No relevant change resist. after 50 cycles	
Vibration	5g; 5-200Hz; x=7.5mm; 10h/axis; on PCB with online resistance observation*	No relevant change resist. after 10 hours	Standard: Without PCB
PC (seconds)	Tjmax=150°C; ΔT=100K; tsw=1.5sec / tdr=5sec on PCB	End of life (until delamination of silicon)	Adjusted to a PCB temperature of ~105°C
PC (minutes)	Tjmax=150°C; ΔT=110K; tsw=9sec / tdr=30sec on PCB with Tjmax ~105°C	End of delamination of silicon	
Further Qualification acc. to IEC 60068			
Corrosive gas test	50ppm H2S; 40°C; 93% RH; 17 days; mounted on PCB	No relevant change resist. after 17 days	standard: Without PCB; 10ppm; 25°C; 70%-80% RH
salt mist	4 spray cycles: 2h spray period (15-35°C; 5% NaCl); storage 20h (38°C - 42°C; 93% RH); after 4 cycles 3 days drying (21°C - 25°C; 45% - 55% RH); mounted on PCB	No relevant change of resistance after Test	standard: Without PCB

* Online resistance observation in current free arms with ~1.3mV

Figure 9: module qualification acc. to IEC 60749 and 60068

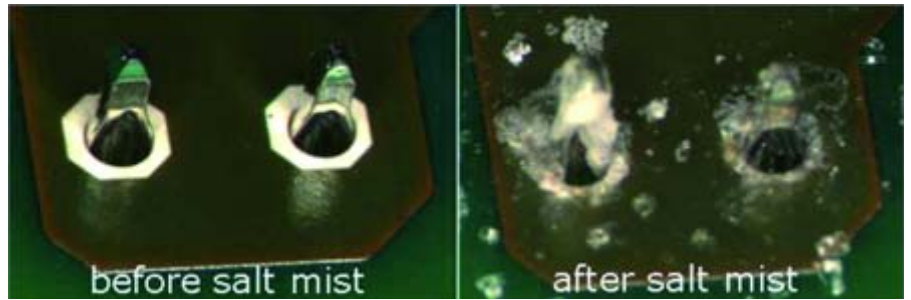


Figure 10: Contacts before and after salt mist

By the corrosive gas test the concentration of 10ppm H2S was set to 50ppm and the temperature in the chamber was increased up to 40°C compared to 25°C and the humidity was set to 93% instead of 80%. These values are out of the limits of the available test equipment.

The green fields denote the boundaries defined in the original standards [6] [7] [8].

All modules related tests have been passed without any measurable contact degeneration (Figure 10).

Also in the online resistance observation, no interruption or conspicuous change has been detected (Figure 11).

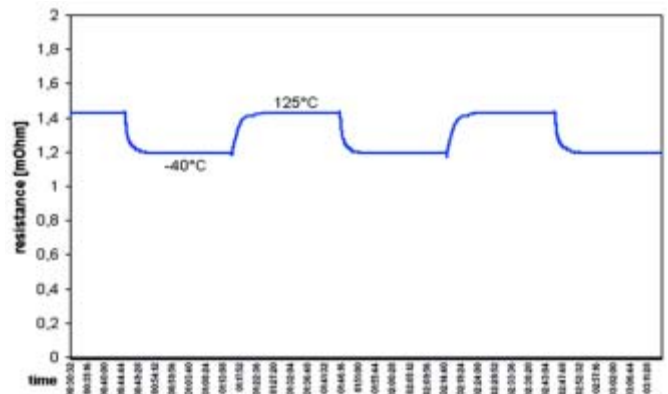


Figure 11: Value pattern (mOhm) of online resistance observation – here of TST

Figure 11 shows the online observation of the terminal resistance in the TST test. No deviation could be noticed over operating time of all tests between the two temperatures of -40°C and +125°C.

The vibration test was made with the same conditions as in the "standard" test (Fig.9) but with an acceleration of 20g. In the standard or special test, it is always difficult to find a representative setup because the geometric design and the masses in real applications are never similar. So it was decided, to realise the test with a small PCB without additional masses and without a fixation at the module. These have also been used for the "standard" vibration test. An online resistance measurement was not possible because the equipment was too sensitive for this test.

The result shows that also a really strong vibration with 20g could not damage or degrade the PressFIT contact (Figure 12).

Reliability & Rework

Mostly it is mandatory to get a design which is suitable for service and repair. As shown in previous publications modules with PressFIT connections can be demounted and the PCB can be used two more times with a new module [1] [3].

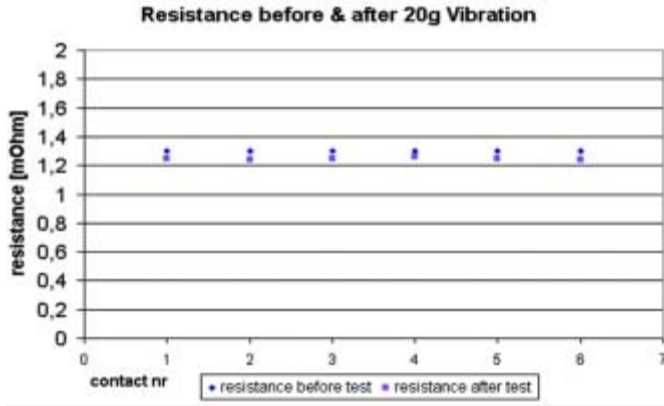


Figure 12: Resistance before and after 20g vibration load

But what's about the reliability of the PressFIT? An additional TST test series with Econo PressFIT modules has been made. Readouts at 50 cycles, 100 cycles and 150 cycles have realised, to get comparability to a test with an identical but reworked setup (Figure 13).

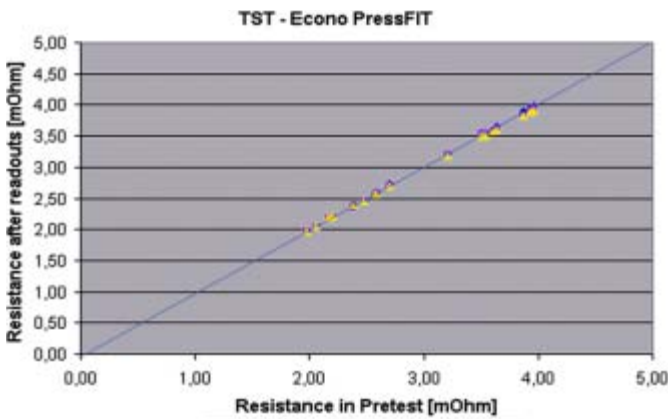


Figure 13: Comparison of resistances after TST from 50 to 150 cycles without rework

By the rework test a first module was pressed into the PCB. After a pre-measurement of the resistance, 50 cycles of TST (-40°C to 125°C) have been made and measure the resistance again. The module was pressed out and a new, second module was pressed in. Again, pre-measurement, TST and measurement of resistance after TST has been done. This procedure was done again so that three modules have been run trough 50 cycles of TST each – all in one and the same PCB.

The PCB has a few connections to measure the resistance of the pins, which have different connection lengths. Due to these different lengths in the setup, there is a wide spread of the single resistance values in the results because they are dominated by the lead resistances between contact and measurement points (Figure 14).

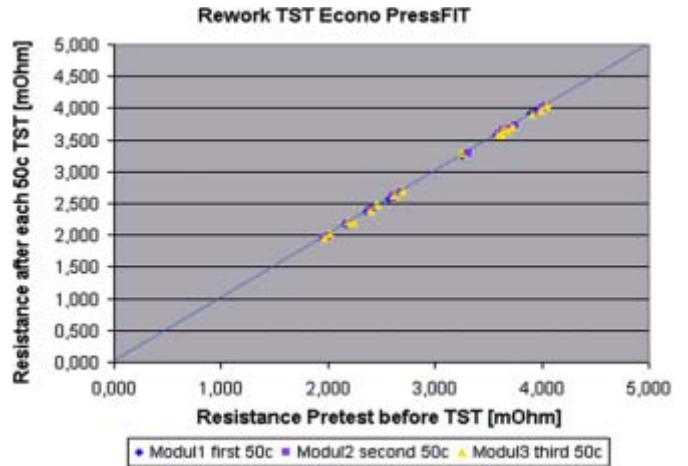


Figure 14: Three modules in three times TST in series with one PCB board.

Conclusion

The result of all the tests shows that there was no measurable contact degradation. The resistance of the connection, is very stable during and after several loadings. This means not only that high current can be handled safely over the lifetime, but also the advanced integrated functions with low voltage and current (e.g. current sensing) will be kept absolute stable beyond the lifetime of the system. Due to this, the PressFIT technology is well suited for the application of power semiconductor modules – especially for future requirements of higher reliability.

Literature

- [1] M. Thoben, I. Graf, R. Tschirbs, "Press-Fit Technology, a Solder less Method for Mounting Power Modules", PCIM 2005
- [2] A. E. Schön, "Kontakttechnologie und Qualitätssicherung bei Kontaktbauteilen", Seminarunterlagen, Starnberg, 2005
- [3] M. Thoben, M. Buschkühle, T. Stolze, "Utilizing Press-Fit for solder less assembly of pin grid connected Power modules", PCIM 2007
- [4] European Standard, EN 60352-5:2001, "Solder less connections – Part 5: Press-in connections – General requirements, test methods and practical guidance", January 2002
- [5] R.Holm, "Electric contacts – Theory and application", Springer Verlag, Berlin, 2000.
- [6] IEC Standard 60749, "Semiconductor devices - Mechanical and climatic test methods", August 2002
- [7] IEC Standard 60068-2, "Environmental testing" Part 52: Test Kb: "Salt mist, cyclic (sodium, chloride solution)", February 1996
- [8] IEC Standard 60068-2, "Environmental testing", Part 43: Test Kd: "Hydrogen sulphide test for contacts and connections", May 2003