Durability of Connecting Hardware under Electrical Load for Power-over-Ethernet Applications

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Durability of Connecting Hardware under Electrical Load for Power-over-Ethernet Applications

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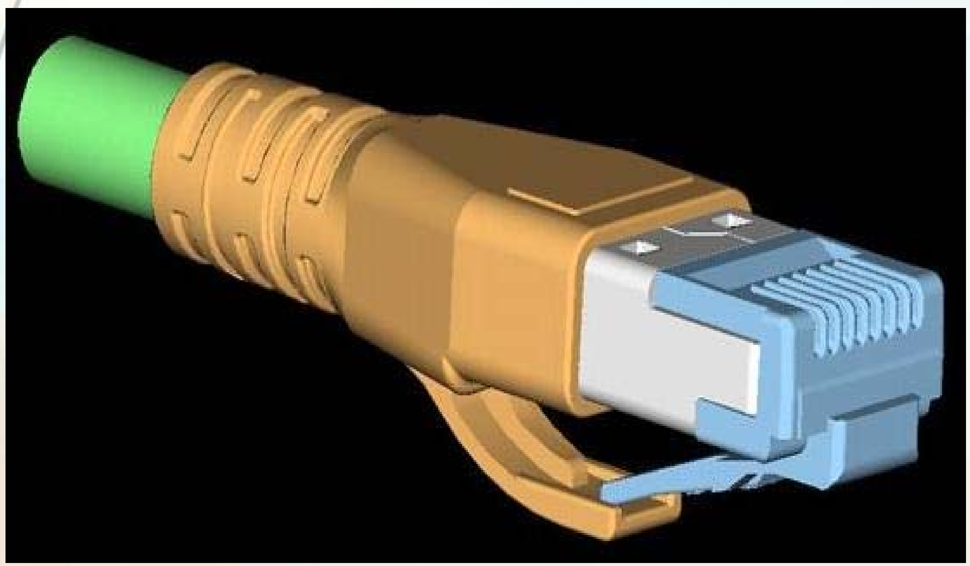
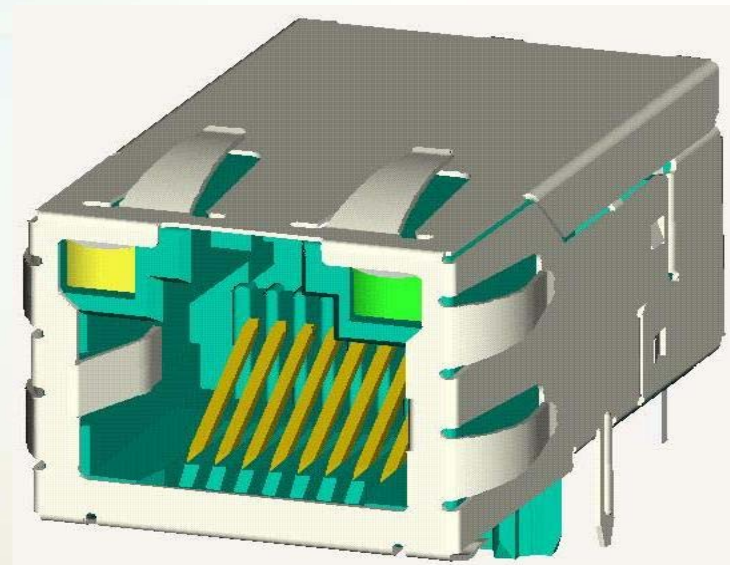
International Electrotechnical Commission
TECHNICAL COMMITTEE No. 48: ELECTROMECHANICAL COMPONENTS AND MECHANICAL STRUCTURES FOR ELECTRONIC EQUIPMENT

EC Cabling News Technical Note April 2007

PoE = POWER – over –ETHERNET

PoE enables network devices to receive power over the same cable that supplies data and eliminates the need in additional power cables and transformers and AC outlets.





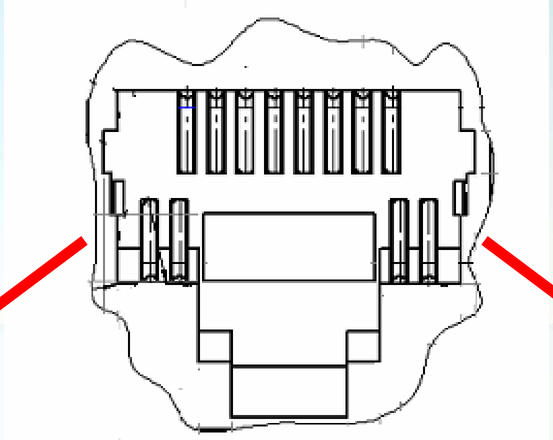
As the result:

the network connecting hardware (RJ45 and ARJ45) are exposed to effects of the power discontinuation

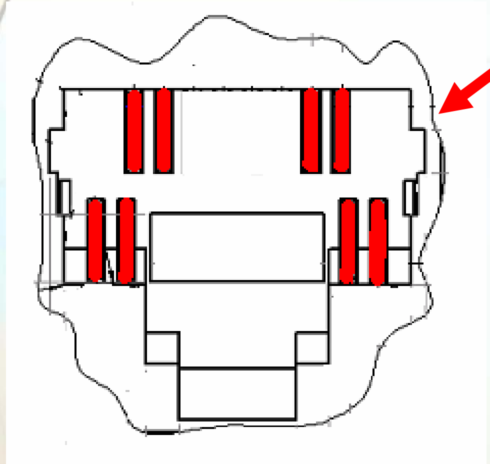
Transmission classes, Connector categories and Interfaces

ISO/IEC 11801	Connector category	Freq. max. Character.	Application	Connecting Hardware Interface
Class C	3	16 MHz	IEEE 802.5 TokenRing	RJ 45
Class D	5e	100 MHz	10 to 1000baseT Ethernet	RJ45
Class E	6	250 MHz	100-1000 baseT	RJ45
Class Ea augmented	6a	500 MHz	10 Gigabit	RJ45, ARJ45
Class F	7	600 MHz	1G over single pair 10 Gigabit	GG45, ARJ45
Class Fa augmented	7a	1000 MHz	10 Gigabit over 2 pairs	ARJ45, Tera
NA	NA	5000 MHz		ARJ45

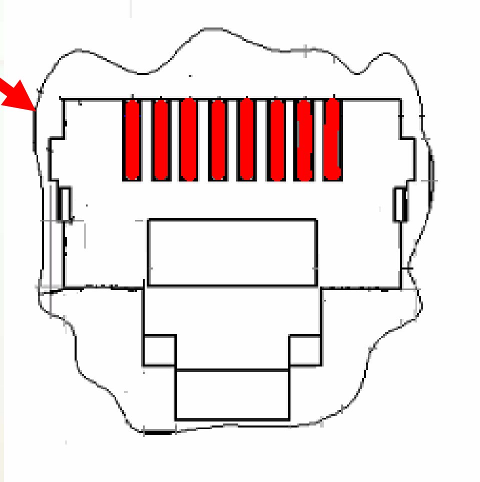
STANDARD CONNECTOR INTERFACES for NETWORKING



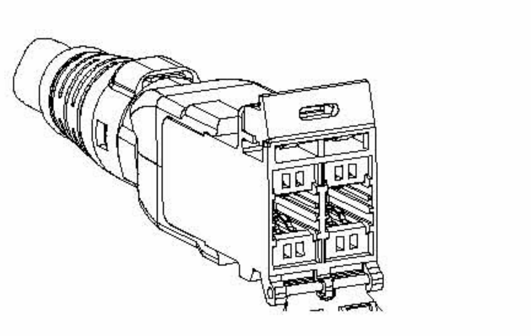
GG45 or ARJ45 HD
12-CONTACTS



ARJ45 HS 8-CONTACTS,
1000 MHz + Category 7A



RJ45 8-CONTACTS,
Up to 500 MHz Cat. 3 to 6A



Tera Connector
Alternative interface

PHYSICAL PHENOMENA
due to
ELECTRICAL CONTACT SEPARATION

- **Effects caused by mechanical abrasion and environmental exposure**
- **Effects caused by electrical discharge**

SPARK	**CORONA DISCHARGE**
Fast, single event, Time independent Large distinct crater	Relatively slow, time dependent Multiple events, shallow craters or pitted surface, erosion

Combination of all

Effects and Acceptance criteria

EFFECTS

Short term

- **Physical/mechanical damage**
- **Electrical Interface Degradation**

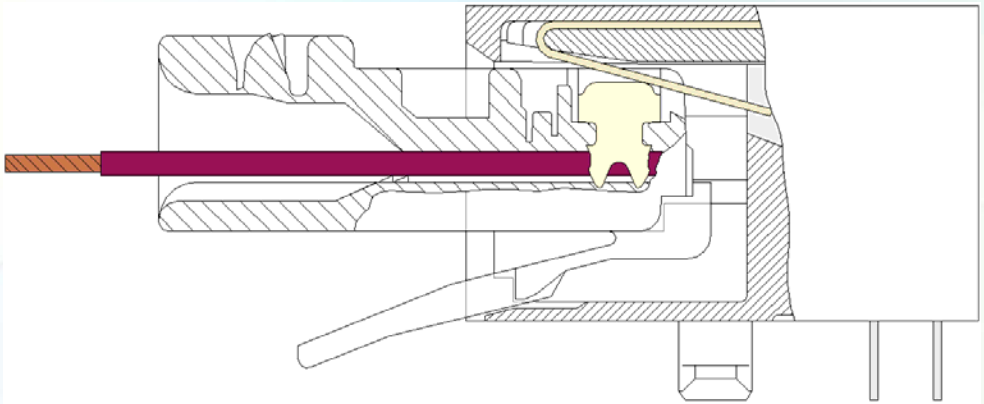
Long term

- **Physical/mechanical damage**
- **Corrosion**
- **Electrical Interface Degradation**

MAJOR ACCEPTANCE CRITERION

LOW LEVEL CONTACT Resistance

LLCR (bulk)



Low Level Contact Resistance (LLCR-bulk)

consists of four components

Plug Conductor Resistance

Plug Blade/Conductor Contact Resistance

Plug Blade/Jack Wire Contact Resistance

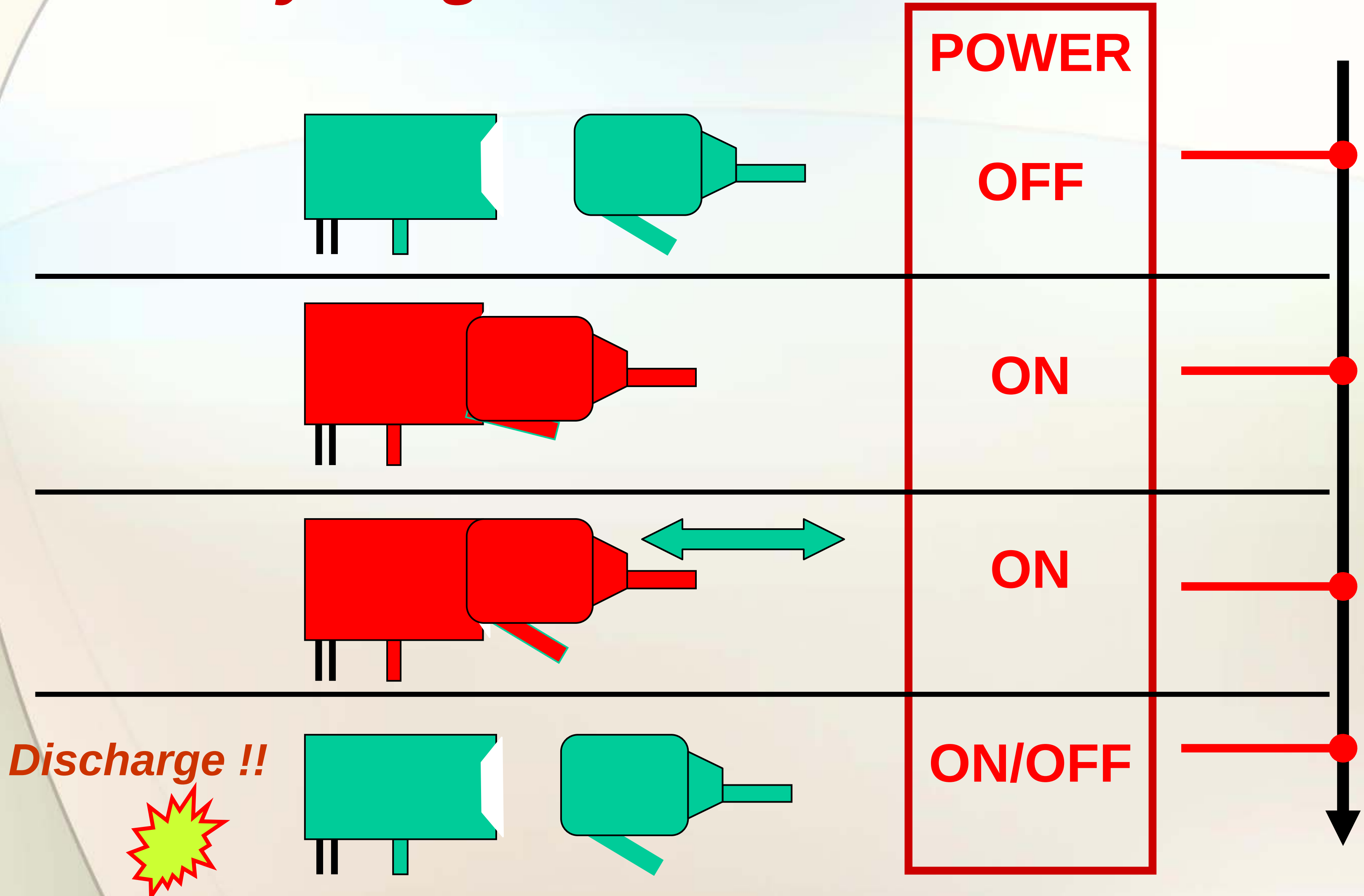
Jack Wire Resistance

Connector Durability under Electrical Load

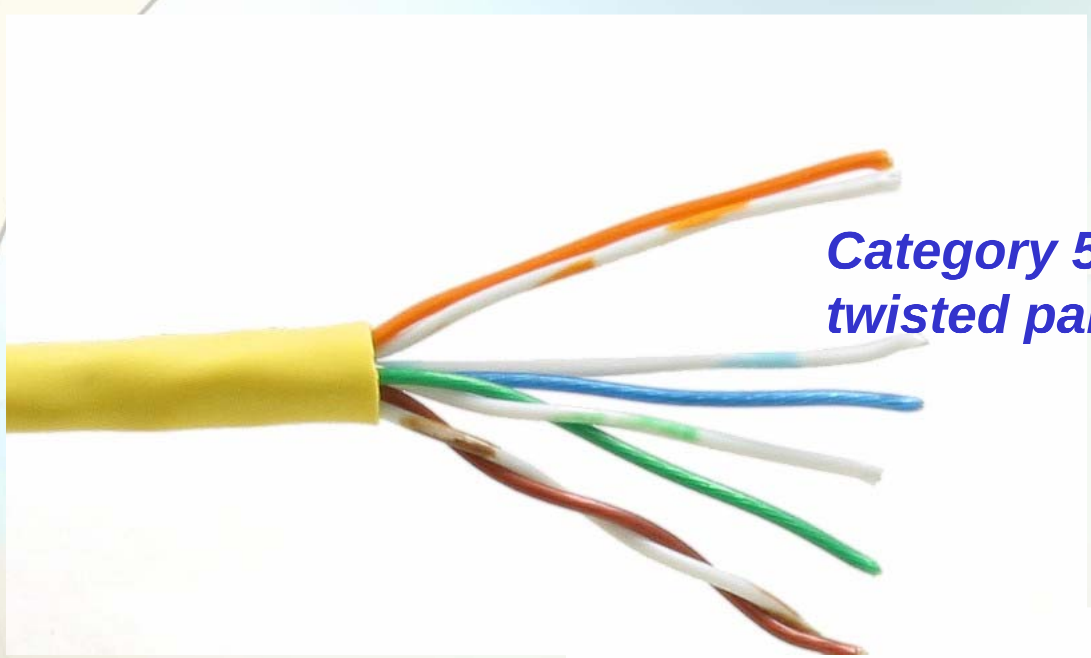
Table 1. Some factors affecting the connecting hardware durability

Test Matrix Variable Options.	
Variable	Item
Connector type	IEC 60603 interface
Connector manufacturer	Various
Speed of separation	Cycle/Hour
Cable length	m
Cable type	Shielded or unshielded
Number of contacts energized simultaneously	0, 1 or 8
Test circuit	A, B, C
Polarity	+/- Plug
Plating and finish	Thickness and porosity

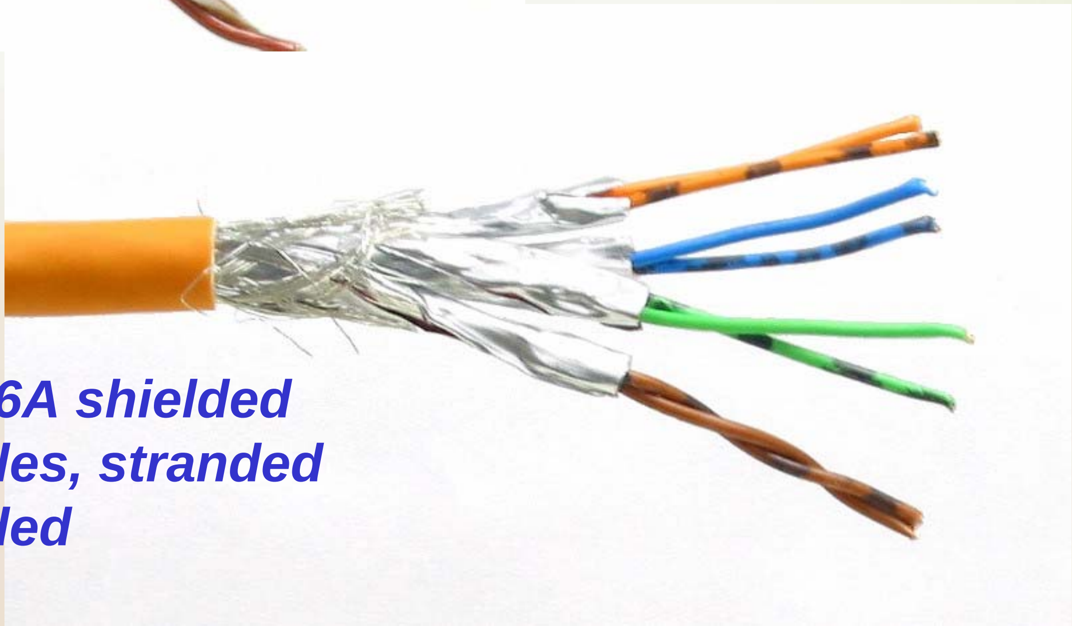
Power Cycling of Connectors



Twisted Pair Cables used in this study

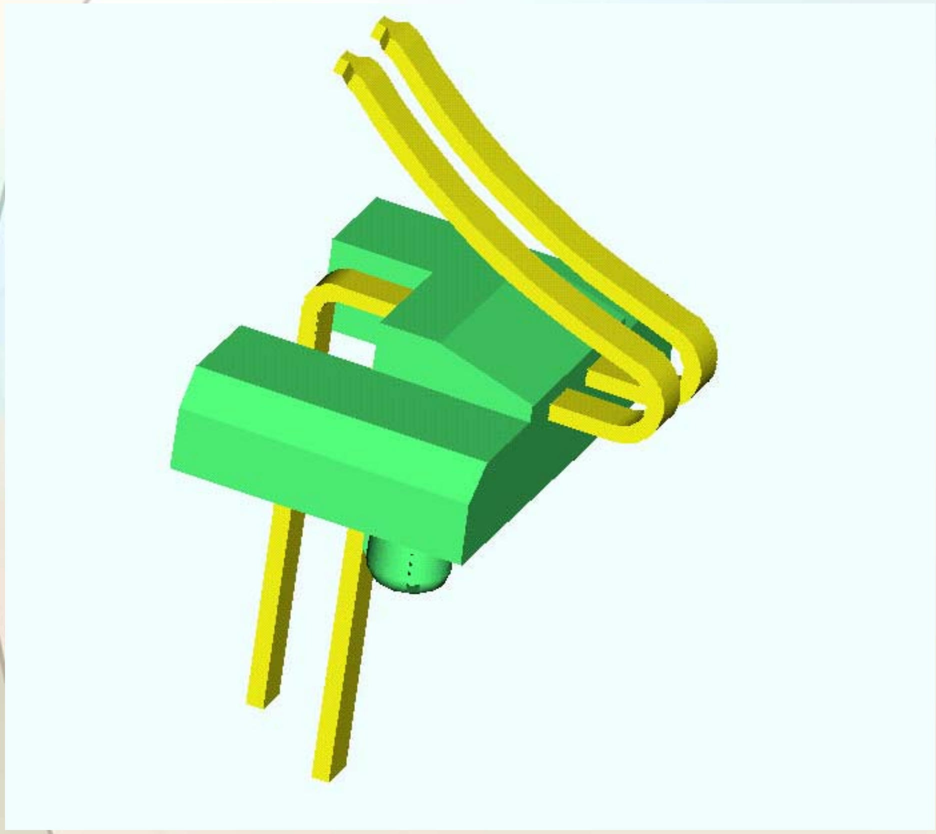


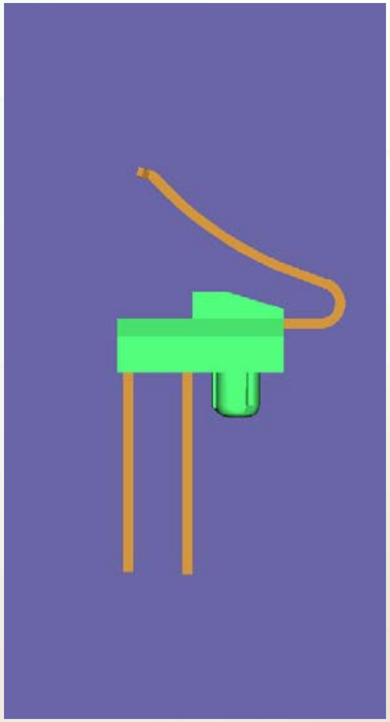
Category 5e (100 MHz) unshielded twisted pair , stranded



Category 7 and 6A shielded twisted pair cables, stranded with pairs shielded

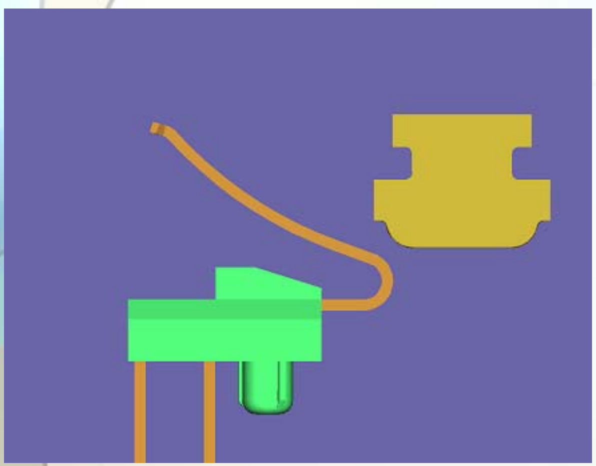
EXAMPLE of JACK Contacts



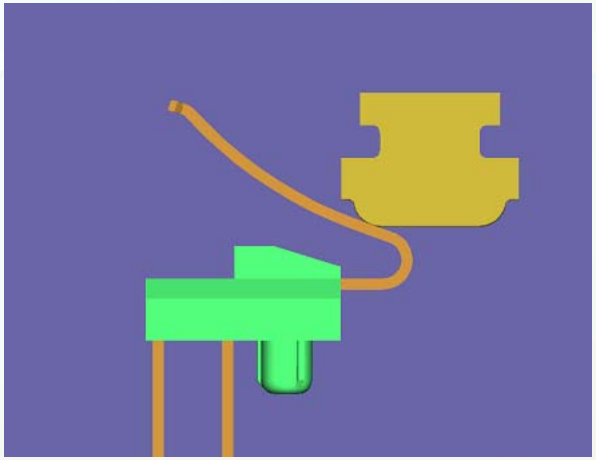


Bel Stewart Connectors

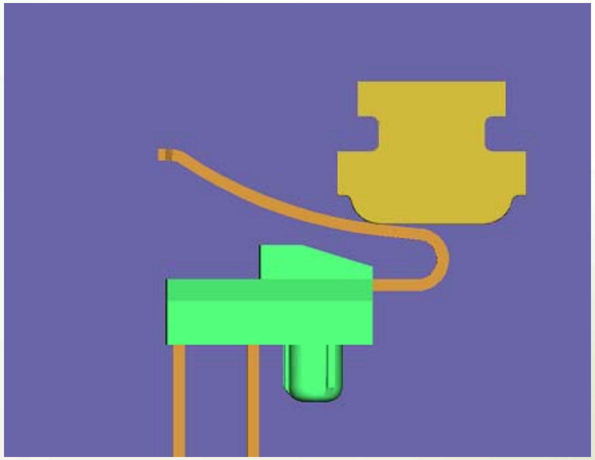
NOMINAL CONTACT AREA in RJ45 and ARJ45 CONNECTORS



Jack-Plug
prior to mating



Jack-Plug
Initial contact

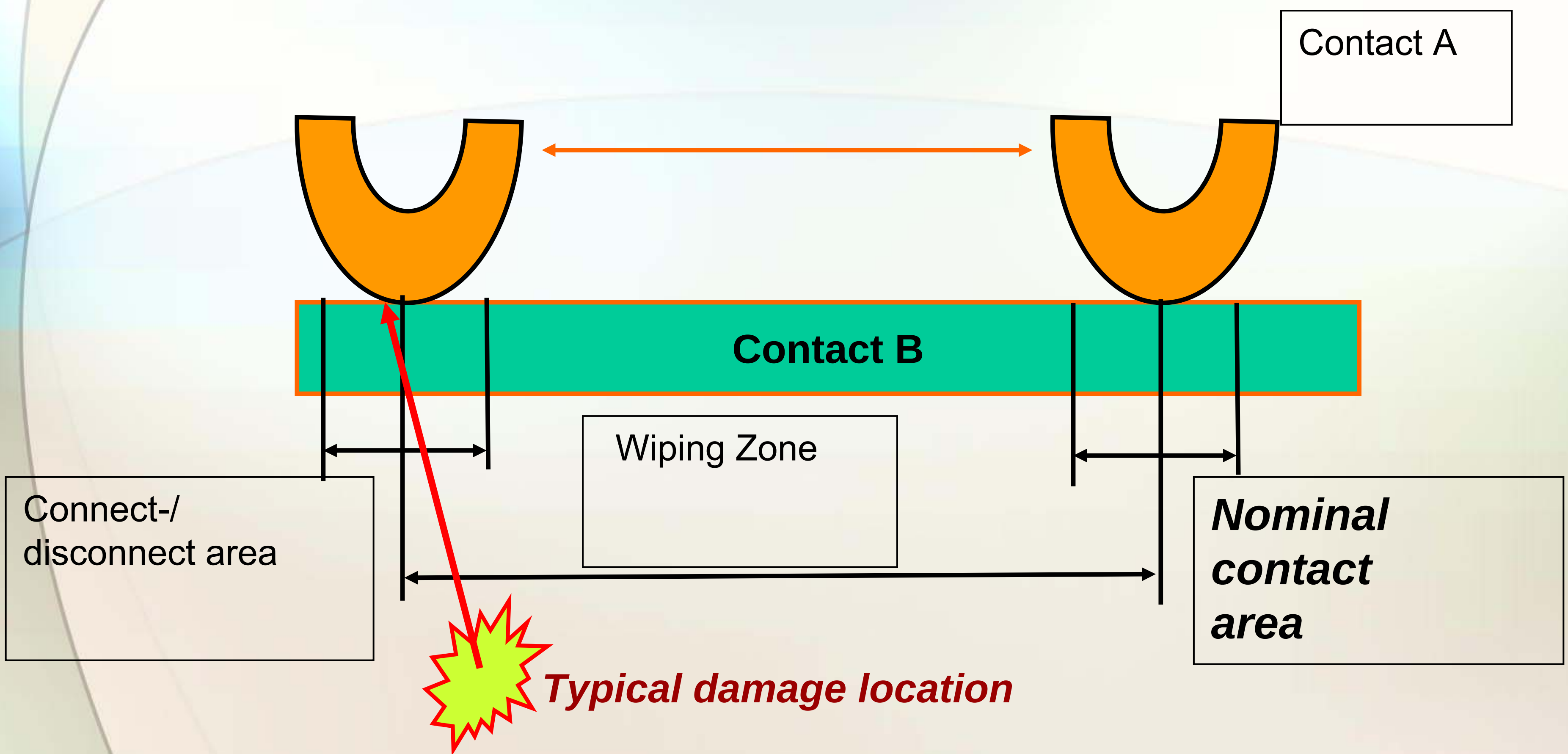


Jack-Plug
Final mating position

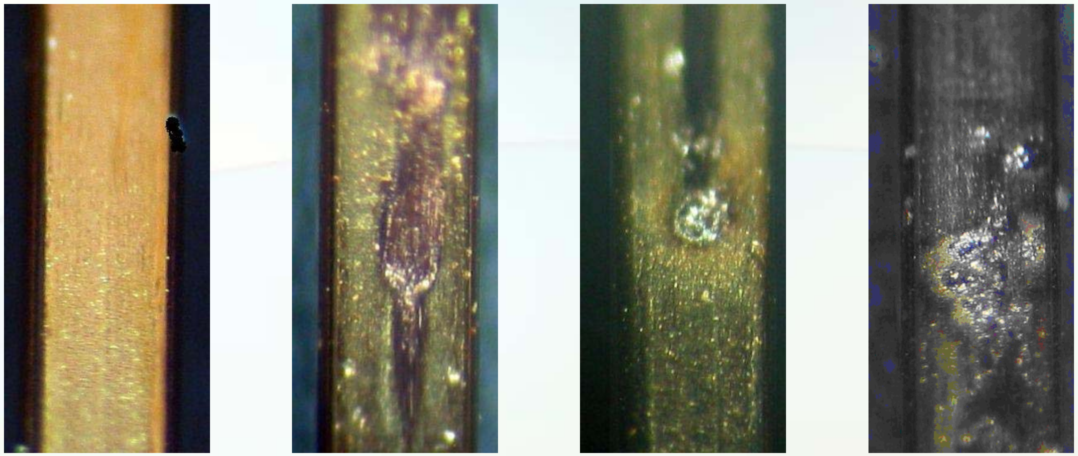
Final mating position typically within <u>0.024' (0.6 mm) +/- 0.012" (0.3 mm) from a nominal position</u> and 0.030" (0.75 mm) from the the initial contact.

<u>Nominal contact area is a final contact position in reference to nominal position</u>

NOMINAL CONTACT AREA in RJ45 and ARJ45 CONNECTORS



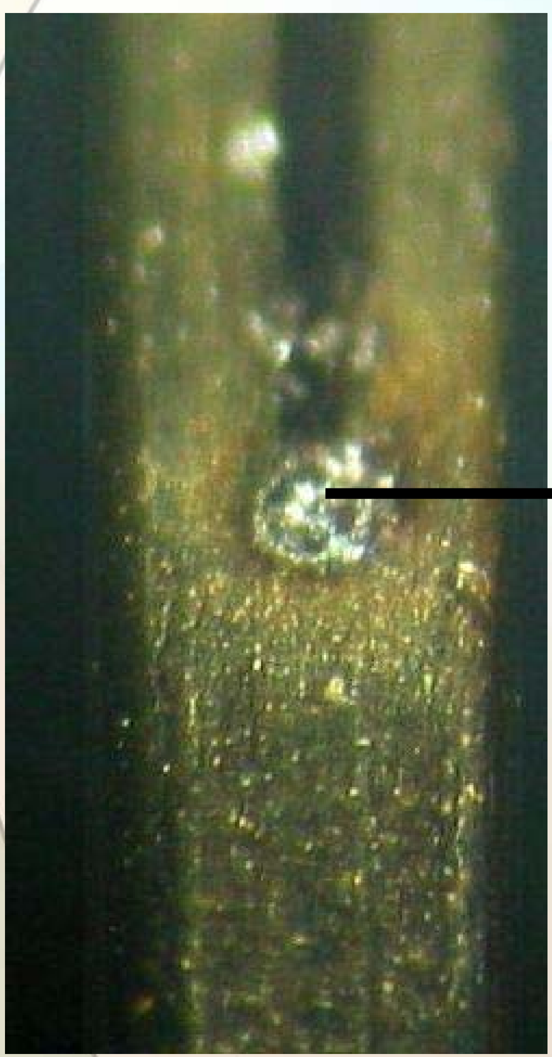
Connecting Hardware Contacts



A) B) C) D)

A) Fresh unused
B) After mechanical cycling without electrical load
C) Crater caused by a spark
D) Multiple craters due to discharges

Typical effect of Electrical Discharge in connectors



Connector Wiping Zone

SPARK CRATER located outside of ***nominal contact zone***

Connector Durability under Electrical Load

Table 2. Selected parameters of the test set up and procedures

Test No	Connector type	Speed of separation, cycle/hour	Cable length, m	Patch cord cable type	Contacts energized simultaneously	Power contact, W	Test Circuit	Cycle	Polarity
Test 1A	RJ45	300	2	5e unsh	0	NA	NA	NA	NA
Test 2A	60603-7-7	300	2	7 shielded	0	NA	NA	NA	NA
Test 3A	RJ45	300	2	5e unsh	1	20	A	Un-mate	+PLUG
Test 4A	RJ45			5e unsh	2	12.6	B	both	
Test 5A	RJ45			5e unsh	4	12	C	both	
Test 6A	RJ45			5e unsh	8	12	D	Un-mate	
Test 7A	RJ45	450	2	5e unsh	1	20	A	Un-mate	-PLUG
Test 8A	RJ45	720	2	5e unsh	8	20	A	Un-mate	-PLUG
Test 9A	RJ45	450	10	5e unsh	8	20	E	Un-mate	-PLUG
Test 10A	RJ45	450	10	6 unsh	8	20	C	Un-mate	-PLUG
Test 11A	60603-7-7	450	10	7 shielded	8	20	E	Un-mate	-PLUG
Test 12A	RJ45	720	10	5e unsh	8	20	F	Un-mate	+PLUG
Test 13A	60603-7-7	450	10	7 shielded	8	20	F	Un-mate	-PLUG
Test 14A	60603-7-7	720	100	7 shielded	8	20	F	Un-mate	-PLUG
Test 15A	RJ45	720	100	6 unsh	8	20	F	Un-mate	-PLUG

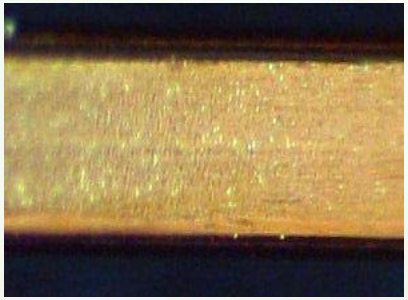
Identify the effects of mechanical operations

Tests 1A and 2A

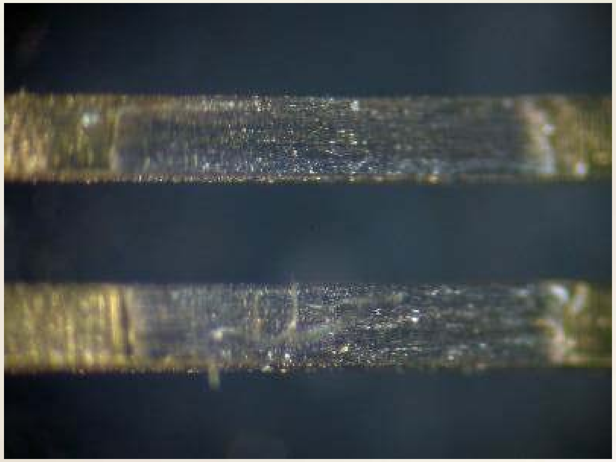
RJ45 fresh Contact

After 750 mechanical Cycles no el. load

ARJ45 fresh contact

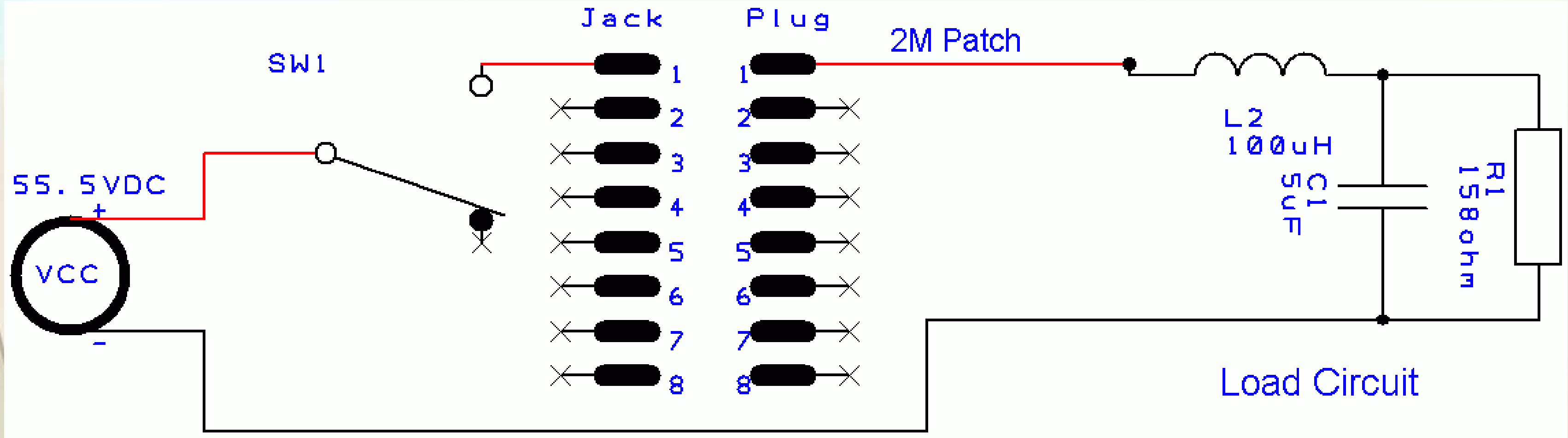


ARJ45 after 750 cycles no el.load



Tests 3A

Objective of this test was to identify parameters of the expected LLCR changes and variations in the LLCR during the unmating cycles only. The power was 20 W per contact. The LLCR was measured initially and after each 80 cycles, using a separate measuring plug. A total of 800 cycles were performed.



Test Circuit A

Overview of IEC TR: Connector Durability under Electrical Load

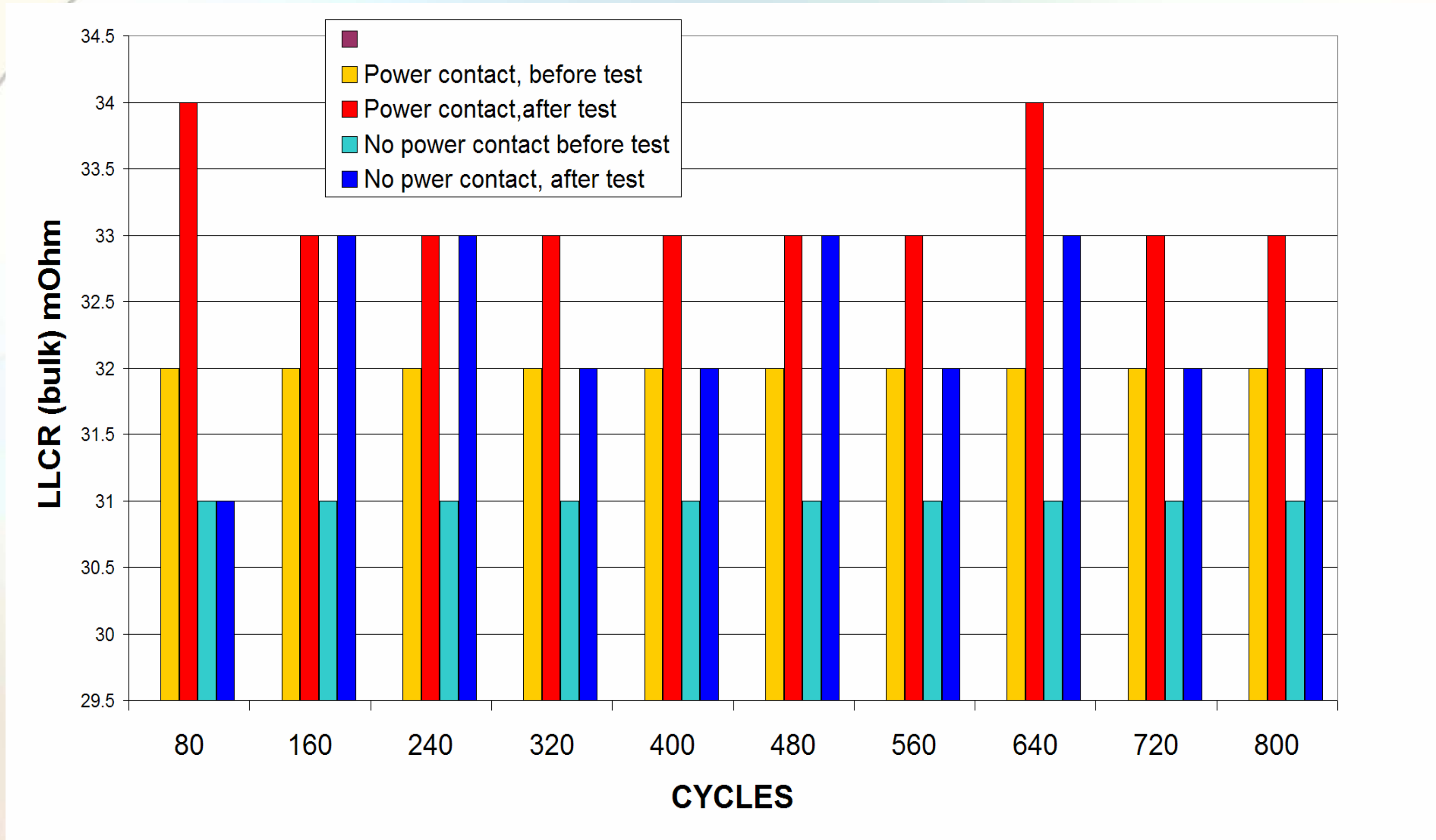
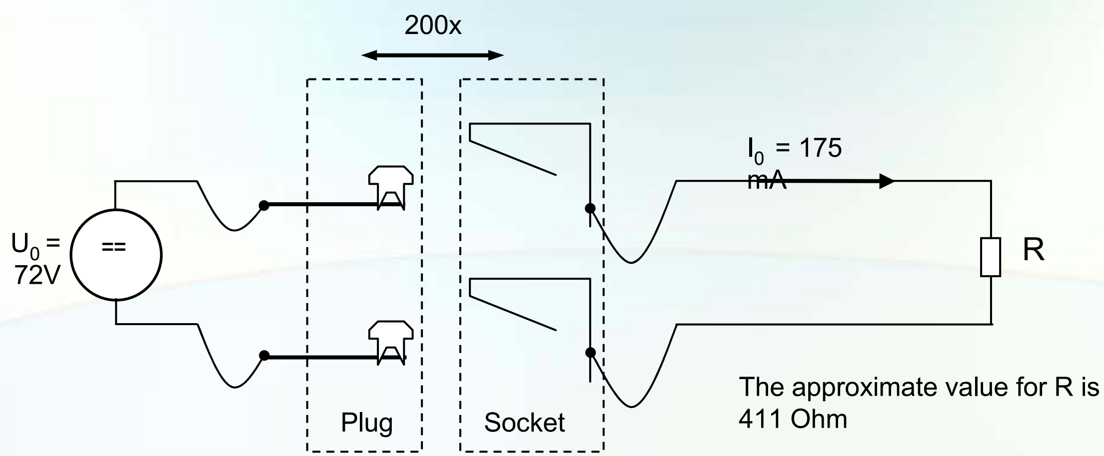


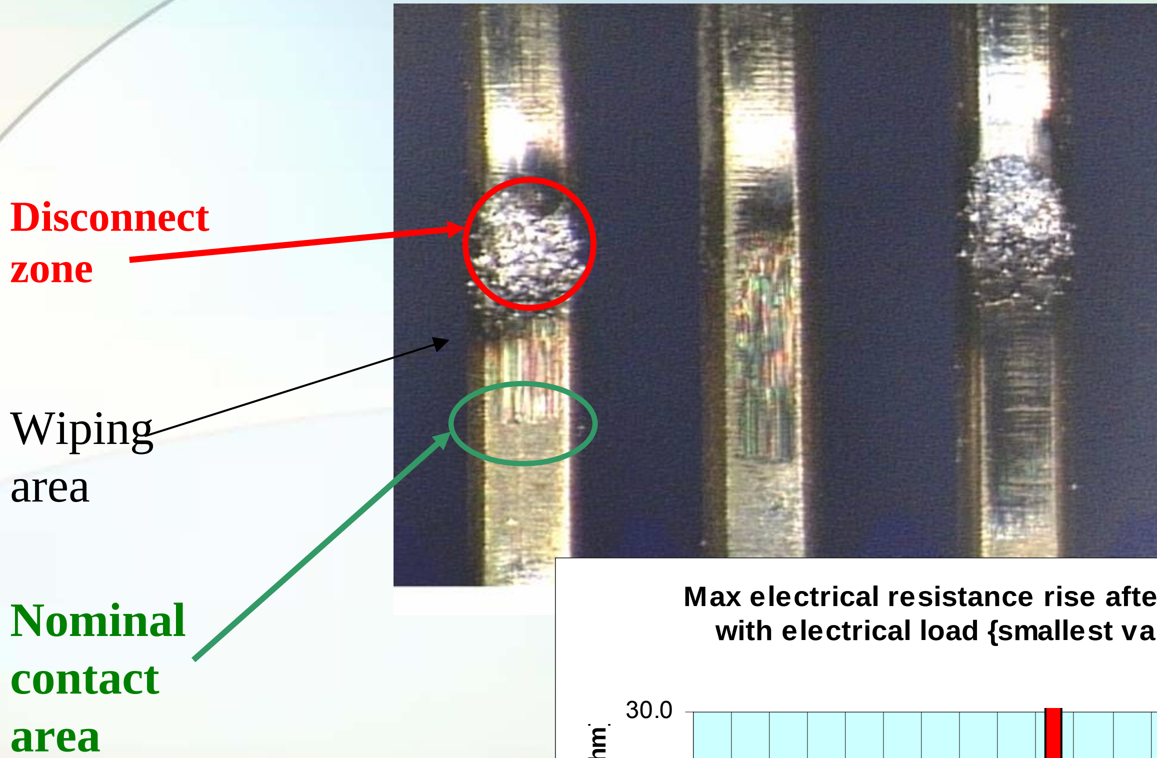
Figure 12. Test results of tests 1A and 3A. (Data for “No power contact before test” and “Power contact before test” represent a single measurement for each contact

Overview of IEC TR: Connector Durability under Electrical Load

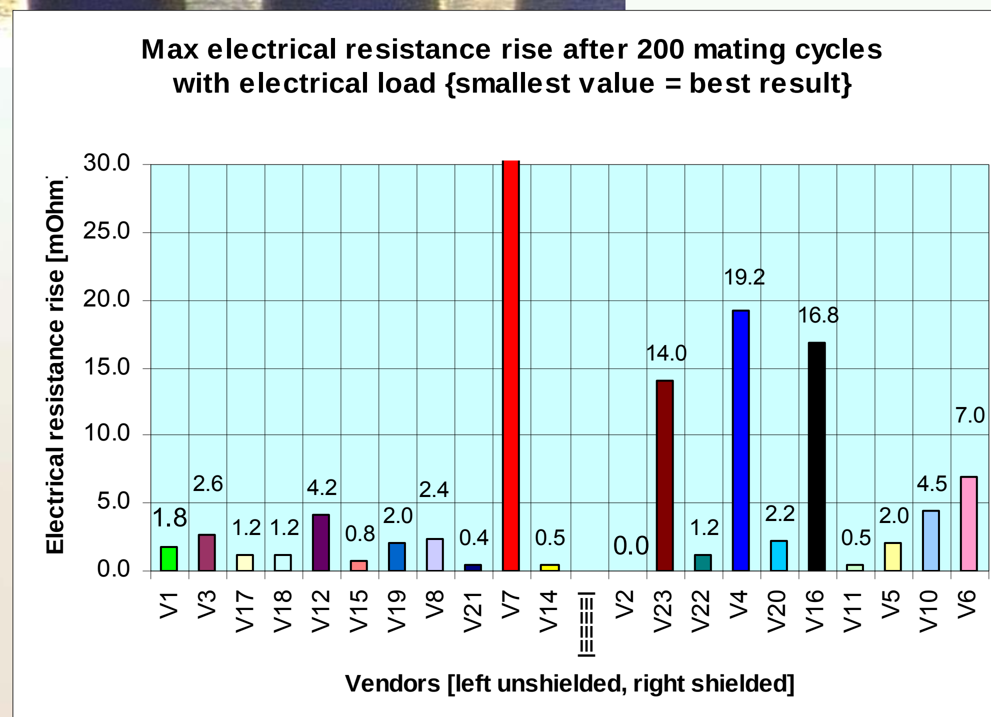


<u>Test 4A: Comparison of different RJ45's with proposed SC25 WG3 requirement</u>

Proposed by SC25 WG3 during the development of the ISO/IEC 11801 2nd Ed: assumed extra voltage of 50% over 48V and the supposed worst case scenario, that when the contacts of the jack do ***not*** open simultaneously, the power of 12.6 W has to be covered by one pair only.
The charging power was present during mating and unmating.

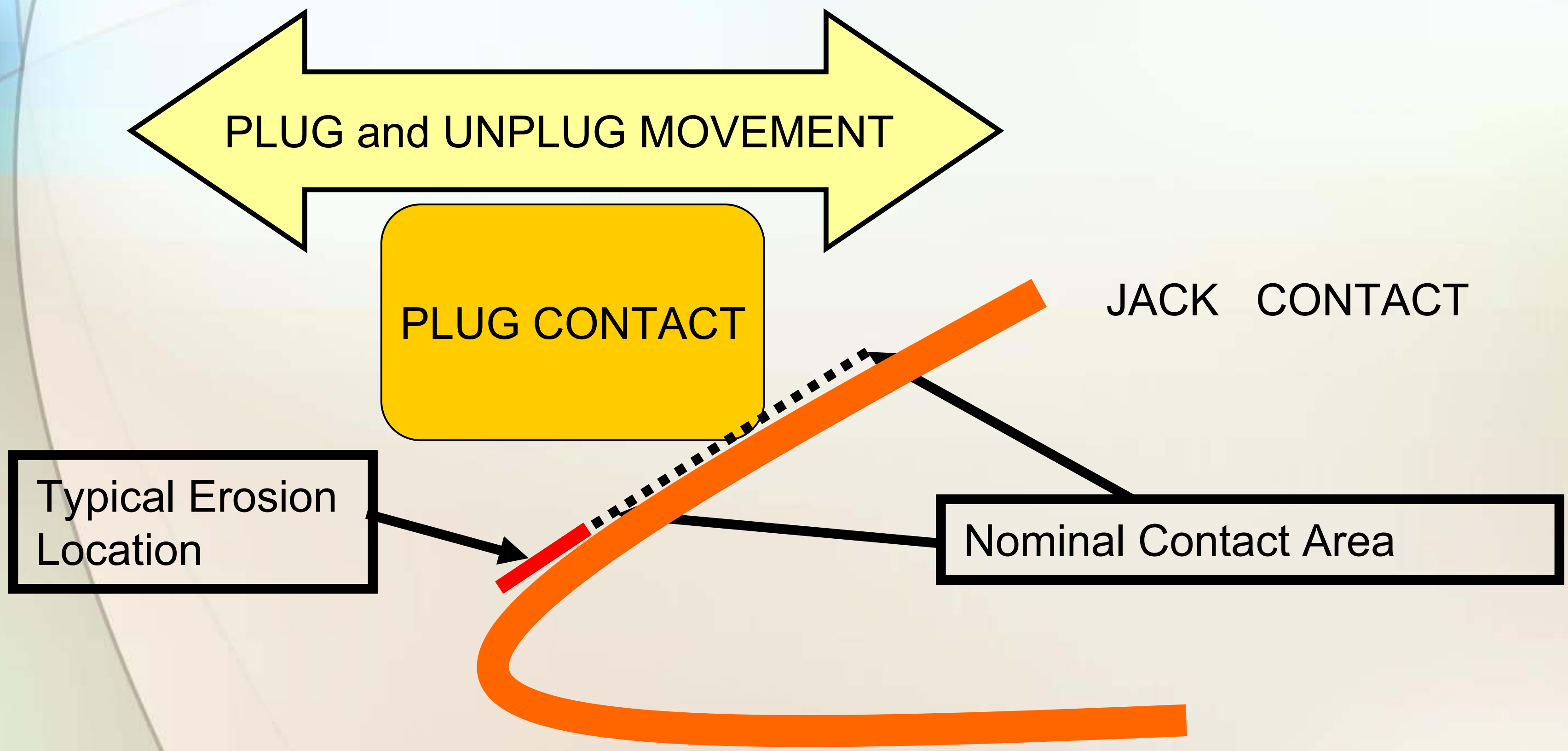


Test 4A. 23 test specimens manufactured by Chinese, European and US suppliers, Shielded and Unshielded



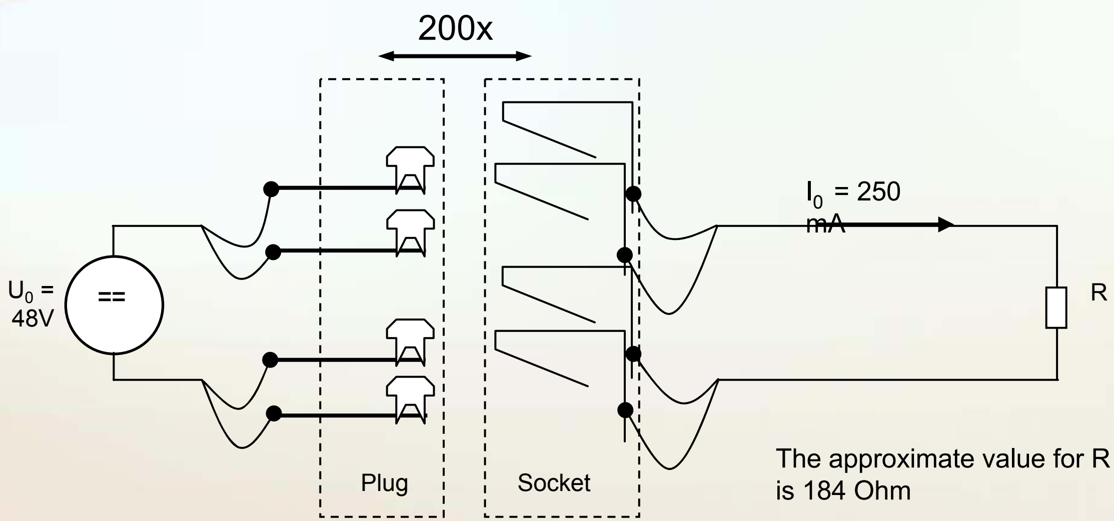
Overview of IEC TR: Connector Durability under Electrical Load

LOCATION of EROSION TYPICALLY OUTSIDE OF NOMINAL CONTACT ZONE (WIPING ZONE)



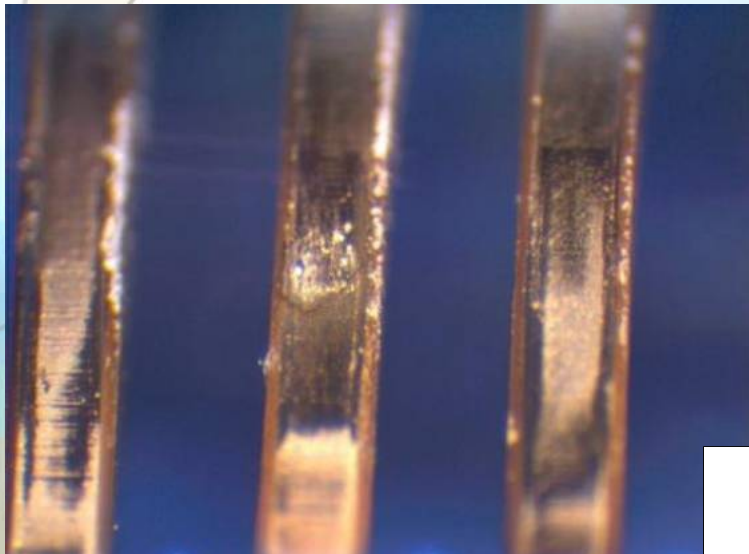
Test 5A: Resistive test setup simulating PoE power stress

This test is to imitate the conditions of IEEE PoE .
The feeding power is split up to both wires of a pair (e.g. to 4,5 and 7,8).
48V, power 12W, resulting in a current of 250mA.
Power was present during mating and unmating.



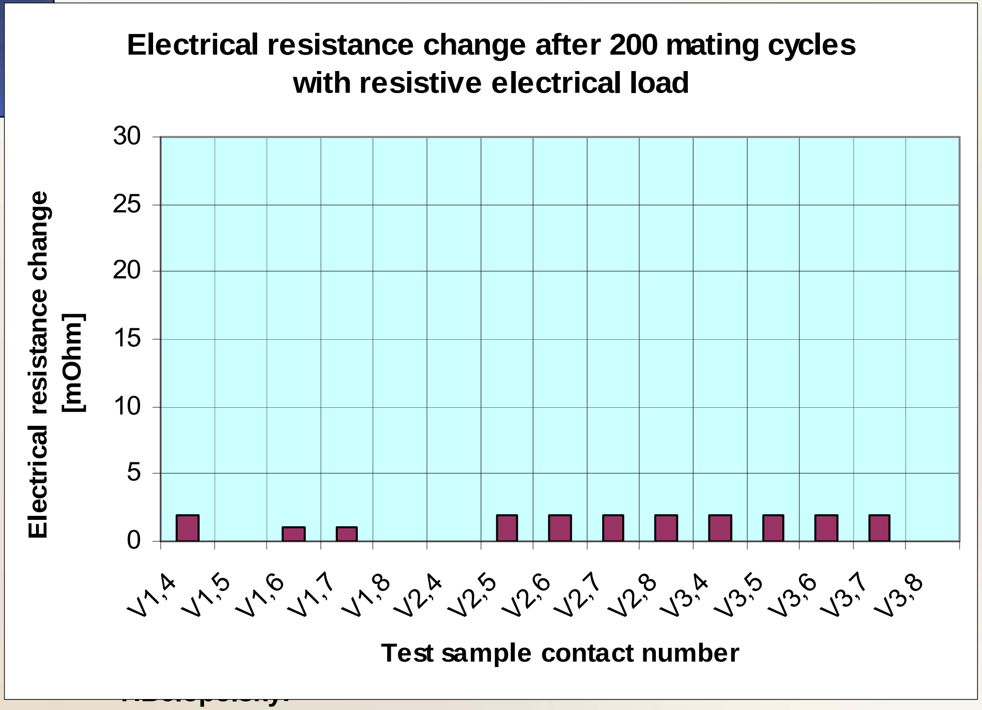
3 test samples: representing 3 manufacturers (Swiss, US and Asian)

Overview of IEC TR: Connector Durability under Electrical Load



Test with resistive load resulted in very little damage to contacts and negligible change in LLCR- irrespective of the connector manufacturer

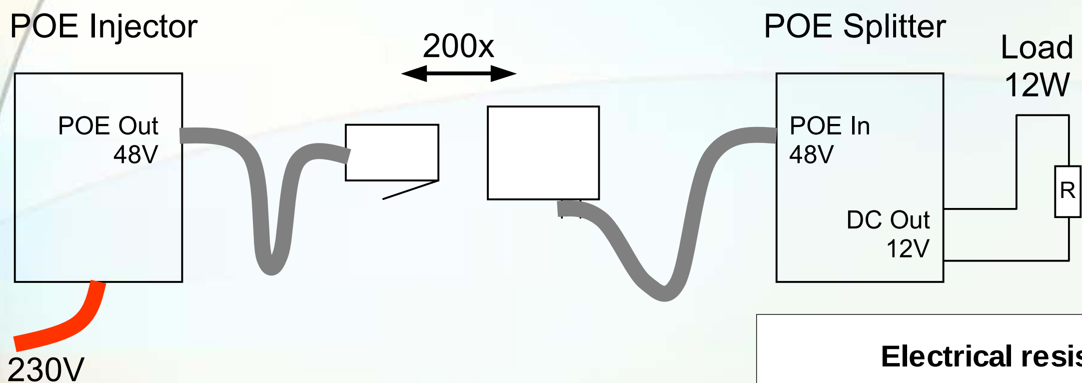
Test 5A results:



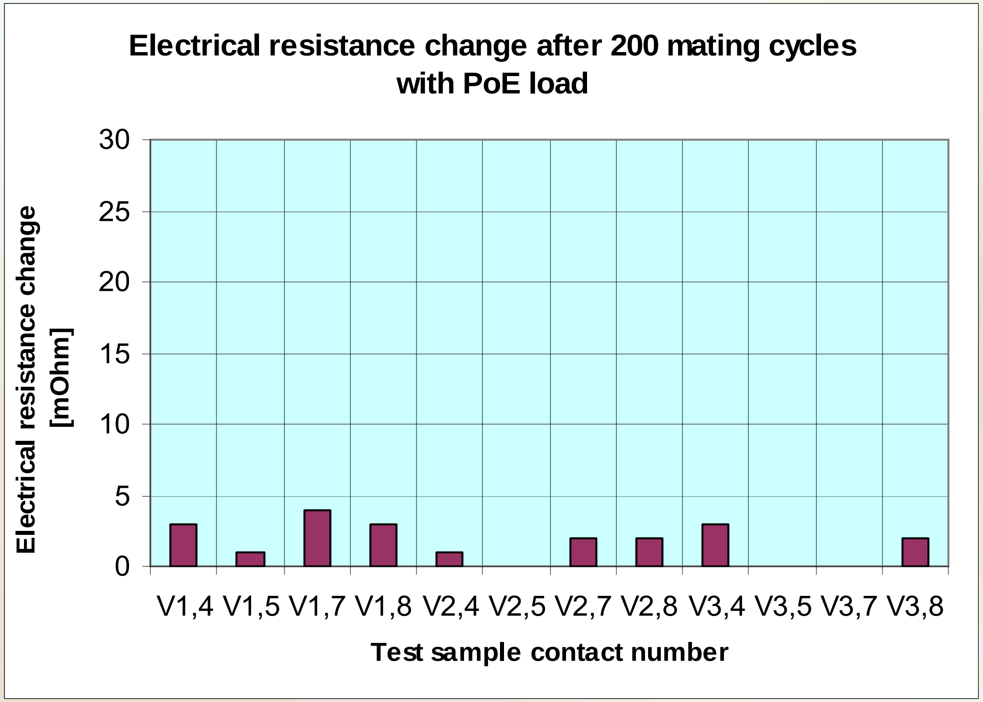
Overview of IEC TR: Connector Durability under Electrical Load

Test 6A: Mating and unmating with PoE hardware

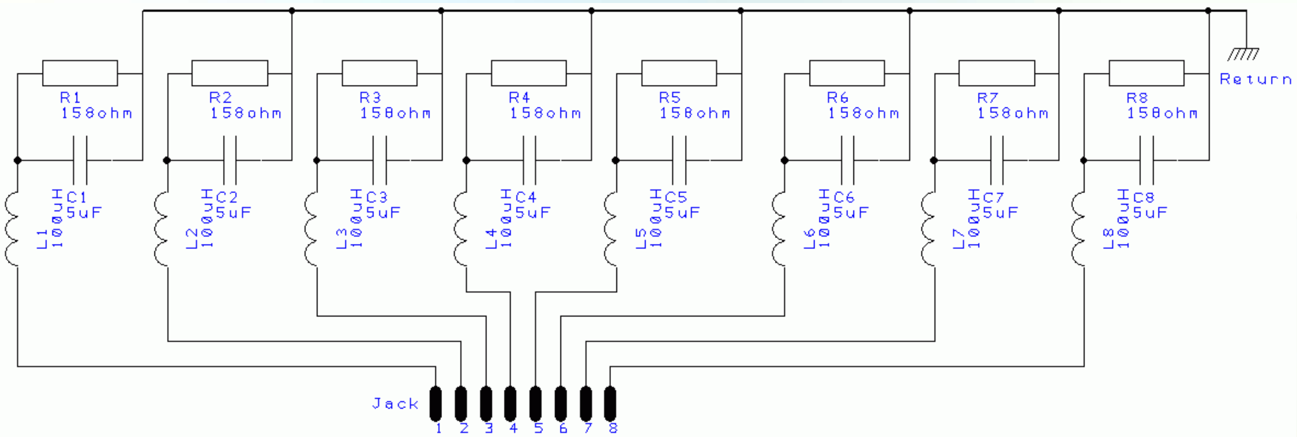
An actual IEEE 802.3af PoE hardware was used in this test supporting the complete functionality of IEEE 802.3af. A resistive load was attached to the 12V output to generate 12W (R ~12 Ohm).

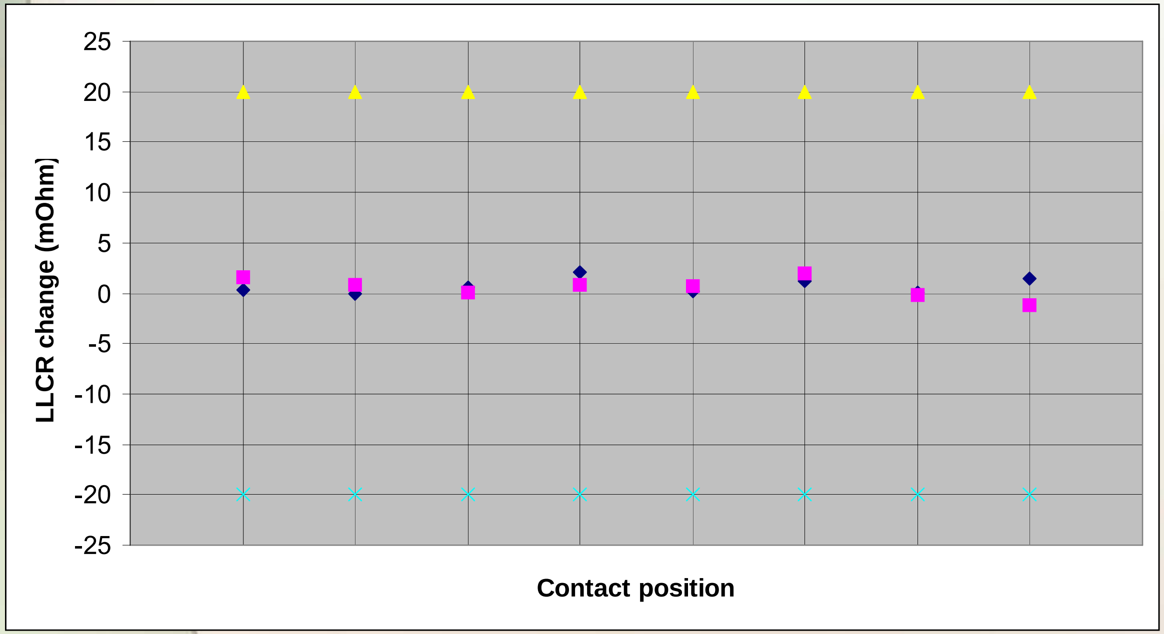


Test 6A results:
Power interruption using PoE equipment did not cause any failures or significant damage



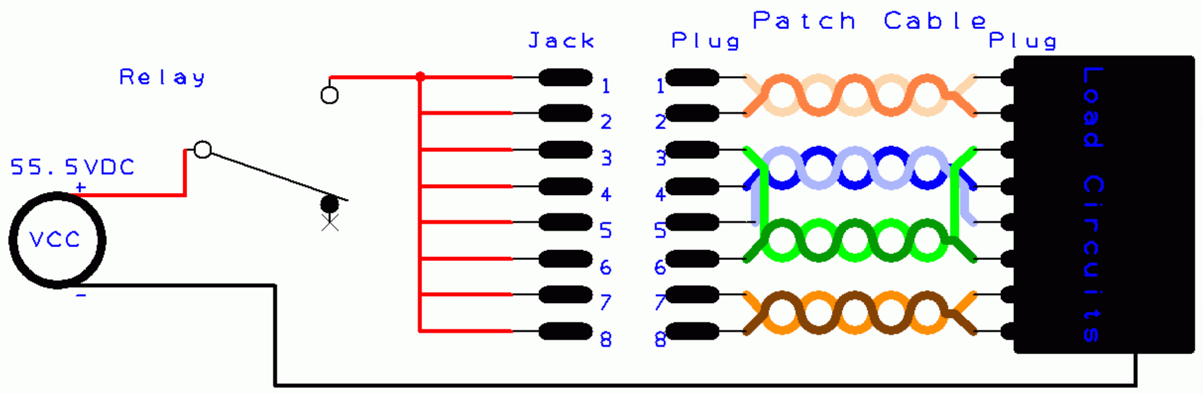
Test 7A and 8A. Effect of Speed of Contact Separation





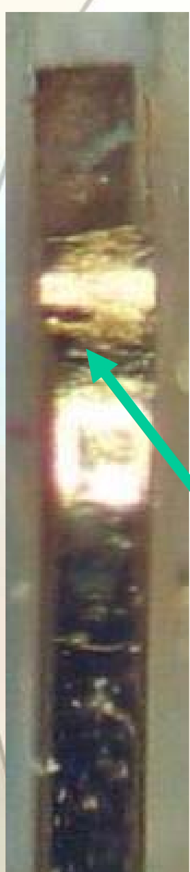
Results: no failures, no effects attributable to difference in contact separation speed

Tests 9A, 10A and 11A. Effect of the patch cord length



The tests were conducted with shielded and unshielded patch cords: 2m, 10 m and 100 m long (see table 2) .
No differences in discharge effects were observed.
No failures

Test 12A: effects of polarity



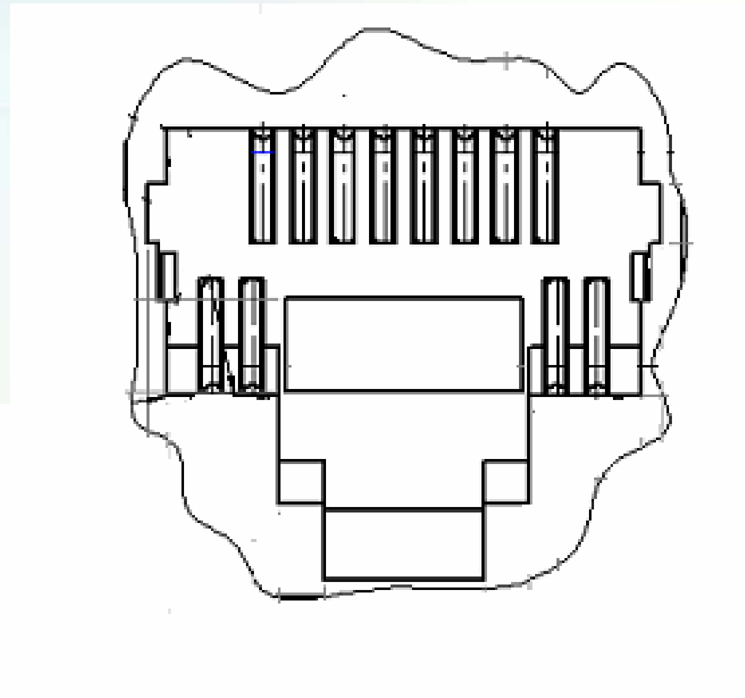
PLUG CONTACT

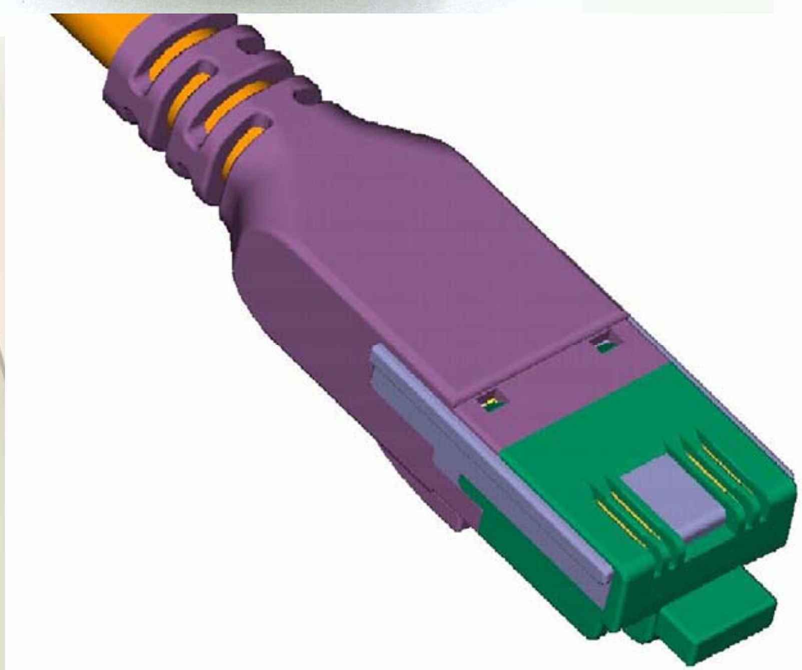
Typical Erosion Location
Outside nominal contact area

Damage was small in comparison to jacks. Two possible factors:

a) jack contact experiences simultaneously a mechanical stress (bending) and electrical discharge leading to greater observed damage
b) that the thermal mass of plug contact is greater in the discharge area

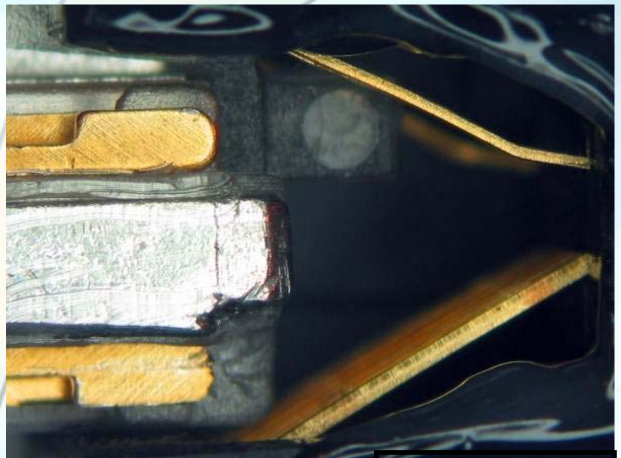
Category 7 and 7A connecting hardware 1000 MHz

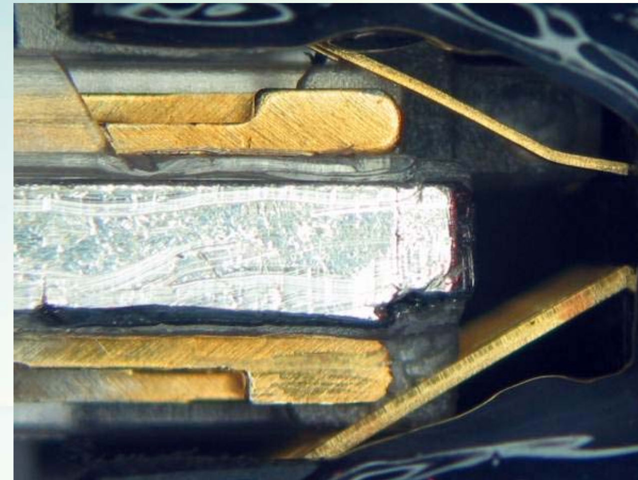


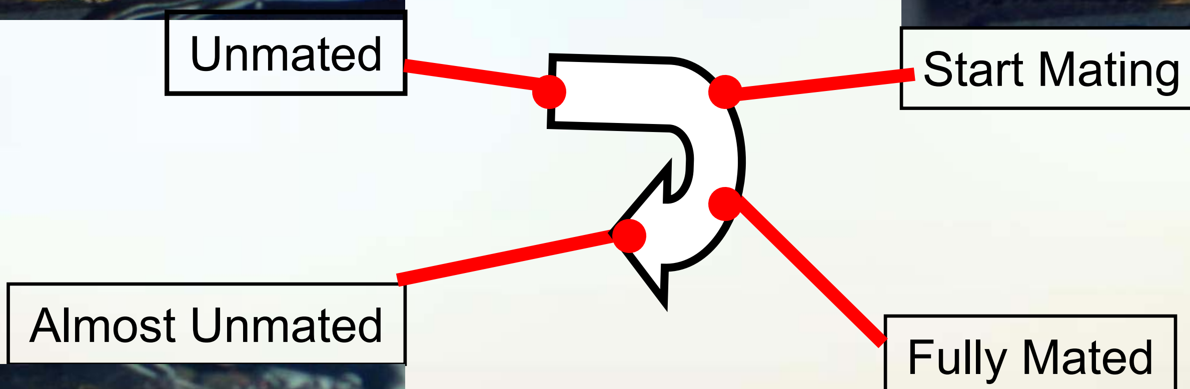


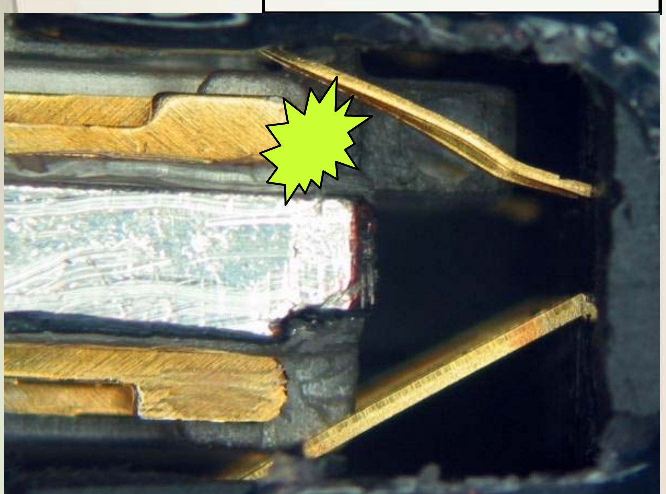
ARJ45

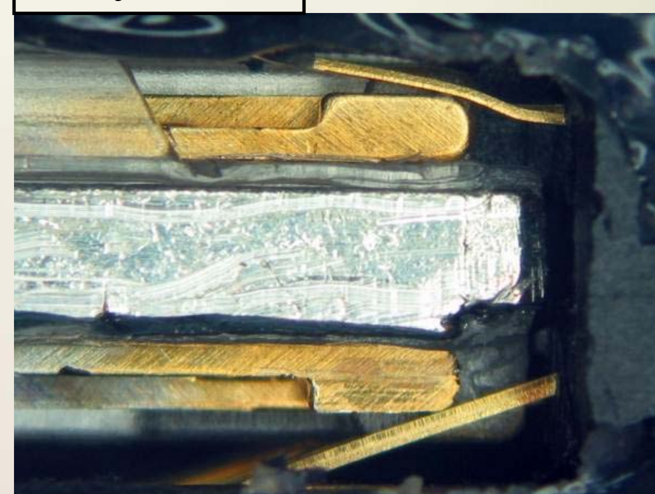
ARJ45 MATING CYCLE





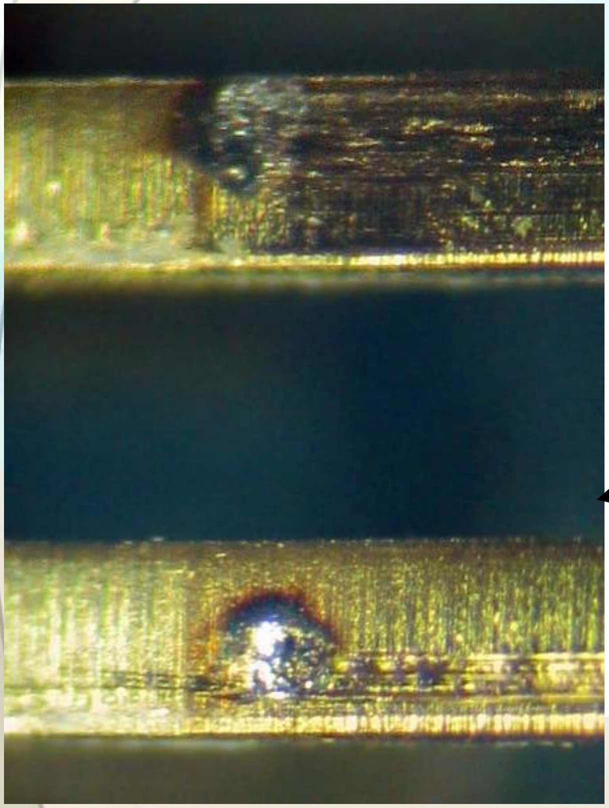


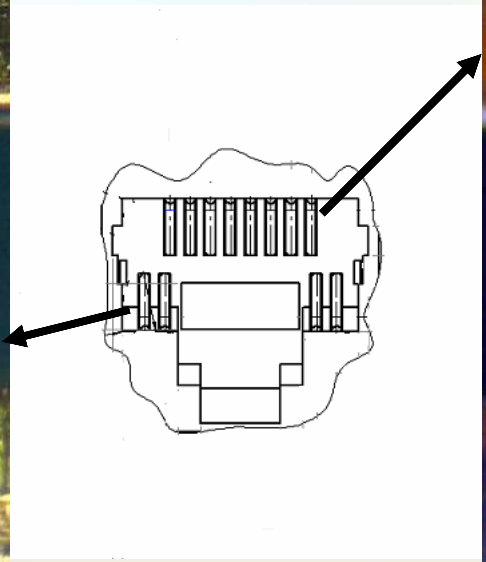


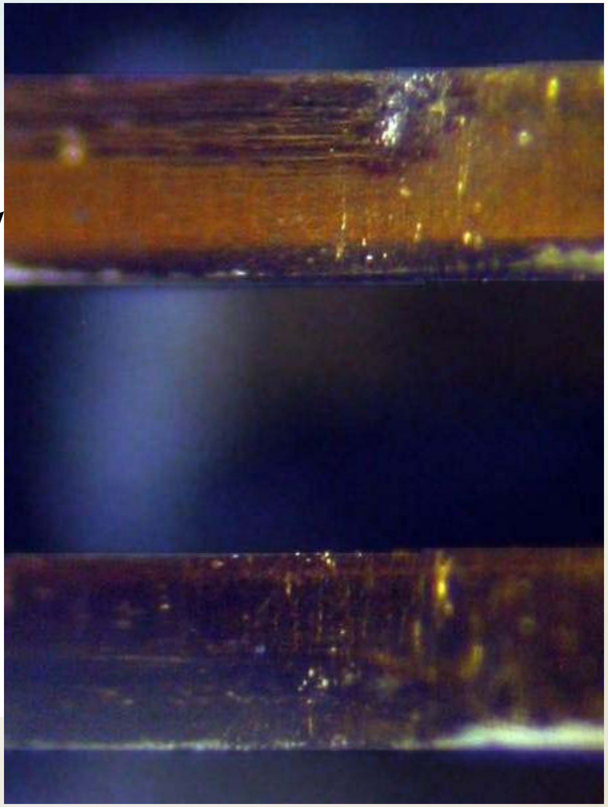


ARJ45 Category 7
Bottom contacts

ARJ45 Category 7
Top contacts



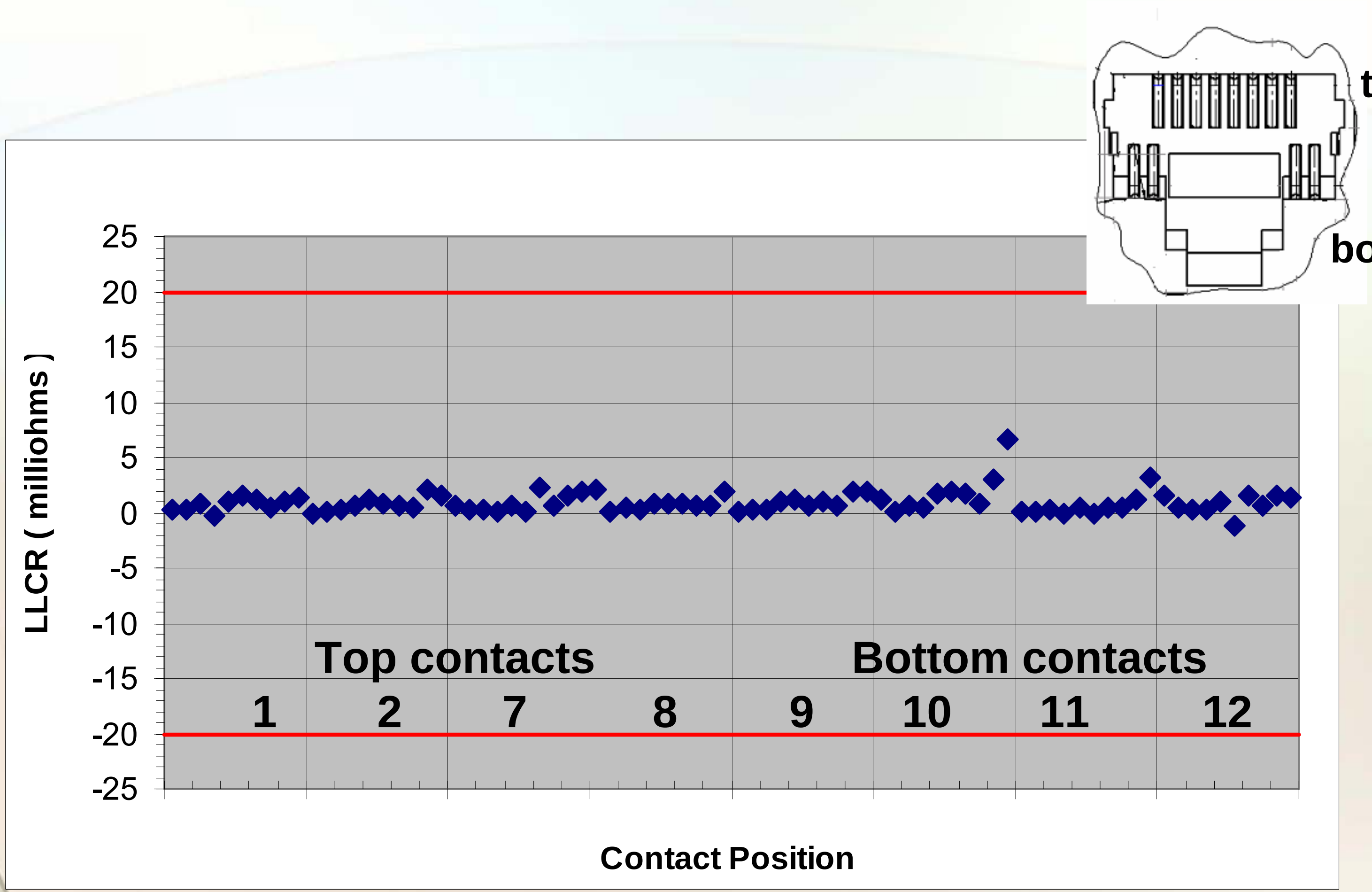




Discharge effects in the area peripheral to contact area

Very little or no visible discharge effects

Change in Bulk Low Level Contact Resistance combined for all groups for ARJ45 HD connectors



Tests 14A and 15A. 100-meter long cable test

During these tests the connecting hardware was mated for 750 cycles using 100-meter long patch cord cables with electrical load. After that the jacks were placed in a climatic chamber for 21 days under the following conditions:

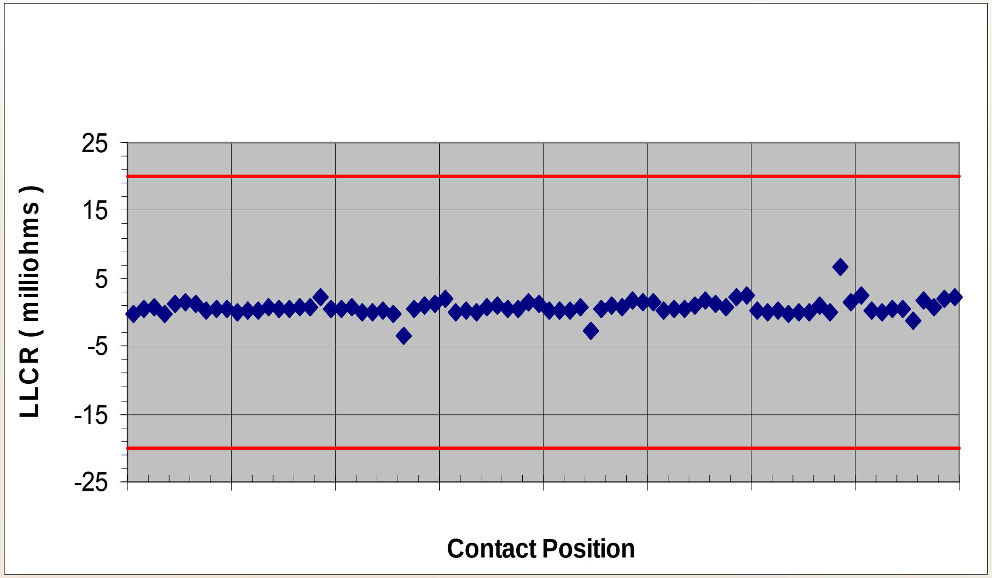
8 hours @ +25 ^{o} C

8 hours @ +65 ^{o} C

8 hours @ -10 ^{o} C

ARJ45 and RJ45 jacks were not mated. After the exposure the jacks were cycled 3 times with a test plug and LLCR was remeasured.

There was no degradation in the LLCR exceeding the specified limits.



Simulation of unmating under power. 100m channel

Connecting hardware: Connecting hardware is simulated as a conductance with a step response.

For reasons of simulation the network is transformed to an asymmetric network.

Equivalent diagram.

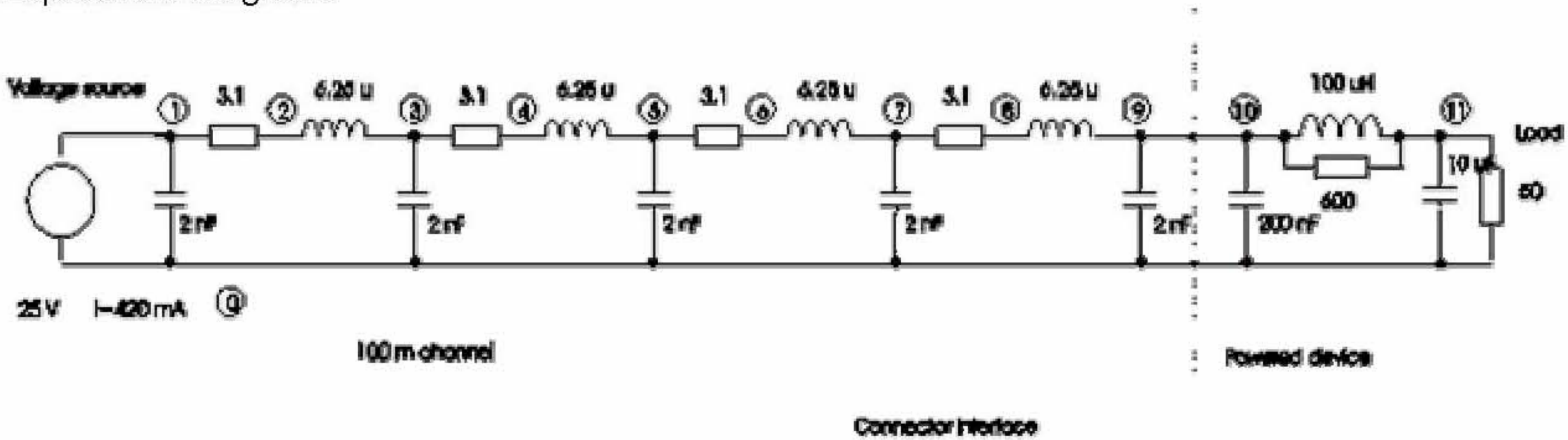


Figure 1. Equivalent diagram of circuit for unmating under load.

ISO/IEC JTC 1/SC 25/WG 3Kna023_CHW_POEP 1

Simulation of unmating under power. 100m channel

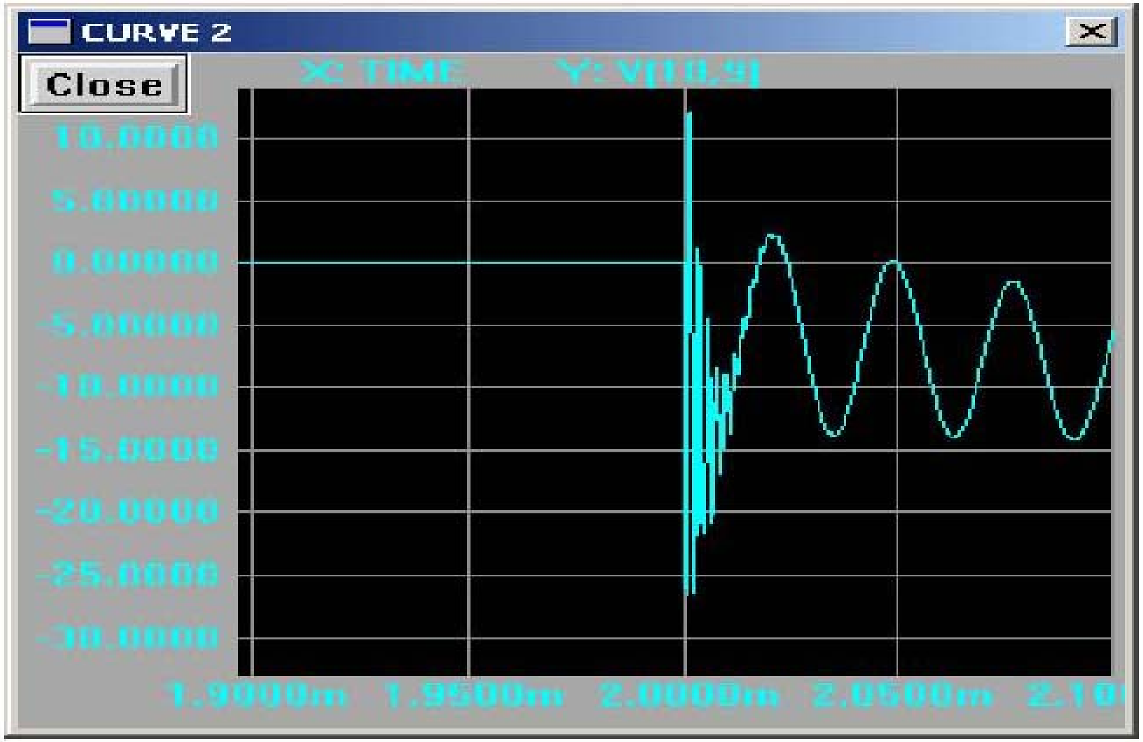
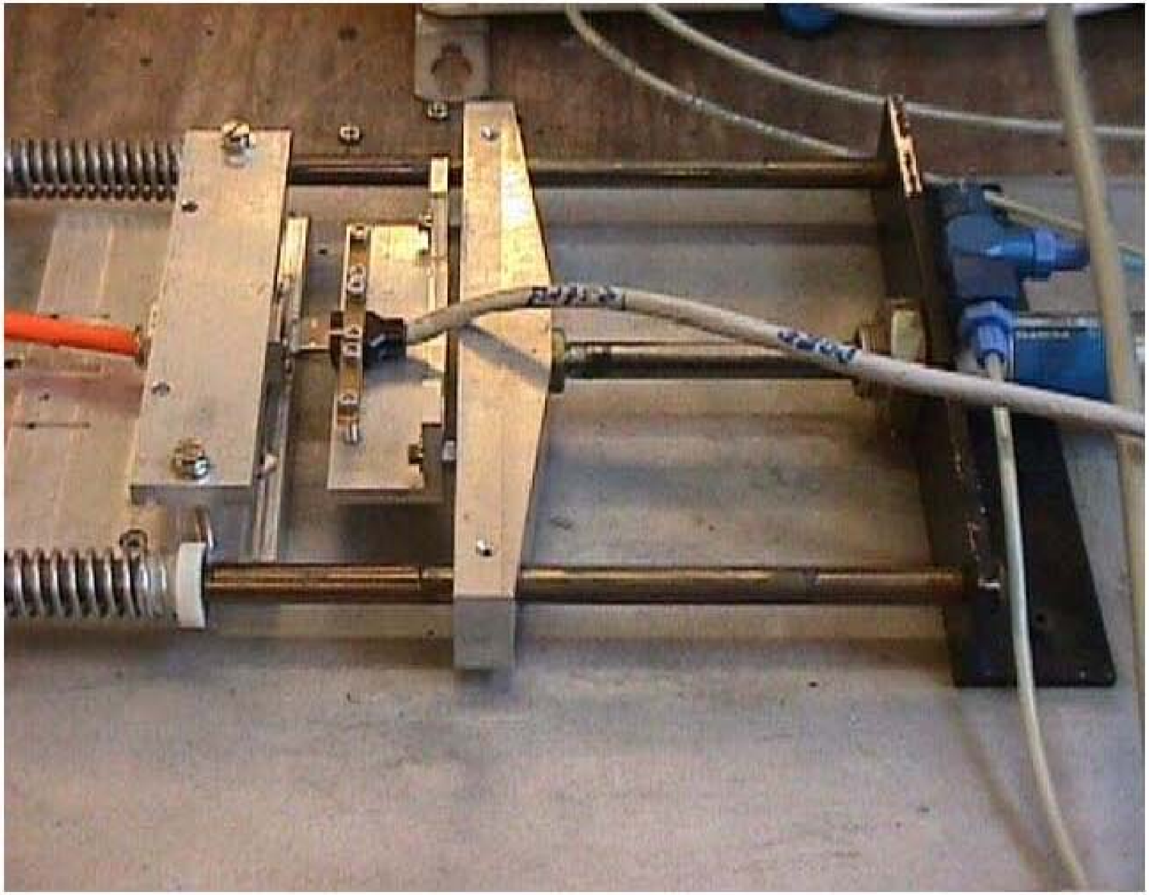


Figure 3. Voltage over contact during break.

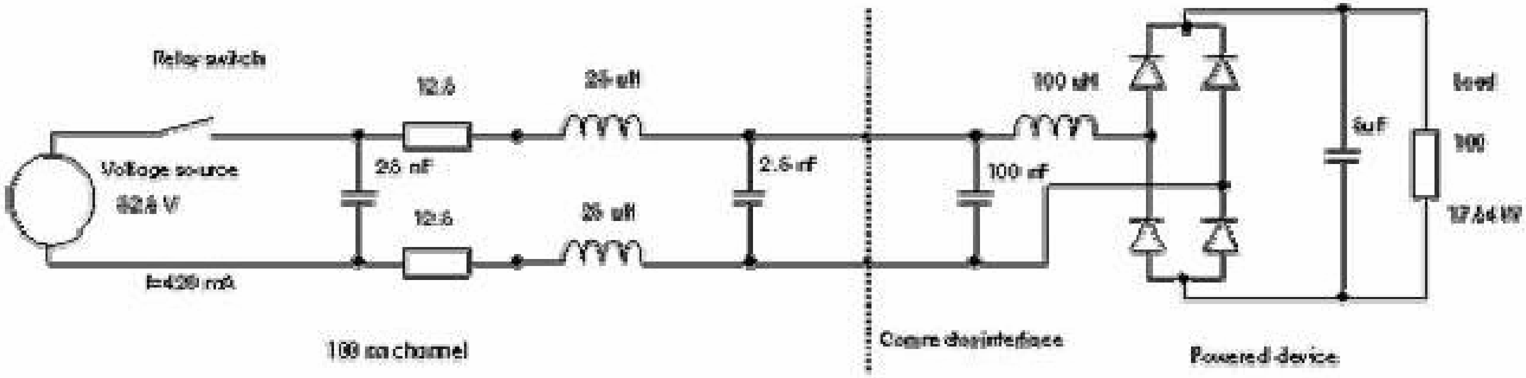
Voltage across contacts during unmating

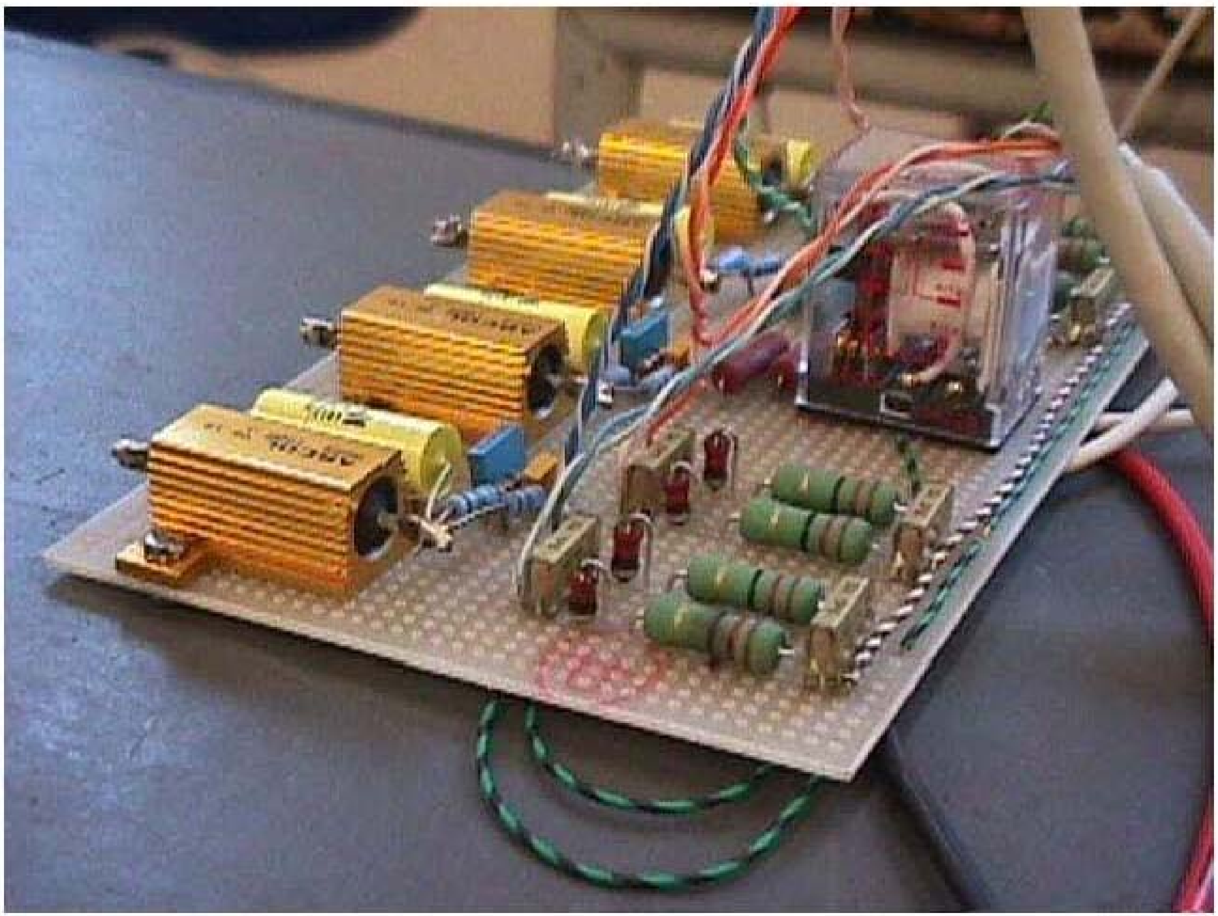
Experimental evaluation of unmating under power



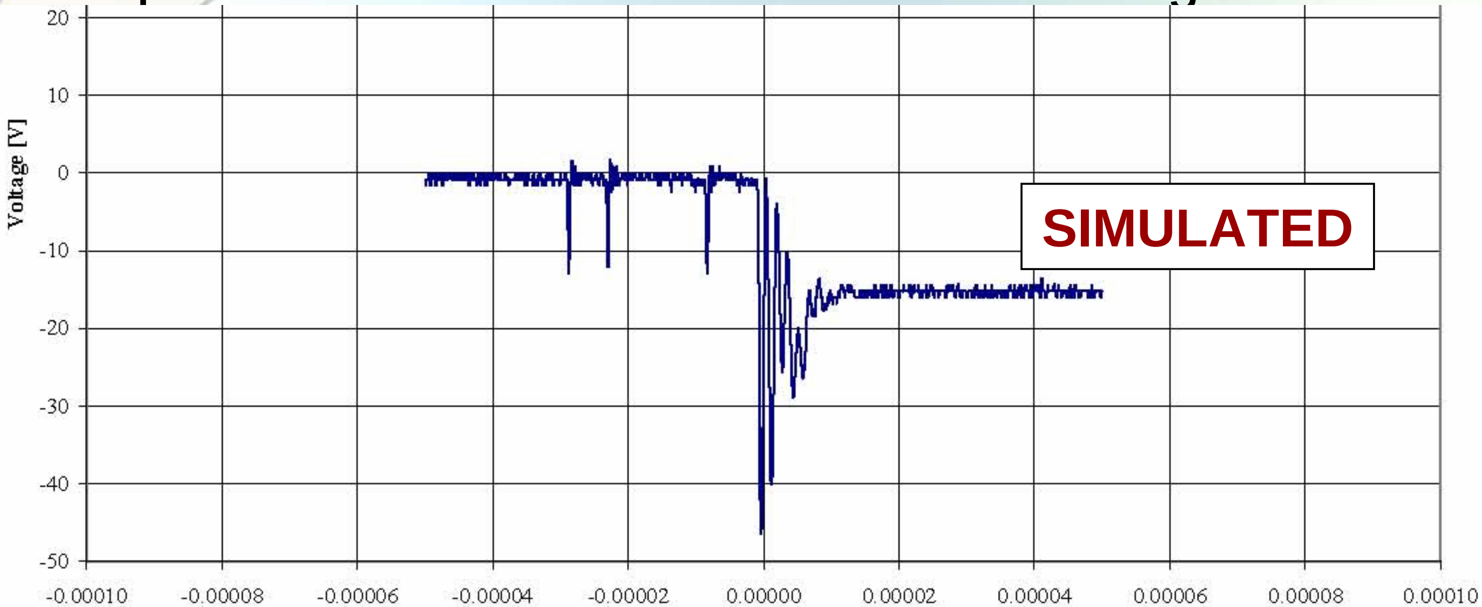
Mechanism for mating-unmating of connecting hardware

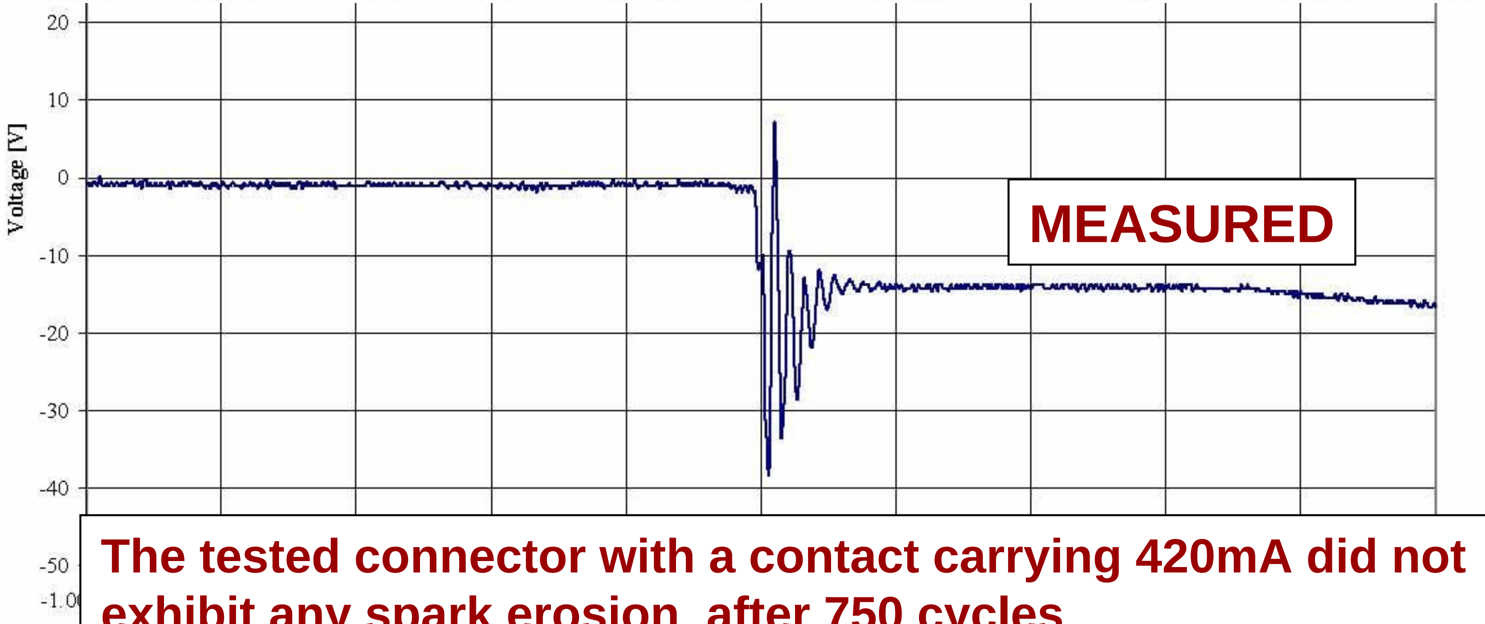
Experimental evaluation of unmating under power





Comparison of Simulated and Measured Voltage waveforms





The tested connector with a contact carrying 420mA did not exhibit any spark erosion after 750 cycles

Observations and Conclusions

- Unmating a connection while transmitting power can cause damage to contacts

- Proper design of the modular connectors should assure that the zone of breaking contact is separate from the zone where contact between plug and jack is made during normal operation. This results in certain immunity to the effects of unmating under the electrical load.

- The reduction in the separation between *a nominal contact zone* and a disconnect zone, could lead to an upper limit of breaking power for modular connectors.

- The voltage waveforms across contacts obtained by simulation and the experiments were very similar

Thank you for your time and attention