# A Contact Remembers: Property Changes after Pulse Current Loading

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# Problem

- During and after high current loading in contact characterization testing has been observed that contact properties such as Cres and maximum current carrying capacity may change
- An examination of significance and cause of such changes appears desirable

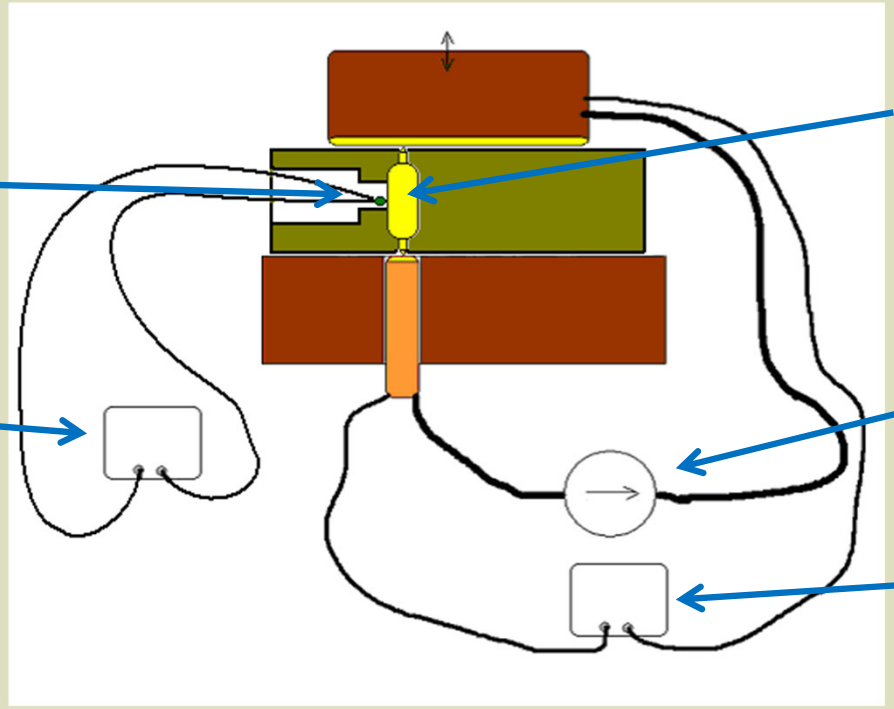
# Approach

- Identify some changes by processing a large number of test data from existing tests
- Conduct a series of targeted tests
- Record changes after first and second passes of tests for the same contact under undisturbed DC and position conditions
- Examine variability after pulse current loading
- Examine variability after further mechanical actuation

# Test sequence

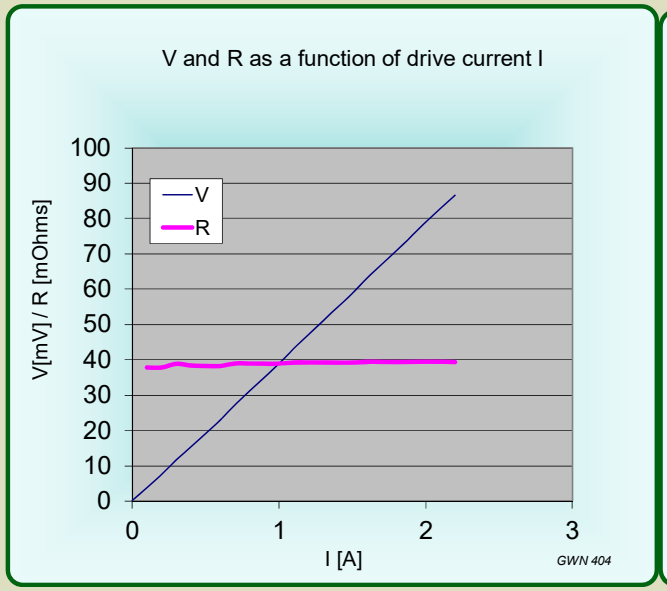
- Set up test environment and run DC test:
  - Establish nominal mechanicals and begin with 0 drive current
  - Slowly increase drive current level until the maximum allowable temperature increase dTmax is reached
- Repeat this test without disturbing contact mechanically
- Repeat this test after actuating the contact mechanically

# Test setup

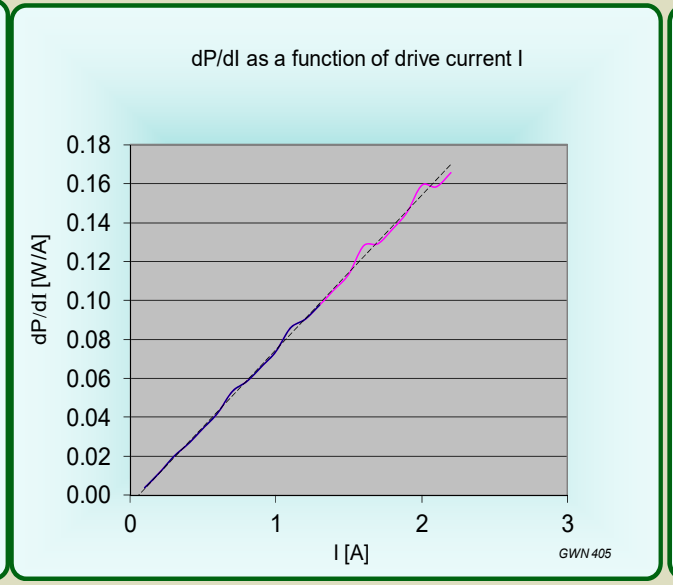


# Data Evaluation

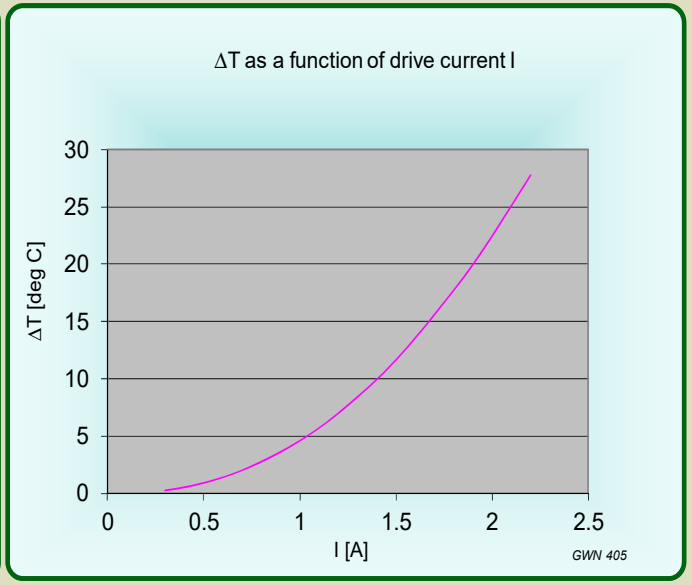
- Acquire the following example graphs as a function of current:




Voltage and resistance




Derivative of power v. current




Temperature rise

# Data evaluation: Determination of *C*urrent *C*arrying *C*apacity

- Find CCC from data at a set temperature increase
  - (over ambient or other selected test temperature)
- Typical temperature rise: 20 °C
- Not a (serious) problem at DC, but different for pulse current loading

# Data evaluation:

## CCC and time constant τ examples

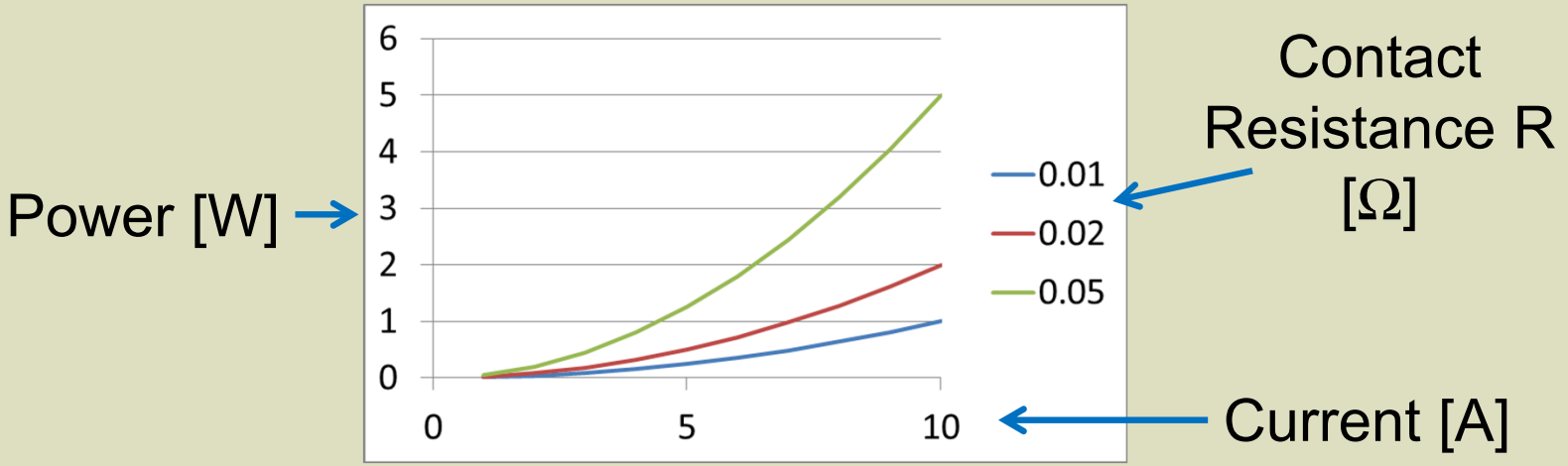
- CCC example for several duty cycles

| | DC | 50% | 25% | 10% | 1% | |
|---|---|---|---|---|---|---|
| Imax | 2.58 | 3.50 | 4.36 | 5.27 | 6.22 | A |

- Low thermal mass together with heat sinking of the contact at either end typically leads to a low (millisecond) thermal time constant τ, which frequently is comparable to the 300 millisecond pulse length used in test here

# Background: Power developed in contact

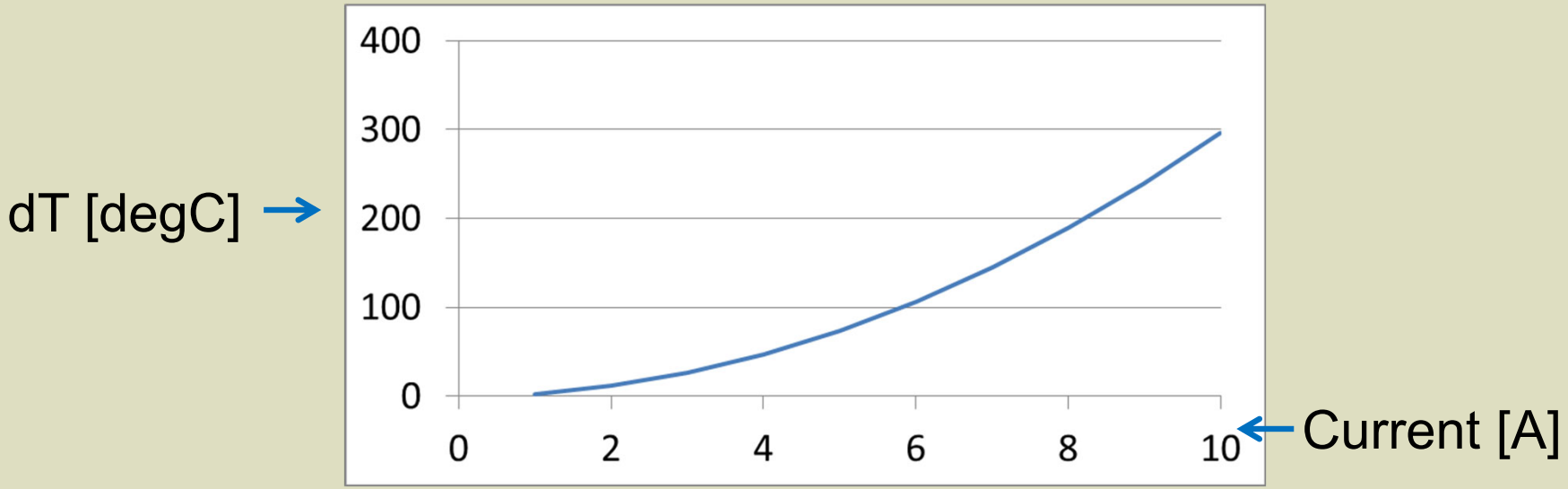
- Power developed in the contact P = I^2 * R




It is evident that despite relatively low resistance power levels in a contact can reach significant values

# Background: Temperature rise (computed)

2mm long contact, cross-section = 4.0 mils^2



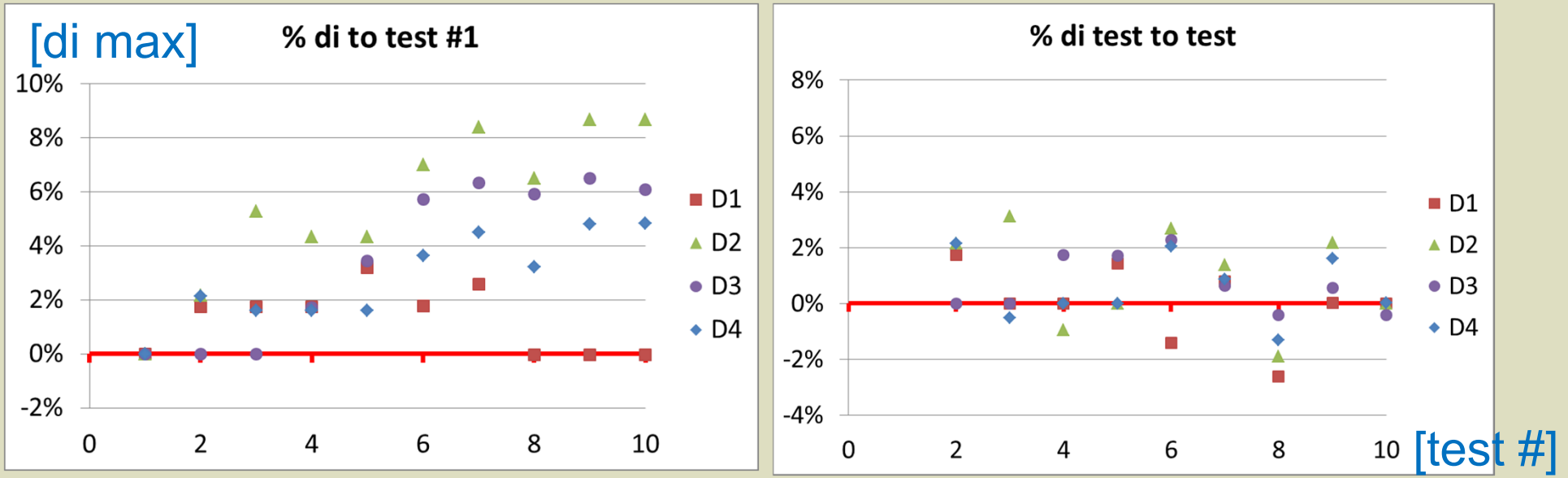

Temperature rise in the contact becomes an issue at higher current levels

# Test/evaluation questions of interest

- Does something happen ?
- What happens ?
- What change(s) occur(s) ?
- Are changes reversible ?
- Possible causes
- Significance of changes

# DC Imax change examples

10 successive tests of 1 contact - DC only, contact type 1



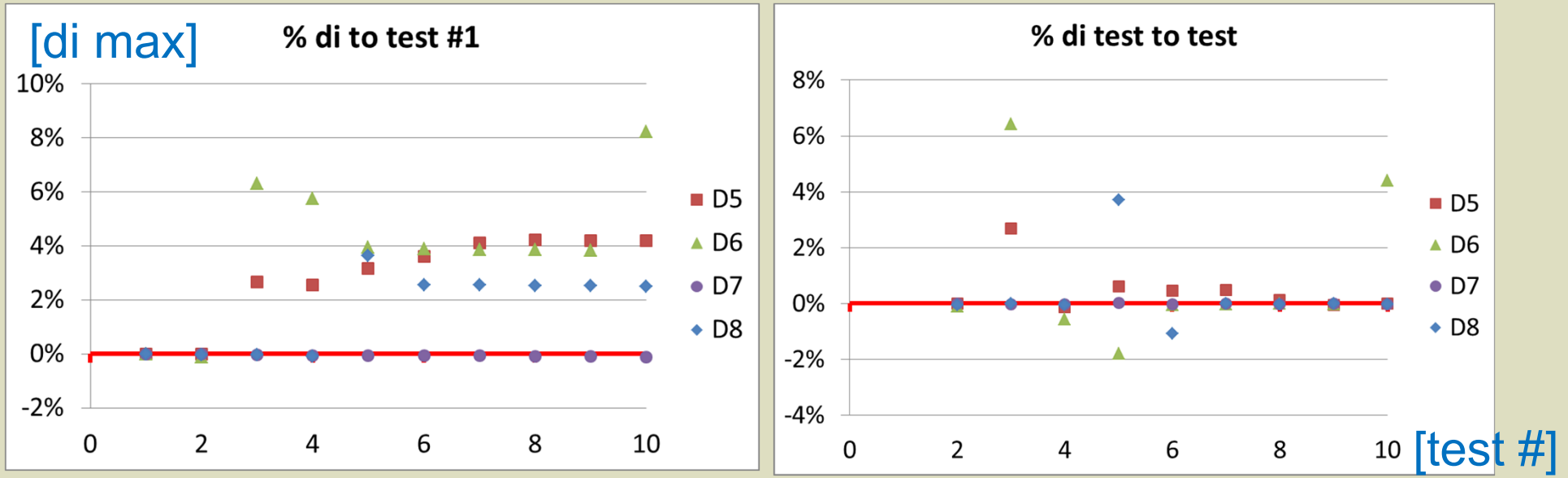

After the initial test max current increases more or less steadily

Possible cause: Reduction of interface resistance

Mechanical actuation increases that change (D2, D4)

# DC Imax change examples

10 successive tests of 1 contact - DC only, contact type 2



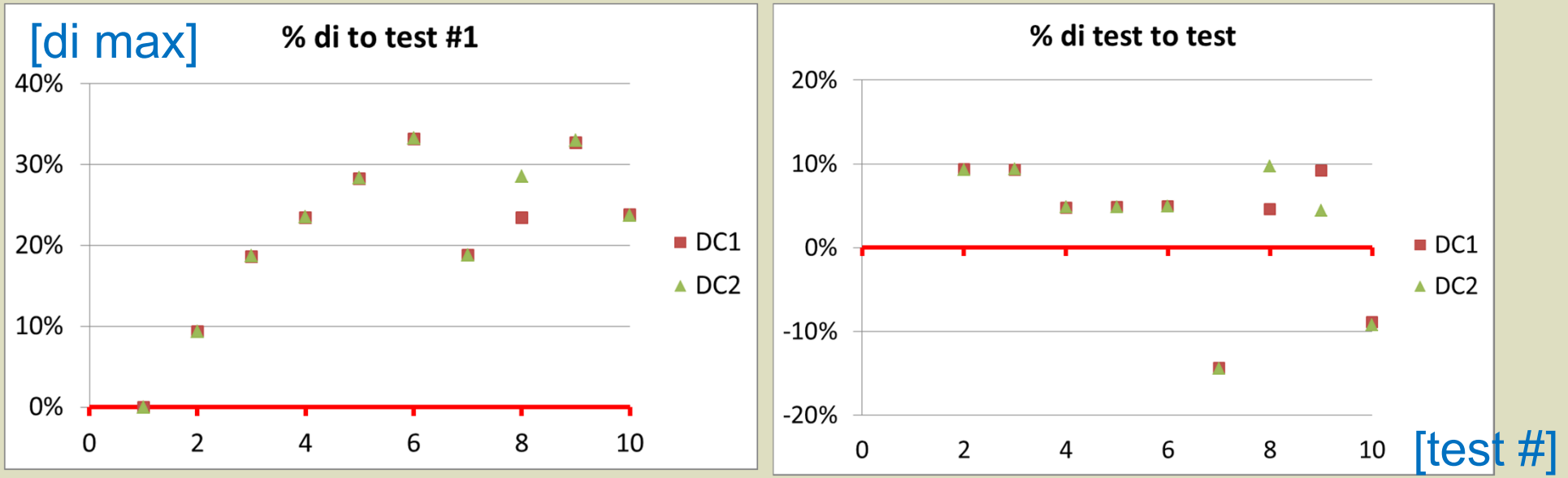

After the initial test max current increases more or less steadily

Possible cause: Reduction of interface resistance

Mechanical actuation increases that change (D6)

# DC Imax change example

DC after complete test sequence w. pulse, contact type 1, unactuated



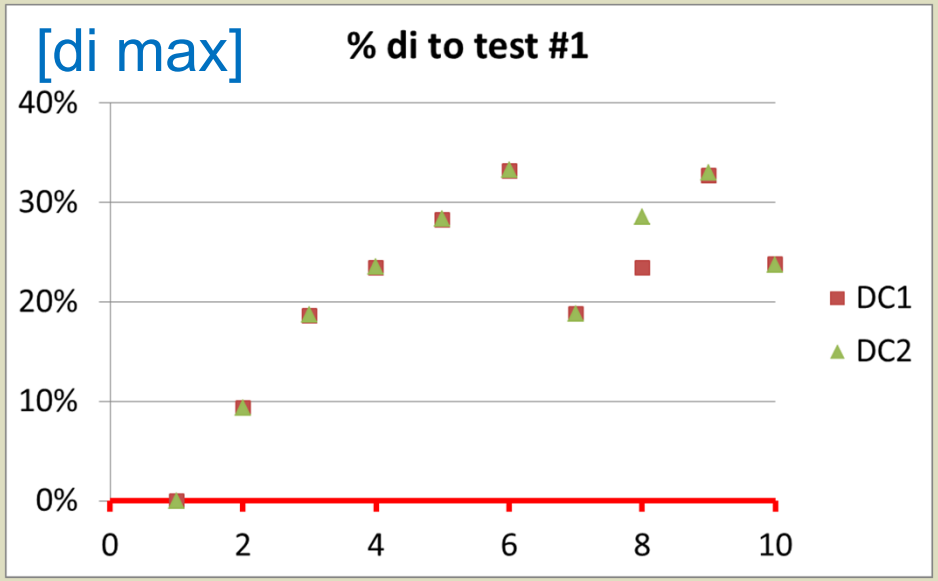

Significant increases of max current is apparent

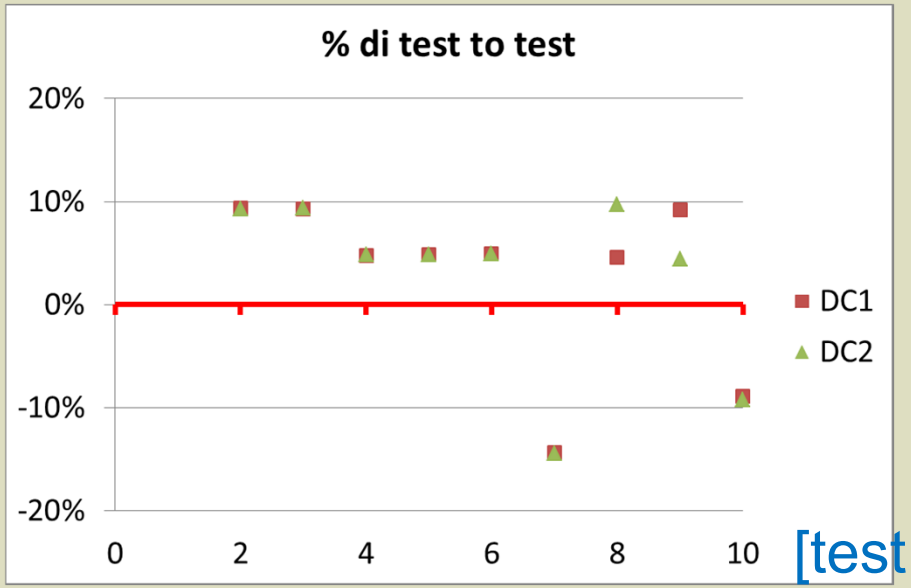
Possible cause: Reduction of interface resistance

High current exposure initially continues to increase that change from test to test

# DC Imax change example

DC after complete test sequence w. pulse, contact type 1, unactuated




Significant increases of max current is apparent

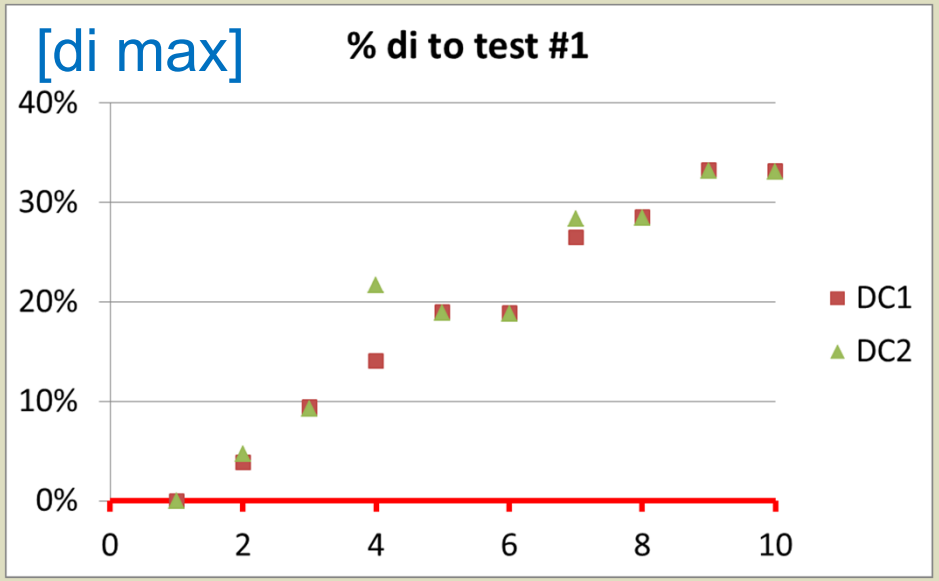
Possible cause: Reduction of interface resistance

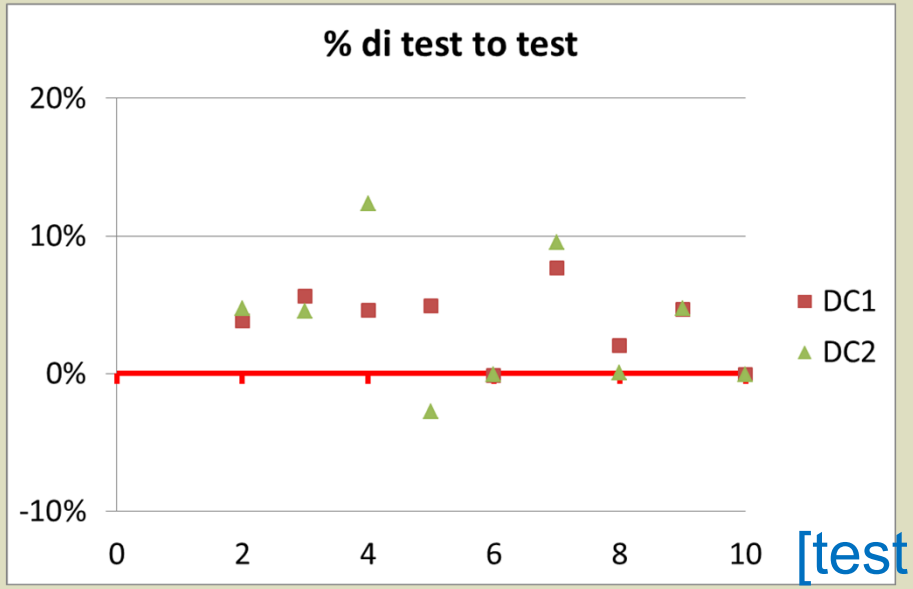
High current exposure initially continues to increase that change from test to test

DC1, DC2 are successive tests (after pulsing, but w/o pulse)

# DC Imax change example

DC after complete test sequence w. pulse, contact type 1, actuated




Steady increase of max current is apparent

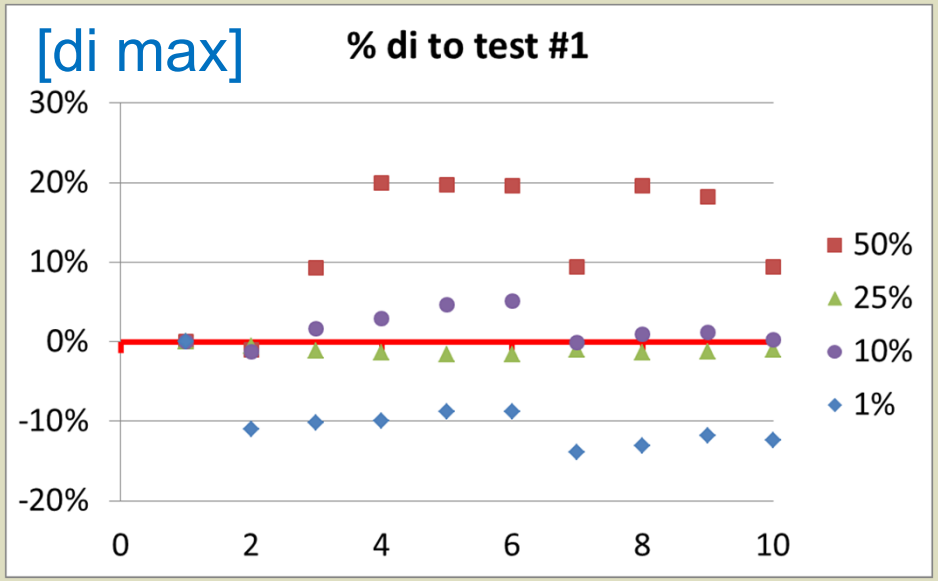
Possible cause: Reduction of interface resistance

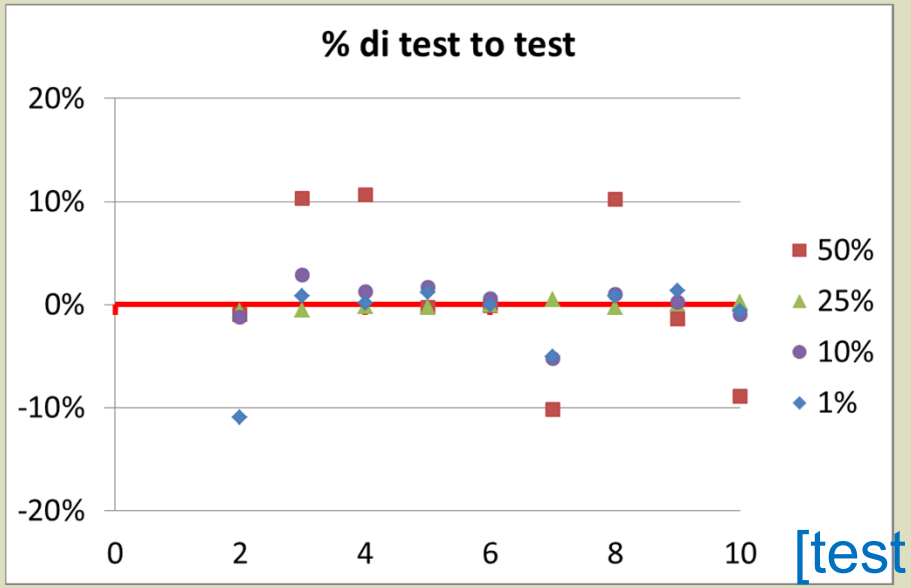
Pulsing and mechanical actuation continue to increase the change from test to test

DC1, DC2 are successive tests (after pulsing, but w/o pulse)

# Pulsed Imax change example

CCC after complete test sequence w. pulse, contact type 1, unactuated



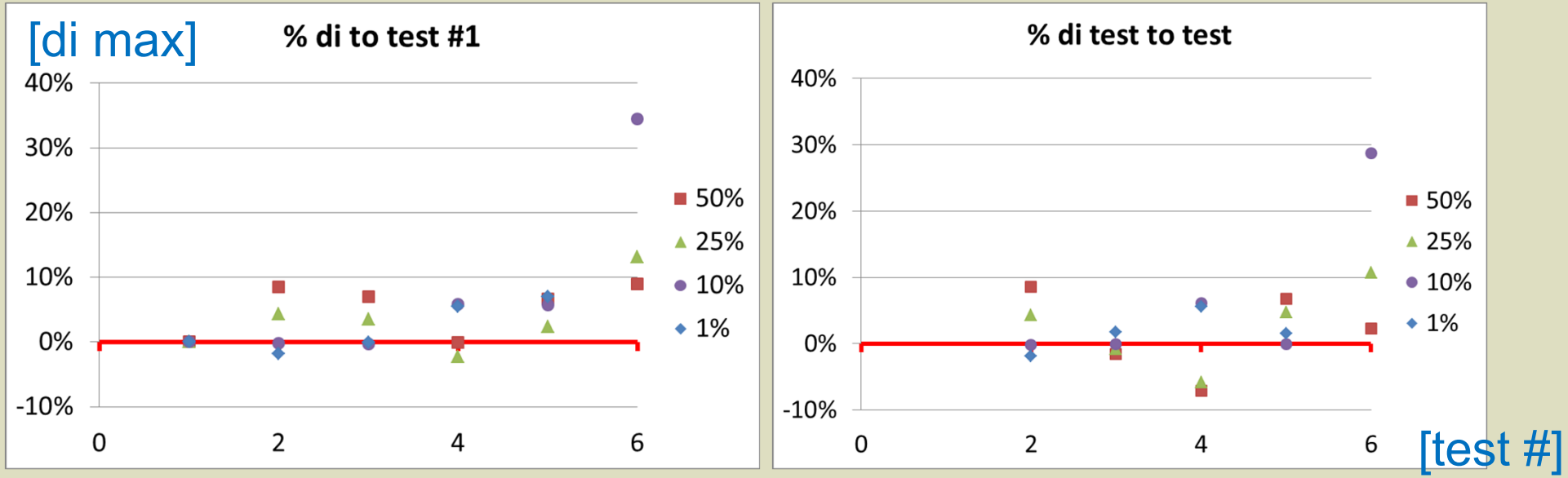

Some increase of max current is apparent

Possible cause: Reduction of interface resistance

Peak pulse current levels during test increased with decreasing duty cycle

# Pulsed Imax change example

CCC after complete test sequence w. pulse, contact type 1, actuated




Some increase of max current is apparent, actuation reduces scatter

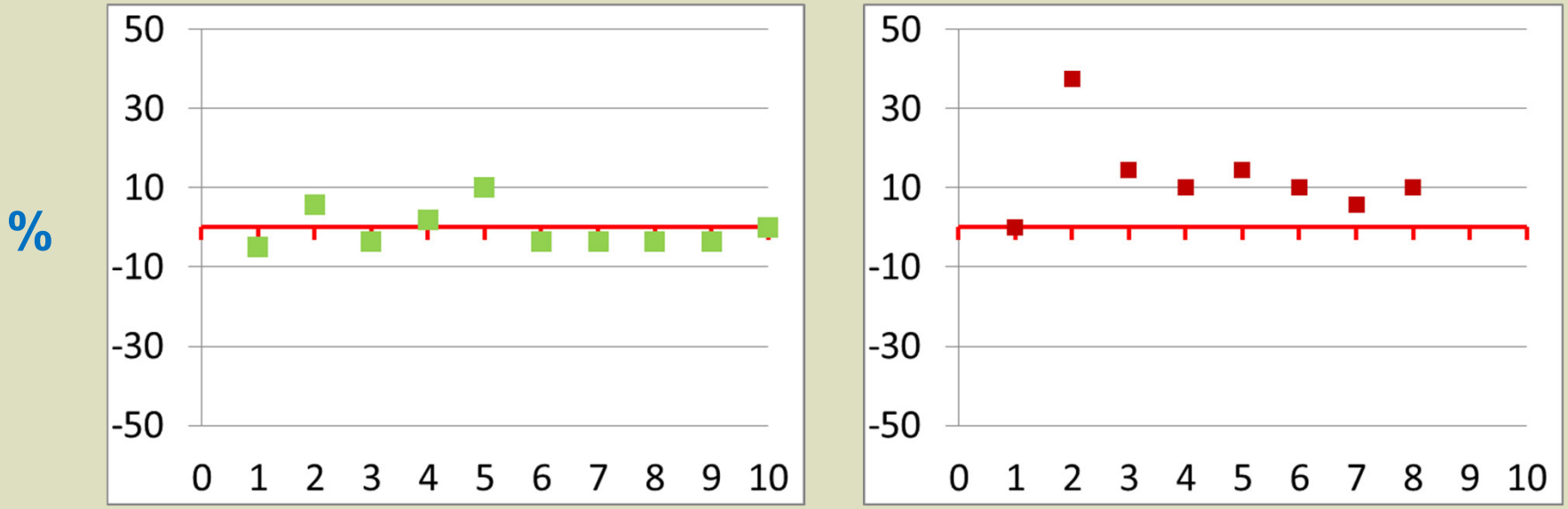
Possible cause: Reduction of interface resistance

Peak pulse current levels during test increased with decreasing duty cycle

# Additional observations during testing

- Data presented on the following slides will show the measured temperature rise (or change thereof) for a given drive current
- This is also an indicator of contact resistance Cres and CCC change (Cres includes the contact interfaces)
- An *increase* in **temperature rise** for a given current means an *increase* in **Cres** and a *decrease* in **CCC**

# Temperature rise change at 0.5 A DC drive




**High contact force**

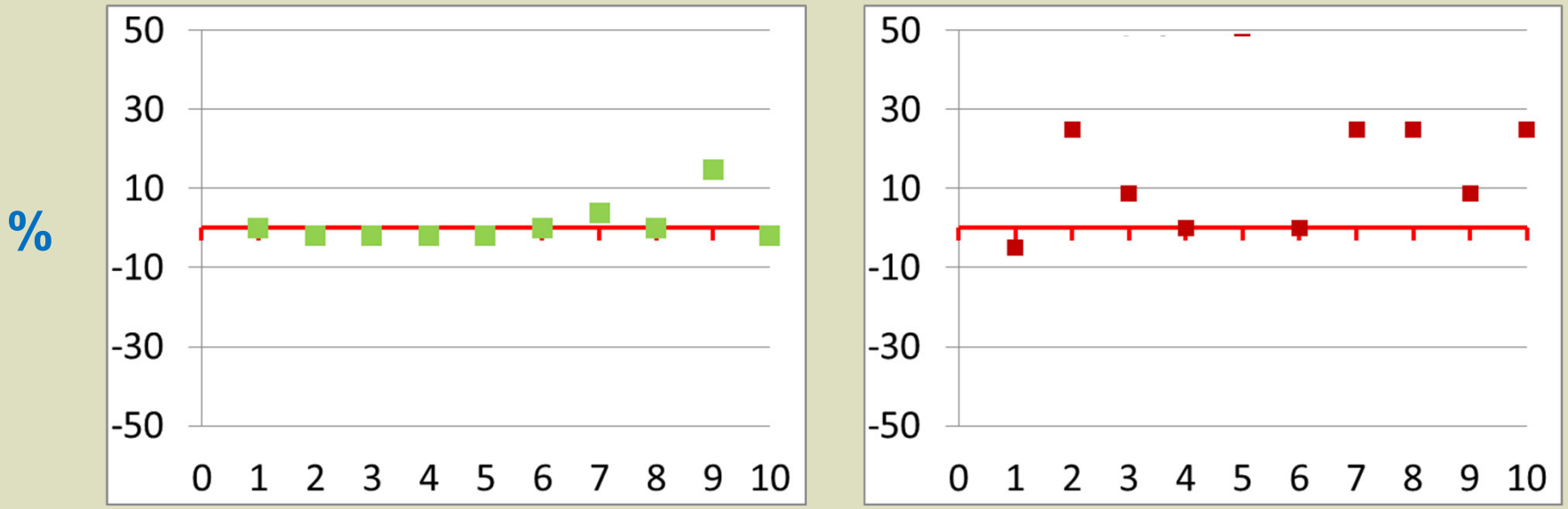
**Low contact force**

**Test #**

10 successive tests of 1 contact, **single piece** construction

Repeated tests on same contact (**without** actuation)

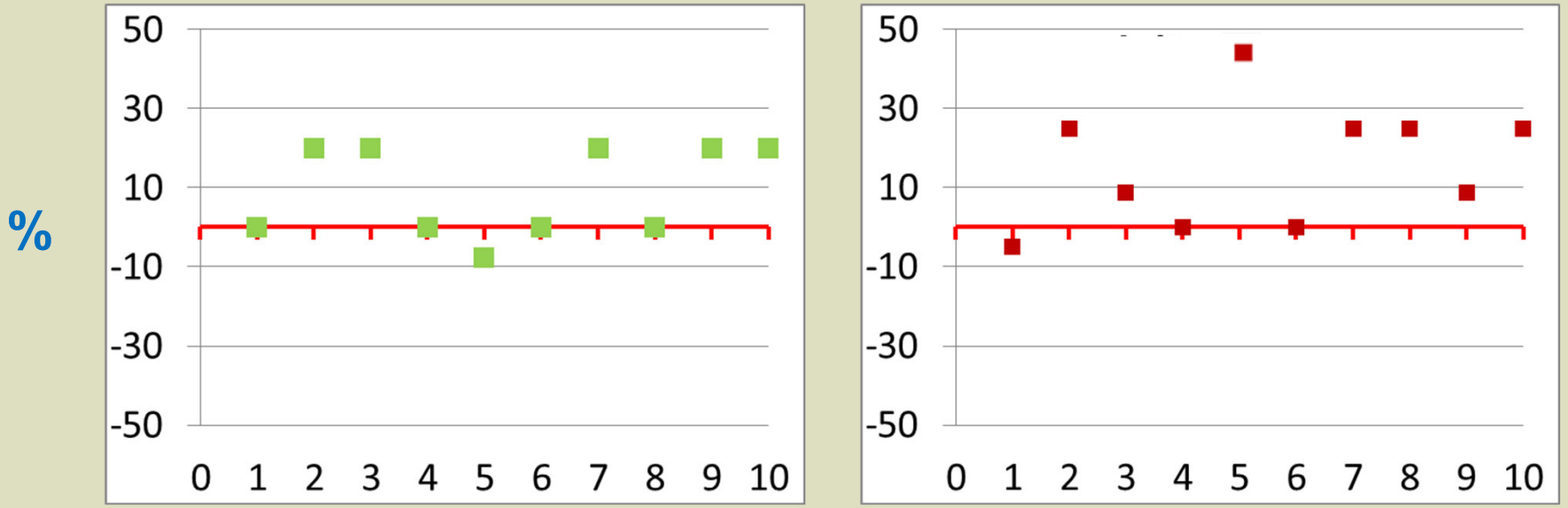
# Temperature rise change at 0.5 A DC drive




10 successive tests of 1 contact, **single piece** construction

Repeated tests on same contact (**without** actuation)

# Temperature rise change at 0.5 A DC drive




Day 1

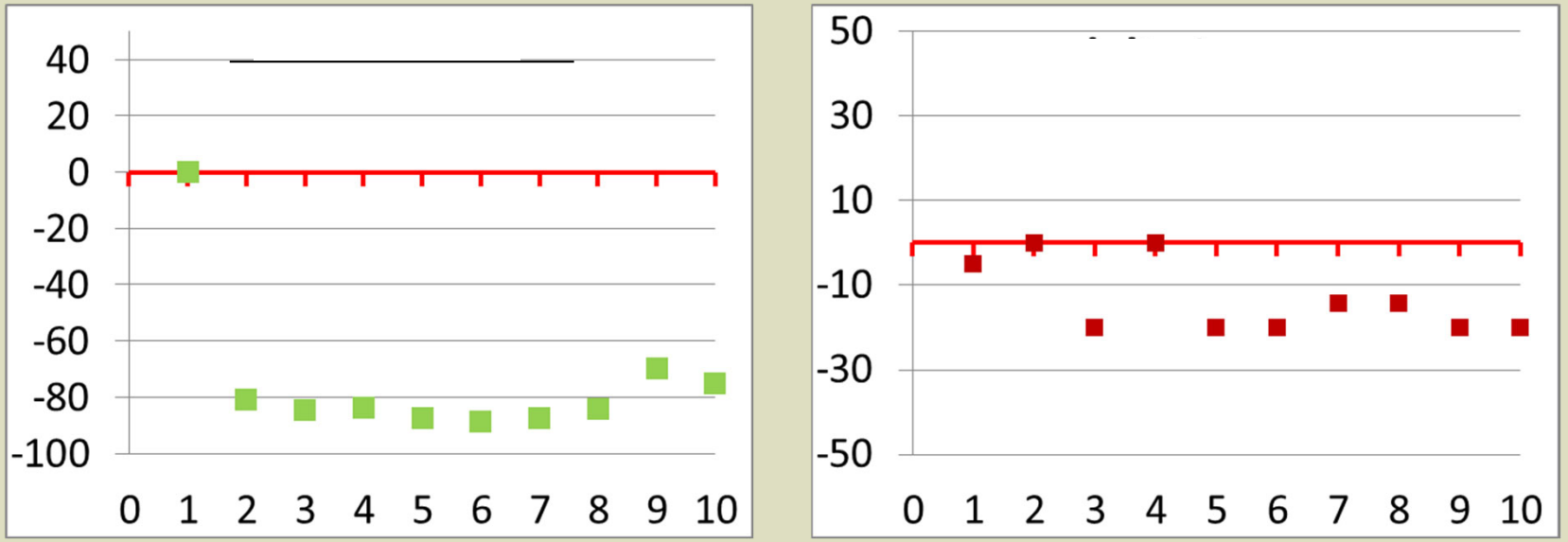
Day 2

Test #

10 successive tests of 1 contact, **single piece** construction

Repeated tests on same contact (**with** actuation)

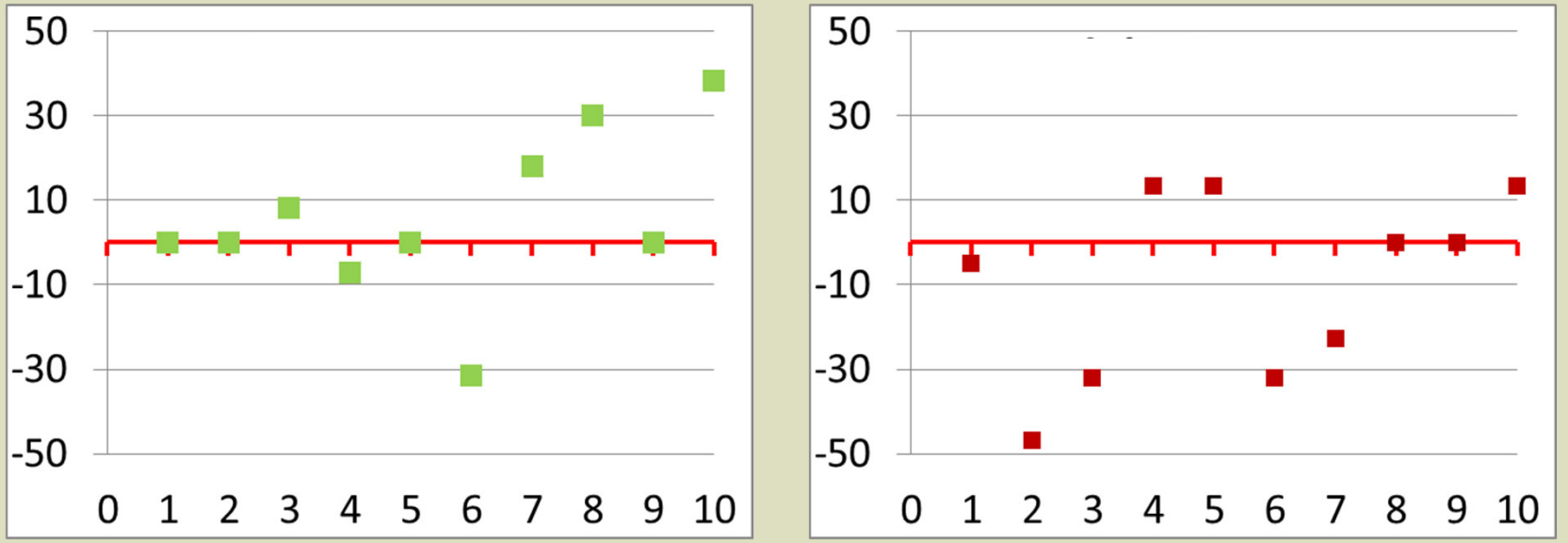
# Temperature rise change at 0.5 A DC drive




10 successive tests of 1 contact, **multi-piece** construction

Repeated tests on same contact (**without** actuation)

# Temperature rise change at 0.5 A DC drive



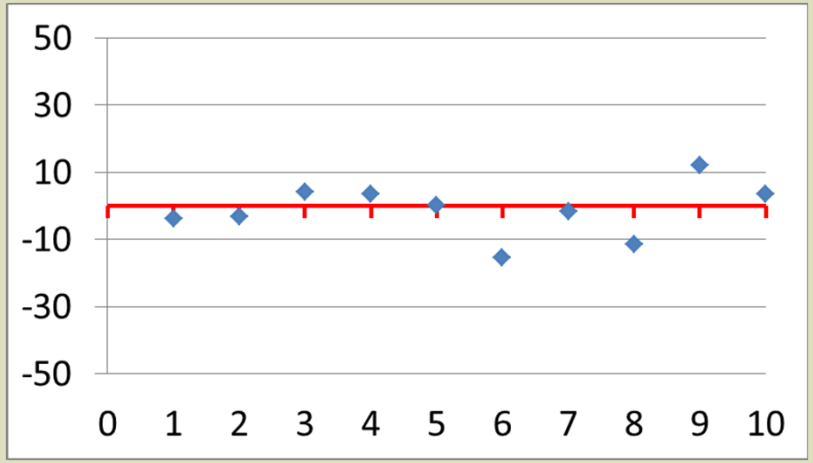

10 successive tests of 1 contact, **multi-piece** construction

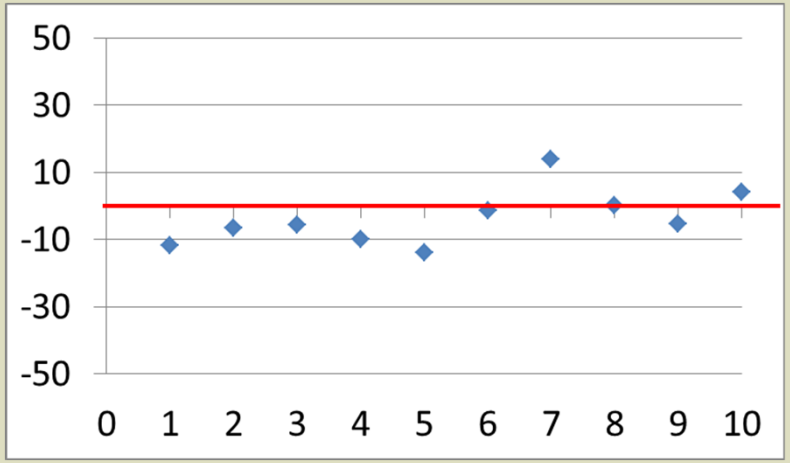
Repeated tests on same contact (**with** actuation)

# Temperature rise change at 1 A DC drive

## (dT2-dT1)/dT1 in %

%



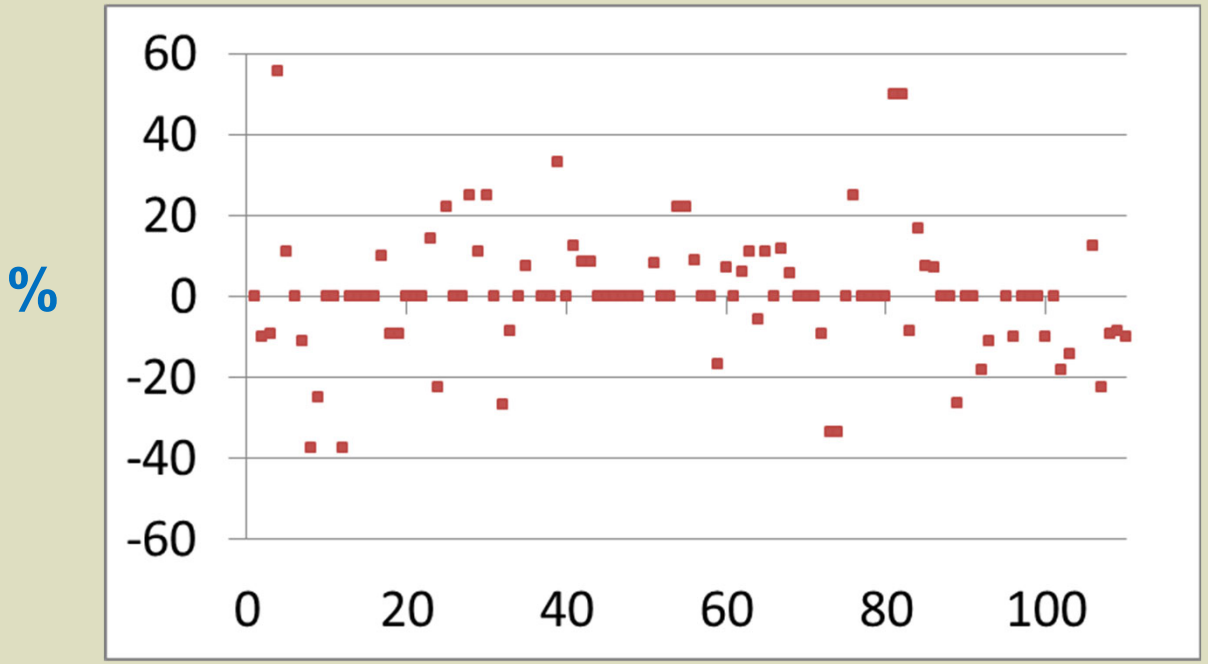




10 successive tests of 2 contacts

Test #

Full test sequence inclusive pulse testing

# Temperature rise change at max. current




220 tests of 110 different contacts:

difference between successive tests on same contact after pulse testing (without actuation)

# Comments

- It appears that pulse current testing often results in higher CCC and reduced Cres after exposure of a contact to high current levels despite the short pulse length
- In cases of reduced CCC it is possible that contact force reduction was an issue
- It must be assumed that the actual temperature in parts of the contact structure exceeds the recorded value (this has been demonstrated to some extent elsewhere with quasi-optical temperature sensing).

# Conclusion

- Pulse current testing alters observed CCC after exposure to high current levels despite short pulse lengths
- Since changes observed during limited temperature rise testing appear reversible it may be suspected that the primary cause of change is due to the contact interface
- Any impact of this on the test floor is likely to be application specific and must be gauged by the end user
- Bulk property changes were not conclusively observed but may become an issue at testing to higher temperature rise levels and possible destruction.

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