Spring Probe CCC – Measurements & Simulations

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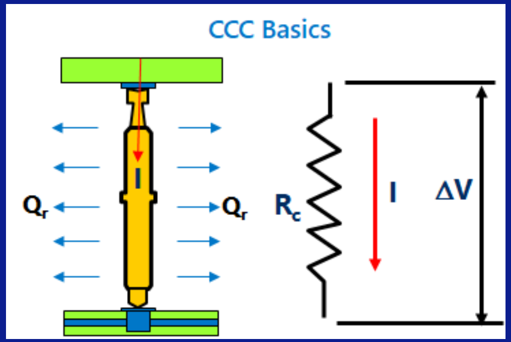
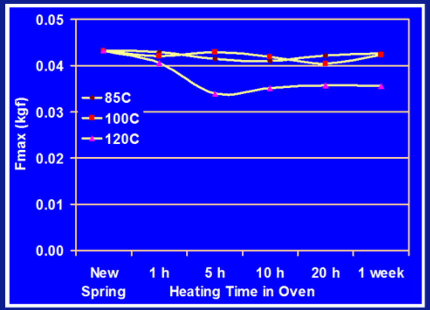
Current Carrying Capacity (CCC) Physics

- Current Carrying Capacity (CCC) definition
  - Refer to probe or other contact's capability of maximum current going through without causing damages or deteriorating performance due to temperature raise caused by heat.
- CCC physical phenomenon
  - Electric current going through probe or any contacts will generate heat due to electric resistance in probe/contacts.
  - Heat generated from electric current will be released to environment through probe/contact house.
  - Heat generated can cause probe/contact temperature rise in probe/contact that will reach steady state or equilibrium to released heat.
- Spring probe/contact failure modes
  - Major failure is spring or contact relaxation or degradation due to losing enough compression force.



Spring Relaxation vs Temperature



Current Carrying Capacity (CCC) Physics

- Probe/Contact temperature raise calculation
  - Total power generated when current I going through probe

$$P = I^2 \times R_c$$

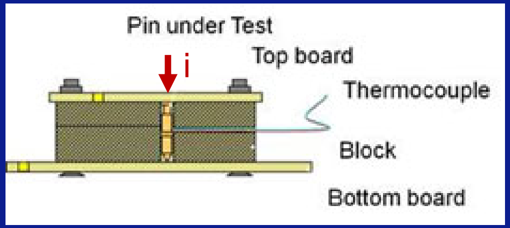
    - Rc refers to total electric resistance (Cres) of probes, which include resistances by material and contact surfaces
  - Heat generated in probe, Q_g, & released to environment, Q_r

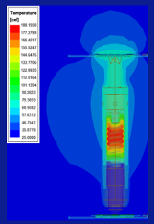
$Q_g \sim P$ $\quad$ $Q_r \sim$ Heat transfer capacity

  - Temperature raise caused by heat.

$$\Delta T \propto (Q_g - Q_r)$$

Probe, Current & Temperature Raise



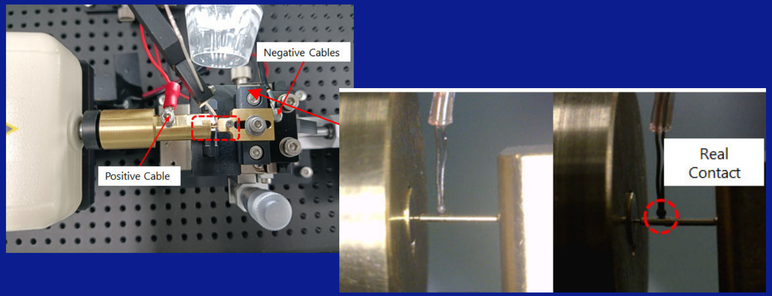


- Major factors impacting probe temperature raises
  - Current going through probes, steady or pulse currents
  - Probe Cres
  - Heat releasing environment, such as socket structure, material & external heat transfer efficiency

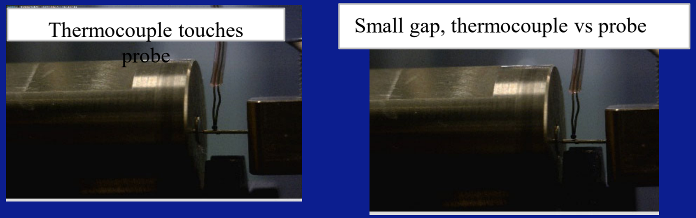
CCC Measurement Methodologies

- Thermocouple methods
  - Thermocouple measures probe temperature by touching the probe body; probe is exposed in still air
- Factors affecting measurement accuracy
  - Reliable contact of thermocouple to probe/contact body
  - Heat transfer environment, such as air flow
- Limitations on thermocouple methods
  - Thermocouple contact status on CCC results
    - Keep thermocouple touching probe tightly as required in CCC test
    - T-rise drops if any small gap of thermocouple tip to probe
  - Differences from probe/contact usage environments
    - Probe/contact houses big impacts on heat transfer, such as structure and materials, etc.
    - Many more probes/contacts in one test socket or interposer

Thermocouple Method: probe in still air



Impacts of thermocouple contacts on probe CCC

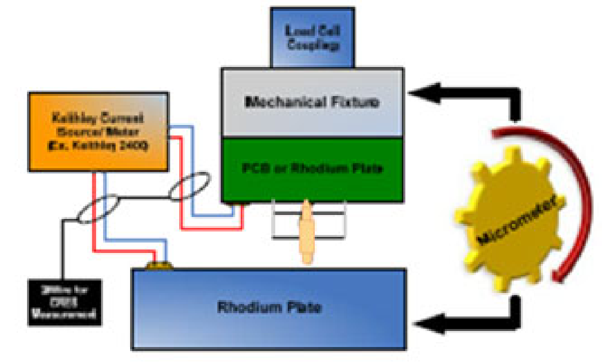


Current(A)	Touching	Gap
	T_raise	T_raise
1	24.6	18.8
2	57.9	45.8
3	105.2	79.1

CCC Measurement Methodologies

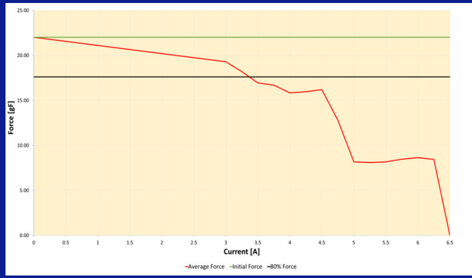
- Force Gauge methods (ISMI)
  - Standard CCC measurement method on probe card technologies by ISMI.
  - Criteria: 20% spring force permanent reduction as current applied.
  - Apply current (2 mins), measure spring probe force
  - Repeat these steps and take current reading when force drops to 80%.
- Pro & con of ISMI methods
  - Measured probe in socket house.
  - Measurements have more uncertainty since spring force generally has more variations, +/-20%
  - ISMI method is mostly developed for contacts with solid piece configuration, such as single wire contact.

ISMI Method



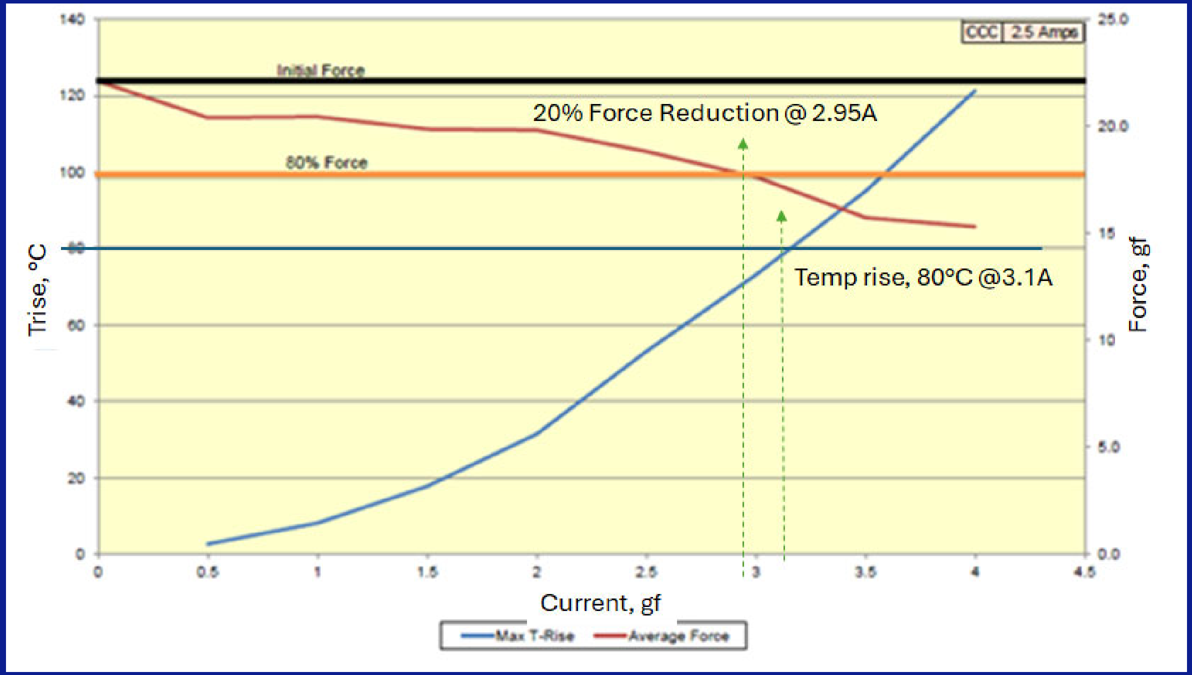
"ISMI CCC Measurement Standard", E Boyd Daniels, IEEE Test Workship" 2009

CCC Measurement Example per ISMI Method



Example of DC CCC Measurements Results

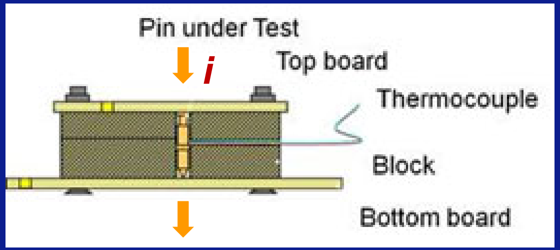
- CCC with both methodologies to get similar results.



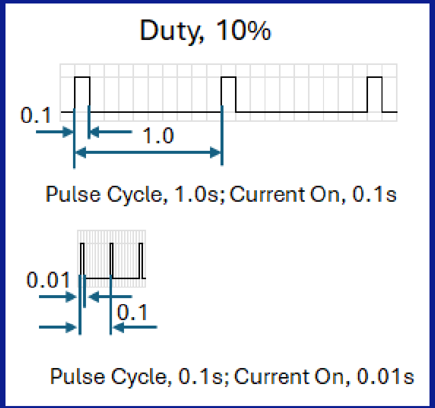
Major Factors Impacting Contacts CCC

- DC current
  - Depends on amount current going through probes
- Pulse current
  - Pulse current Duty%,
    - $Duty\% = \Delta_{on}/\Delta_t$
    - Δ_{on}: time of current going through
    - Δ_t: total time in one pulse
  - Amount of current
  - Time of current on
    - 10% duty: $\frac{0.1s}{1.0s}$ vs $\frac{0.01s}{0.1s}$ vs $\frac{0.001s}{0.01s}$
    - 50% duty: $\frac{0.5s}{1.0s}$ vs $\frac{0.05s}{0.1s}$ vs $\frac{0.005s}{0.01s}$
- Socket & teat transfer environment
  - Socket material & structure
  - External heat transfer, such as still air or flow air

Current Through Probe



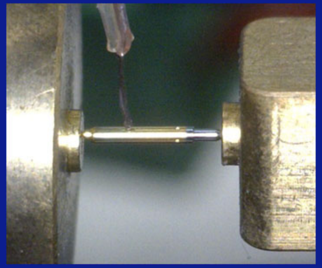
Pulse Current Variation

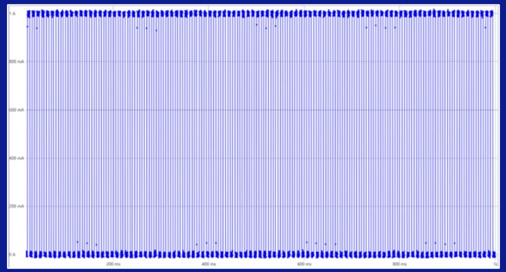


Pulse Current Measurement Example

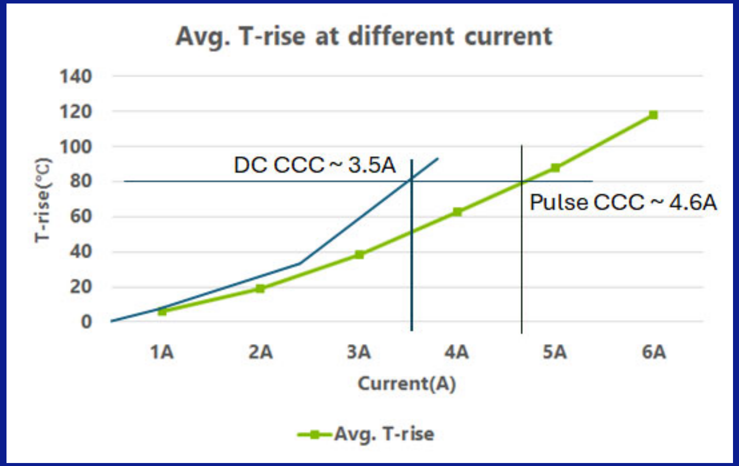
- Measurement Setting
  - Duty cycles: 50%
  - Pulse current: 1A,2A,3A,4A,5A,6A
  - Duration time: 100s to reach steady state
  - Pulse time: 0.005s
  - Off time: 0.005s
- Measurement Results
  - Pulse CCC @ 80°C Trise: ~ 4.6A
  - DC CCC @ 80°C Trise: ~ 3.5A

Pulse Current Test Set up





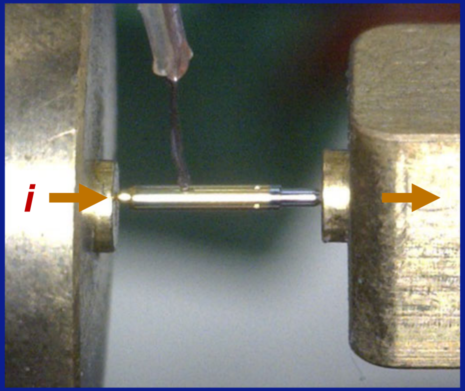
Pulse Current CCC Results



Thermal Simulations on Probe CCC

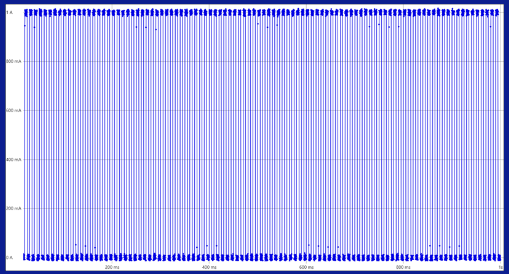
- Why CCC Simulation
  - Avoid limitations on measurements
    - Differences of lab set up vs end use environments
    - Contacts & house structure
    - Multi factors in setup to affect CCC results
    - Complexity of measurements for pulse currents
  - Quick responses to customer demands
  - Predict CCC when developing new contact configuration
  - Able to simulate extra high temperature environment, which is hard to achieve in lab measurements
- Boundary conditions
  - Ambient Temperature in Chamber is considered at 23°C
  - T Rise = Measured Temperature – Ambient Temperature
  - Simulating for steady state analysis.
  - Following Material Properties are considered for respective Material

Spring Probe in Air

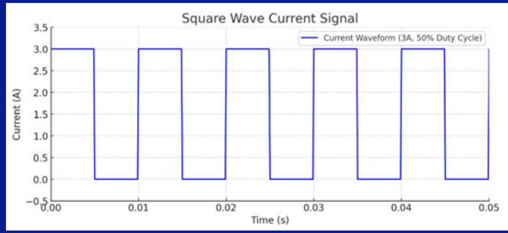


Thermal Simulations on Probe Pulse CCC

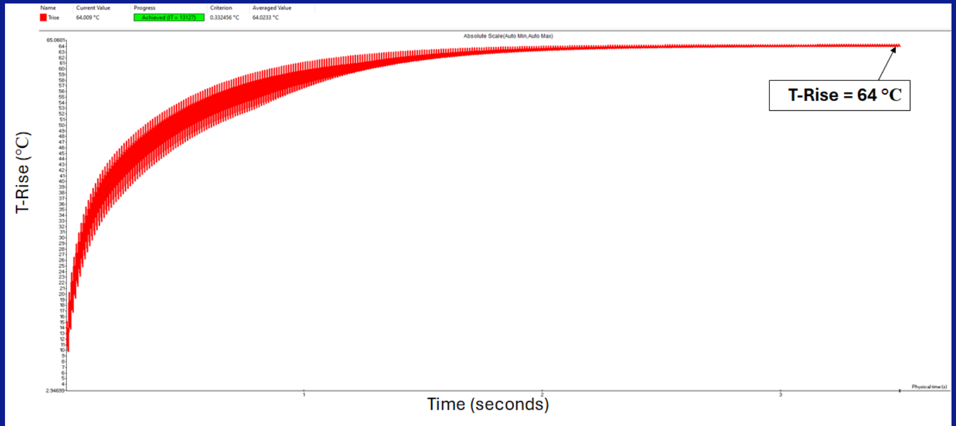
- Pulse CCC simulation
  - Pulse current: 1 ~ 6A
  - Duty time: 50%
  - Width: 0.005s
  - Off time: 0.005s



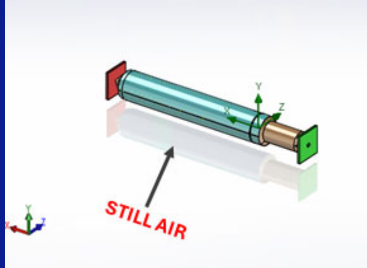
Pulse Current (example)



Temperature Rise to Steady Status



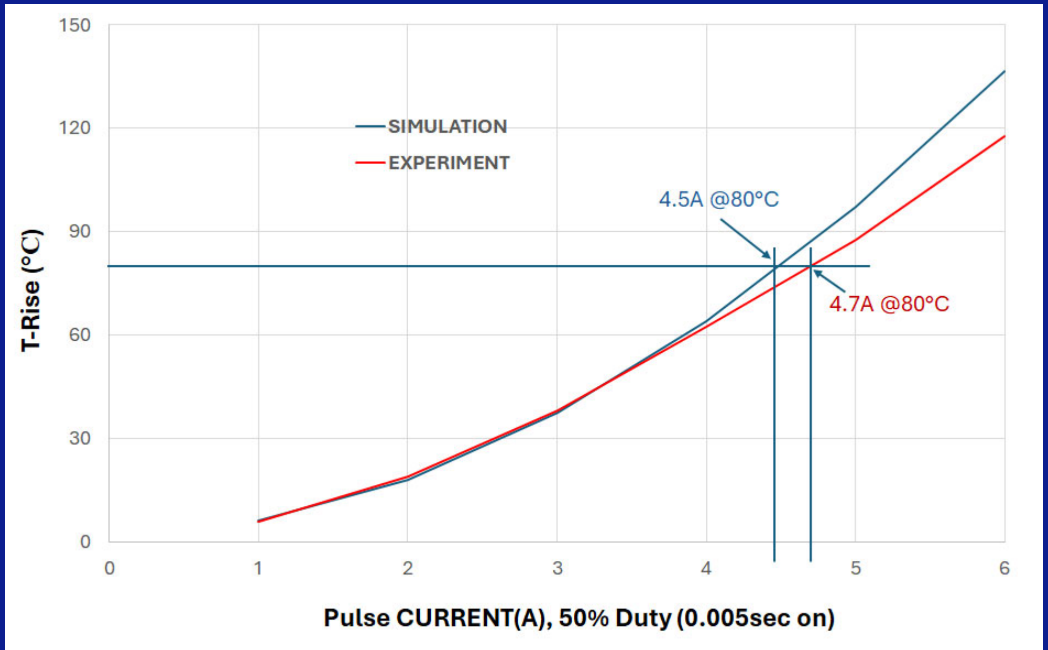
Simulations Model



Thermal Simulations on Probe Pulse CCC

- Simulations vs Experiment Results:
  - Simulation, 4.5A @80°C
  - Experiment: 4.7A @ 80°C

Pulse CCC, Simulations vs Experimental



Summary

- Physics of contact CCC follows basic heat transfer principles.
- Contacts CCC are affected by various factors
  - Currents going through contact, DC or pulse current
  - Contact structure and materials
  - Measurement methodologies have impacts on CCC results
- Thermal simulations on heat transfer can be applied to predict CCC

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