Characterization of the thermal properties of OFHC copper at cryogenic temperature

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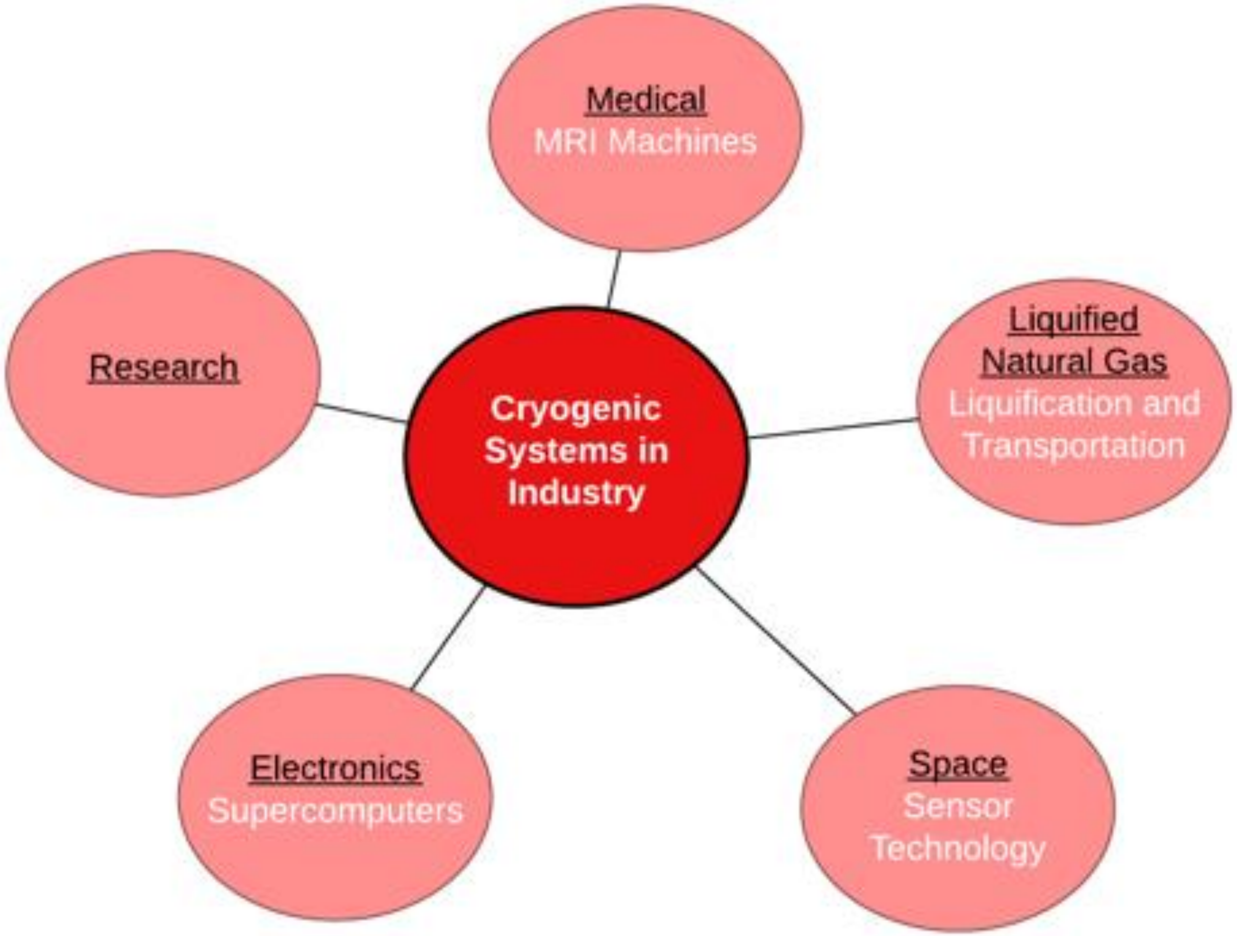
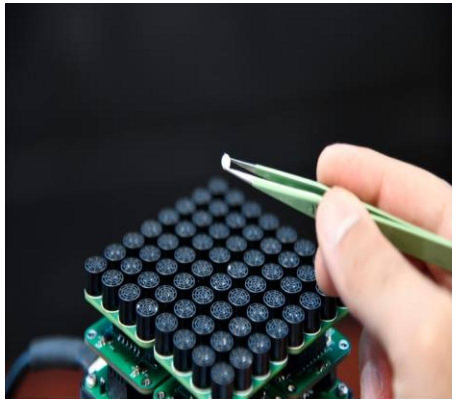
This work was made possible through a collaboration with Northrop Grumman

Applications



Cryogenic Cooling

Devices / Heat Sources

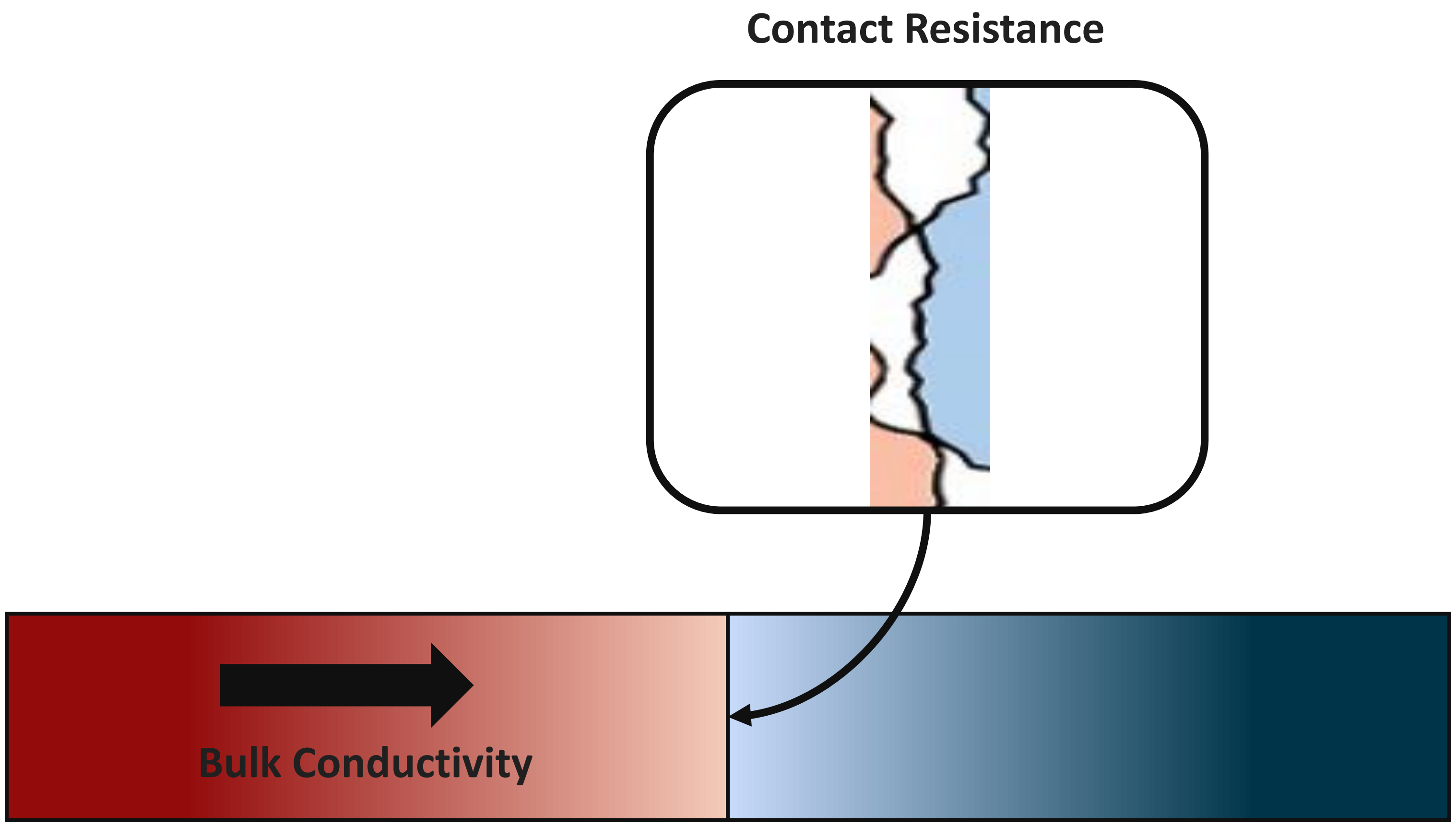


Heat Path

Cooling Device

https://www.northropgrumman.com/what-we-do/disruptive-concepts-and-technologies-quantum-technology/

Heat Path



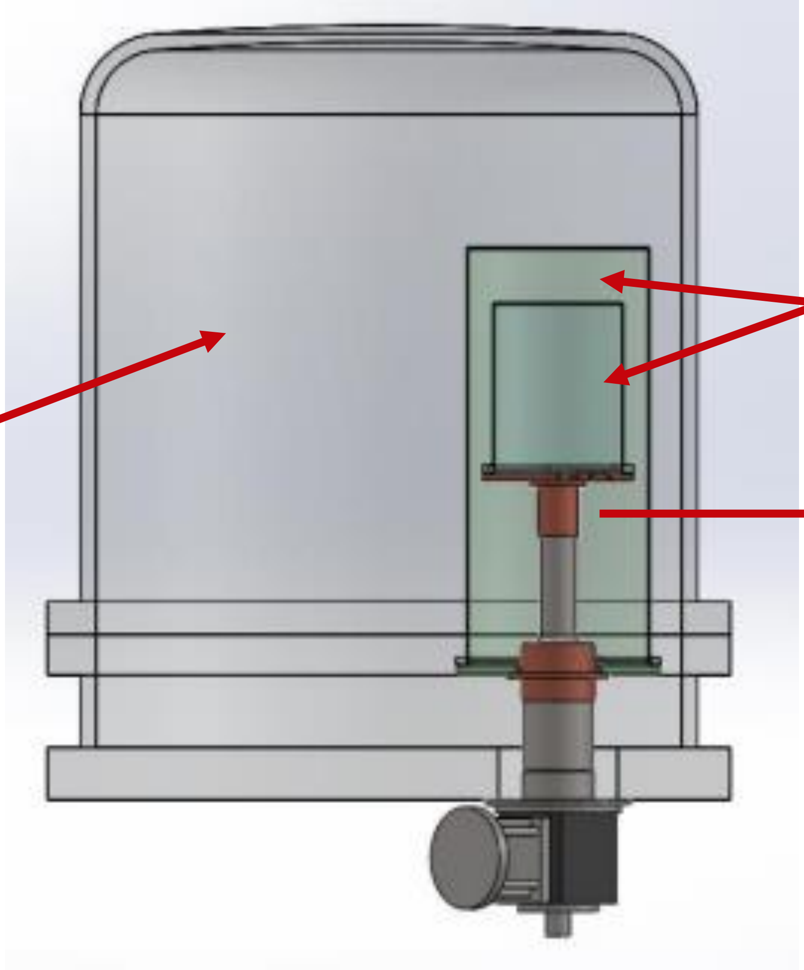
Presentation Overview

1. Bulk Thermal Conductivity
   - Determine a range of thermal conductivity to expect from samples sourced from commercial vendors

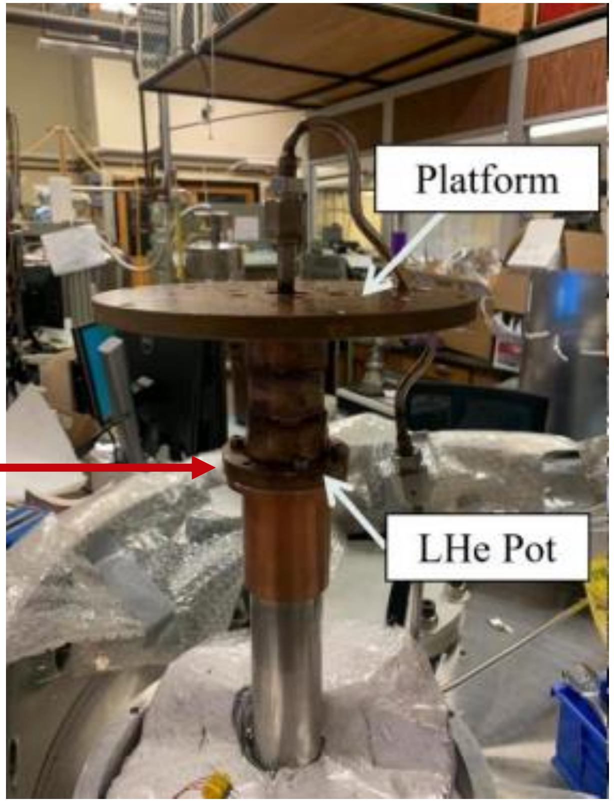
2. Thermal Contact Resistance
   - Determine the effect applied force has on thermal contact resistance

System Overview

System held in a high vacuum



First and second stage thermal jackets covered with MLI

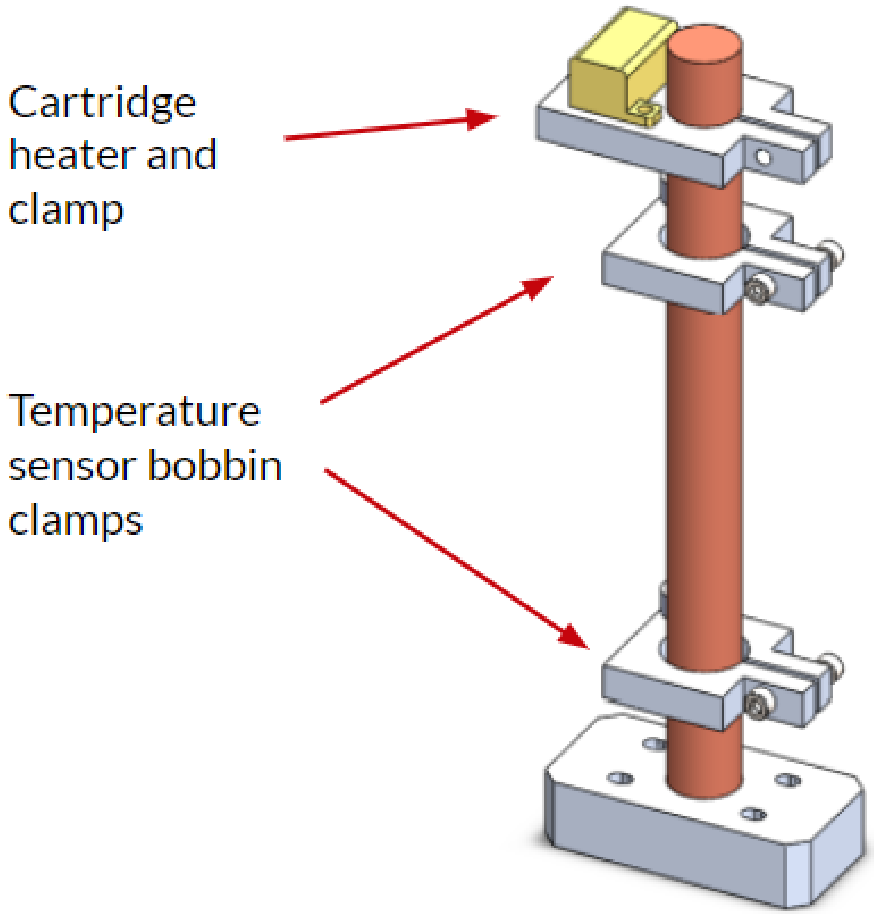


Thermal Conductivity Experimental Setup

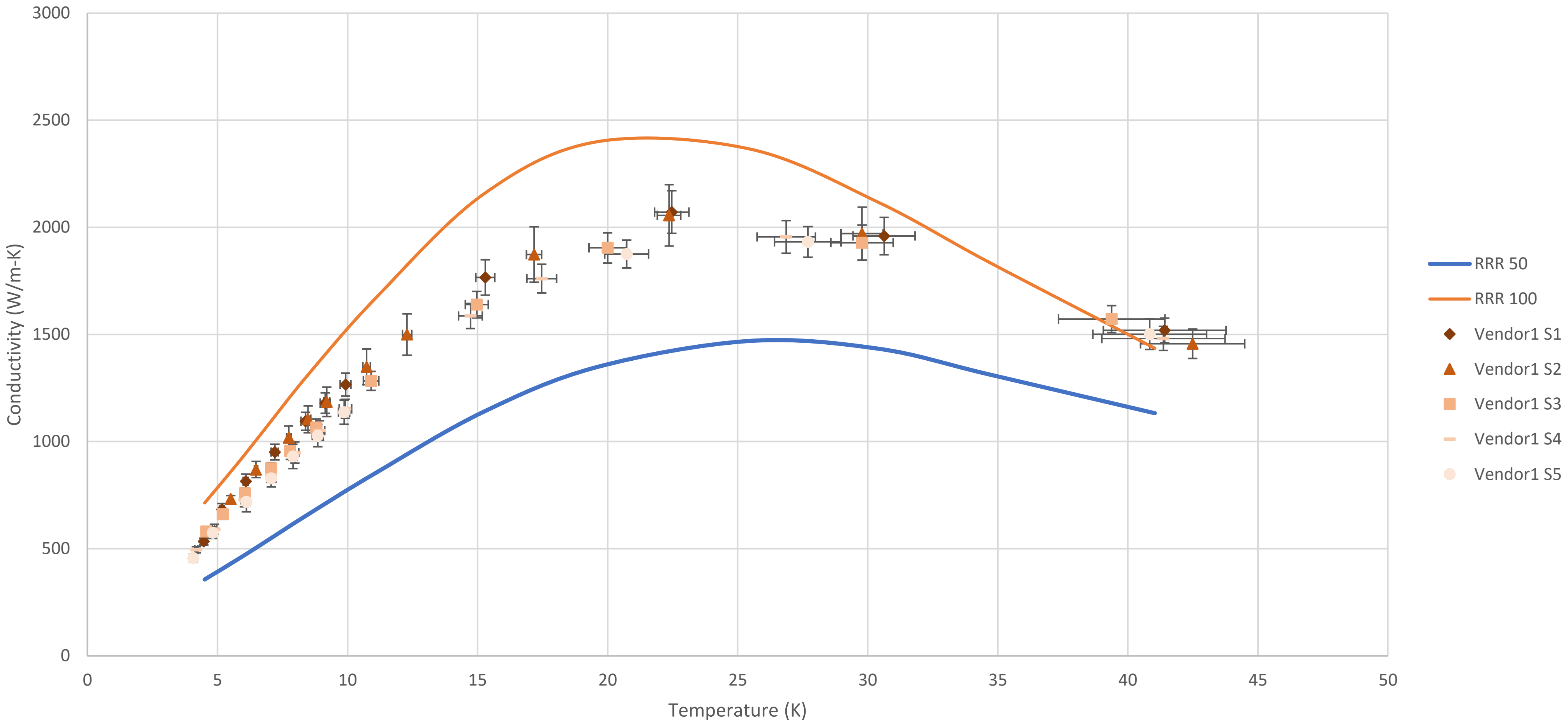
Fourier's Law

$$Q = -kA\frac{\Delta T}{\Delta x}$$

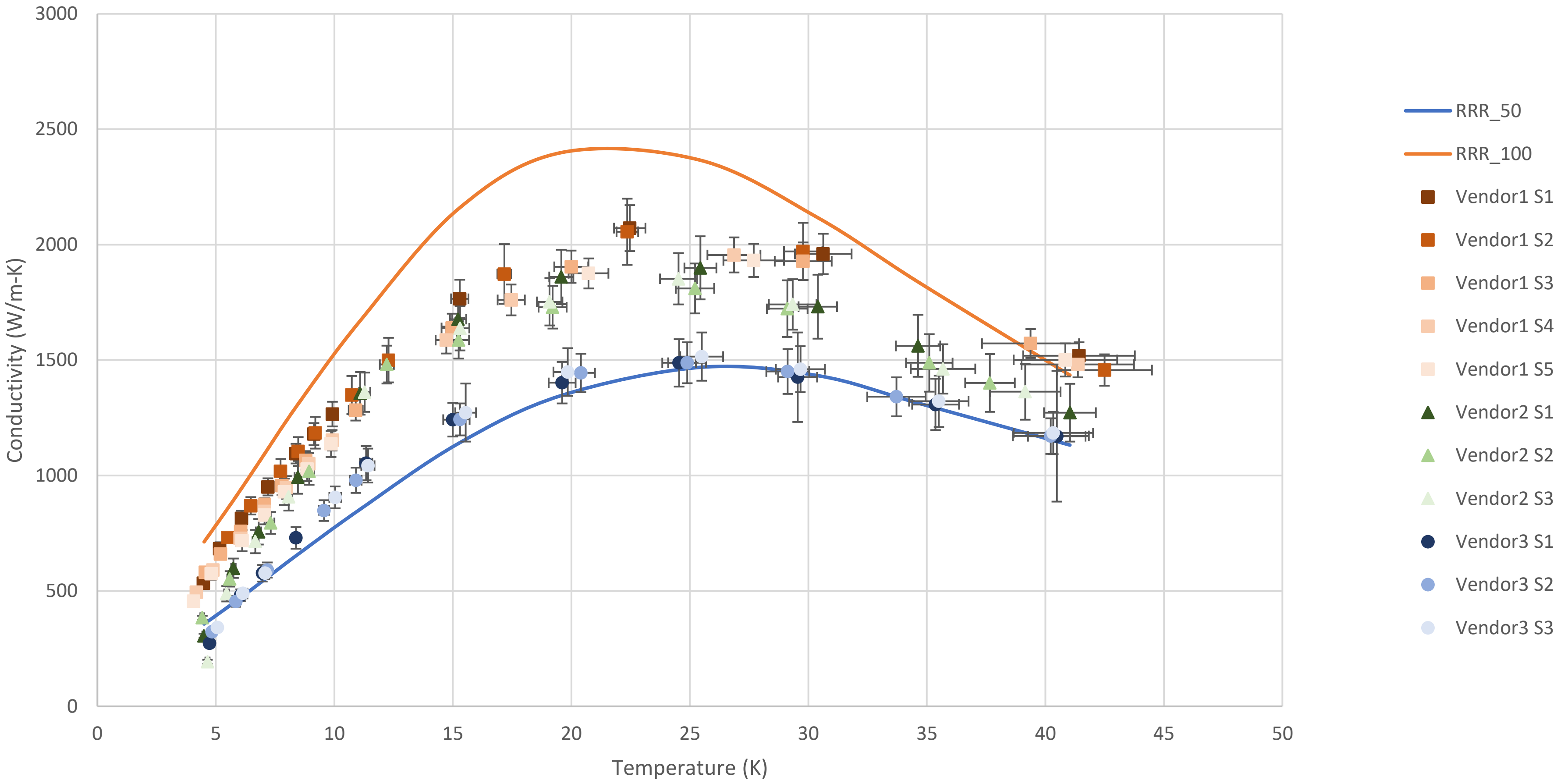
Q is the heat input
k is thermal conductivity
A is cross sectional area
ΔT is the measured temperature difference
Δx is the distance between temperature measurements



Thermal Conductivity Results



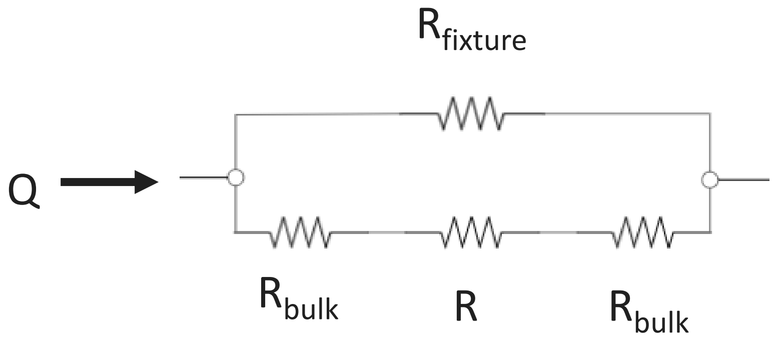
Thermal Conductivity Results

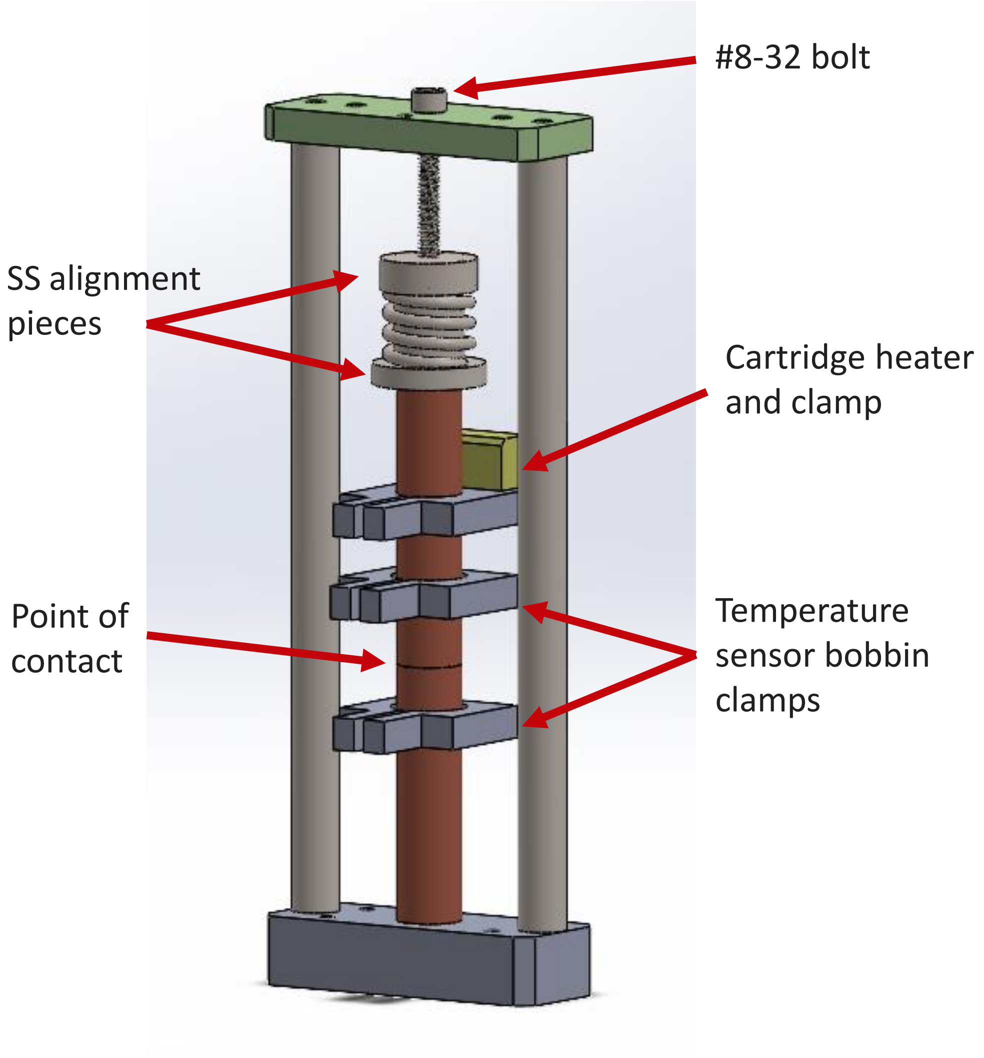


Thermal Contact Resistance Experimental Setup

$$R = \frac{A(\Delta T - \Delta T_{bulk})}{Q - Q_{fixture}}$$

R is contact resistance
ΔT is measured temperature across point of contact
ΔT_{bulk} is the temperature drop in bulk material
Q is the heat input
$Q_{fixture}$ is heat flow through fixture
A is the sample cross sectional area



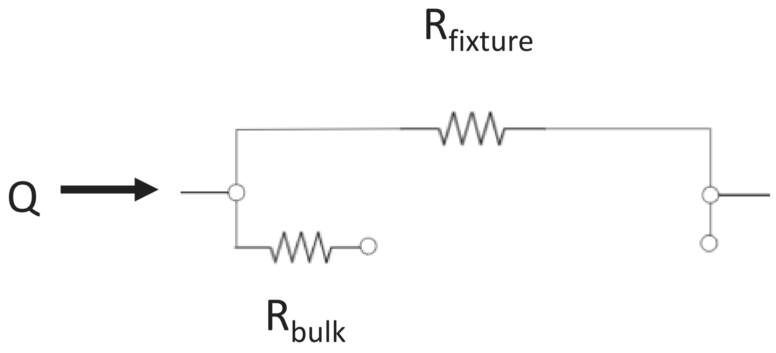


Heat Flow Through Fixture

$$Q_{fixture} = \frac{\Delta T_{fixture}}{R_{fixture}}$$

$\Delta T_{fixture}$ is the temperature drop through the fixture

$R_{fixture}$ is the thermal resistance of the fixture



Temperature Drop Through Bulk Material

$$\Delta T_{bulk} = \frac{(Q - Q_{fixture})L}{kA}$$

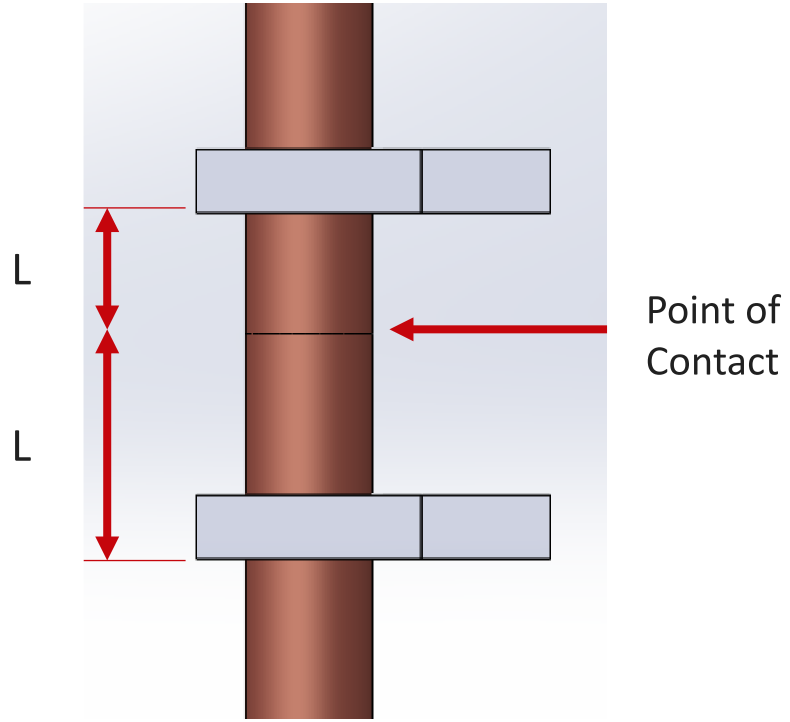
L is the distance between temperature sensor and point of contact

k is the conductivity of the sample

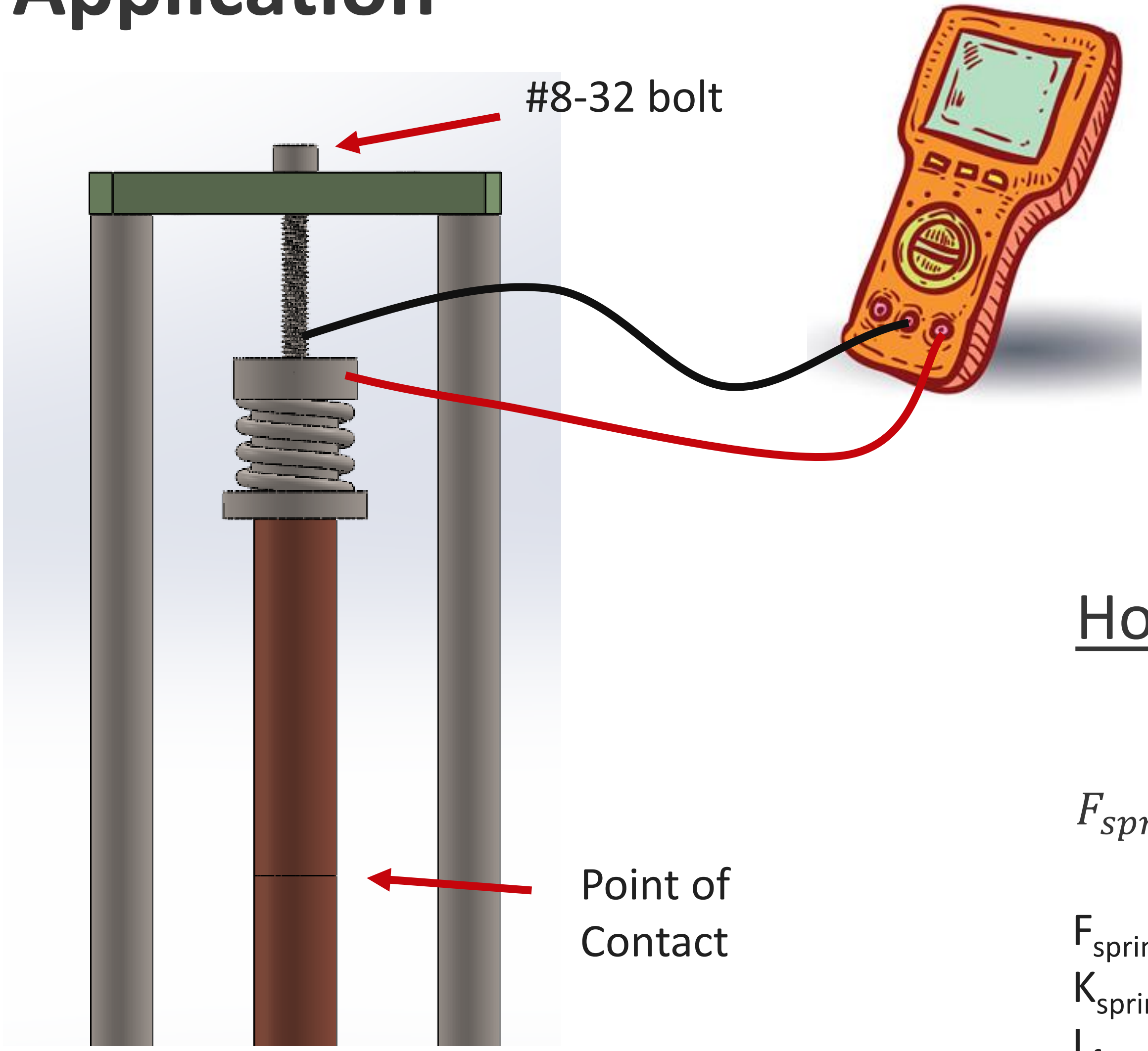
Q is the heat input

$Q_{fixture}$ is heat flow through fixture

A is cross sectional area



Force Application



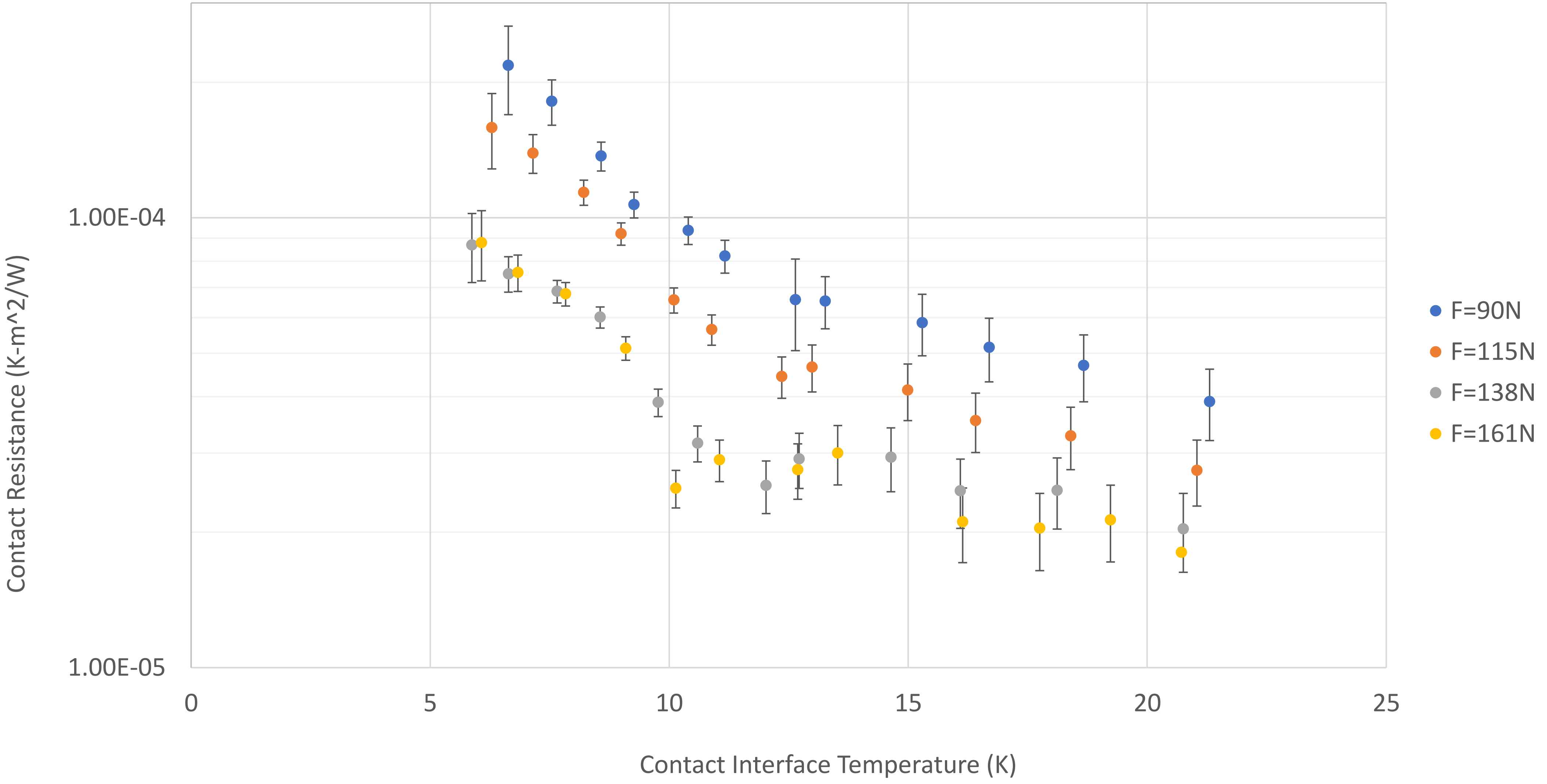
Hand-held multimeter used to detect continuity to determine contact

Hooke's Law

$$F_{spring} = k_{spring}(L_{free} - L)$$

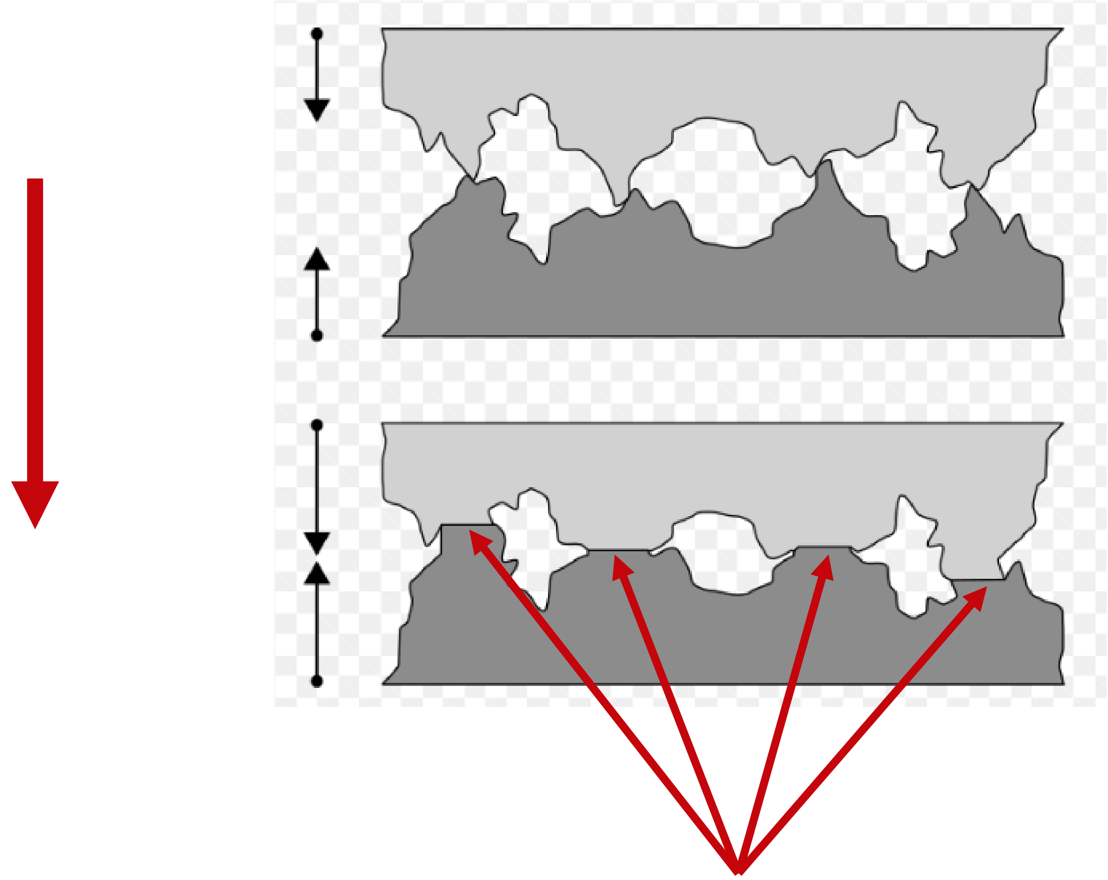
F_{spring} is the spring force
K_{spring} is the spring constant - 18.6 N/m
L_{free} is the spring's free length - 2.54 cm
L is the spring length

Thermal Contact Resistance Results



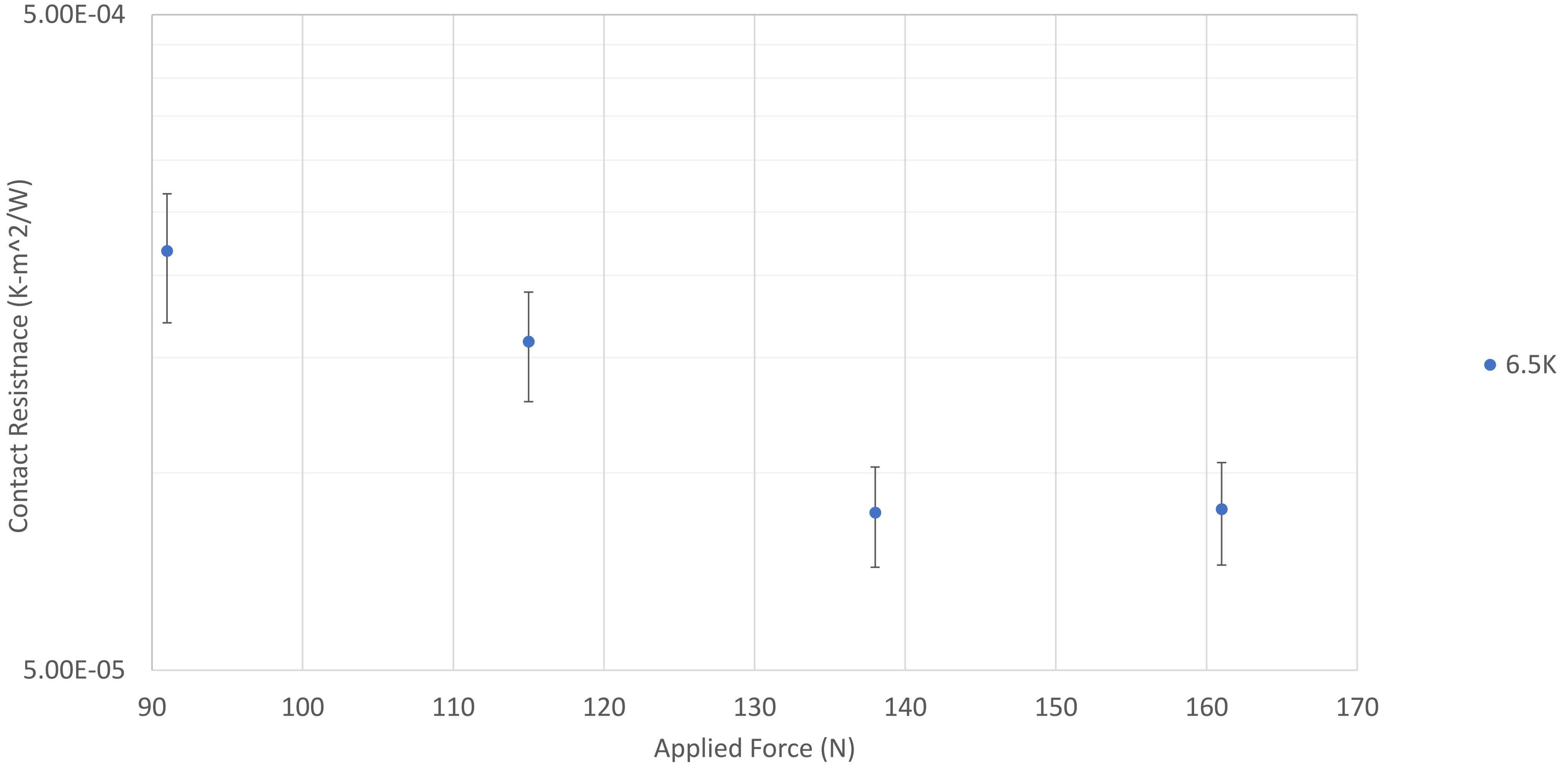
Asperity Deformation

Applied Force
Increases



Contact Area Increases

Thermal Contact Resistance and Force Relation



Conclusion

Bulk Conductivity:

- Samples from the same vendor have very similar values of conductivity
- The conductivity of OFHC copper sourced from commercial vendors is expected to be in the RRR range of 50 – 75

Contact Resistance:

- Generally, as force at the contact surface increases, contact resistance decreases
- At higher forces, contact resistance begins to converge to a constant value