Seebeck Measurement System

Thermoelectric Measurements

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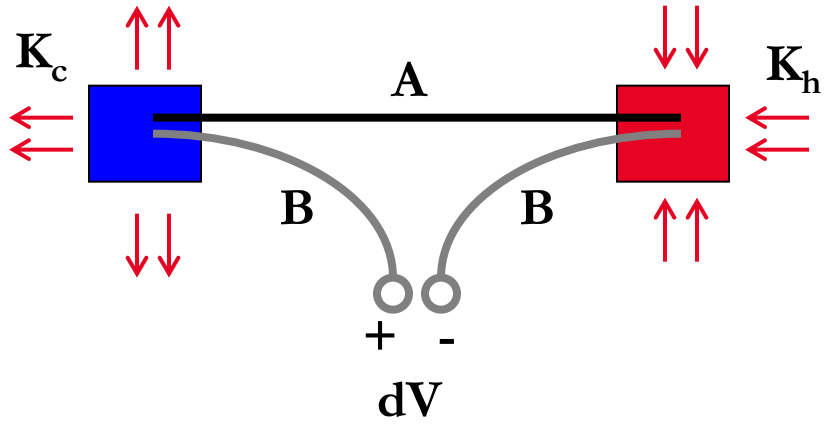
The Seebeck Measurement System

The Seebeck Effect

- The Seebeck Effect, or thermoelectric effect
  - Direct conversion of temperature differences into electricity
- Discovered in 1821 by Thomas Johann Seebeck
  - Found that a voltage existed between two ends of a metal bar when a temperature gradient, ΔT, existed in the bar
  - When a closed loop is made of two metals with a temperature difference, a magnetic field is produced.
    - Effect is that a voltage, or thermoelectric EMF, is created in the presence of two metals with a temperature difference between the junctions

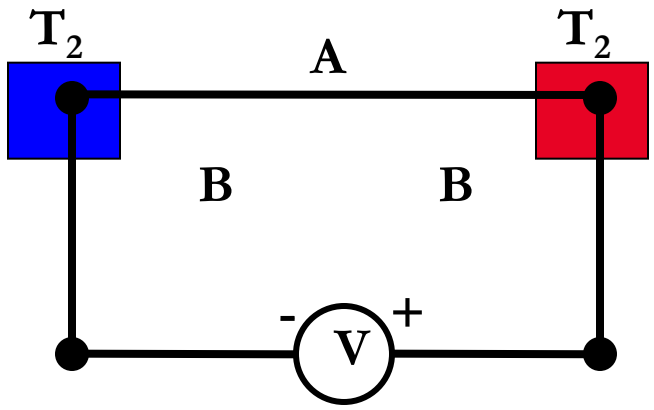
The Seebeck Effect

$$dV = S_{AB}(K_h - K_c)$$



- A and B are a pair of dissimilar metals, whose two junctions are held at different temperatures
- $K_h - K_c$ is the difference in temperature of the hot and cold junctions
- S_{AB} is the relative Seebeck Coefficient, thermoelectric power
  - Varies with the level of the temperature at which the temperature difference occurs
- dV – voltage difference across the terminals of an open circuit
  - Does not depend on the distribution of temperature along the metals between the junctions

The Seebeck Effect



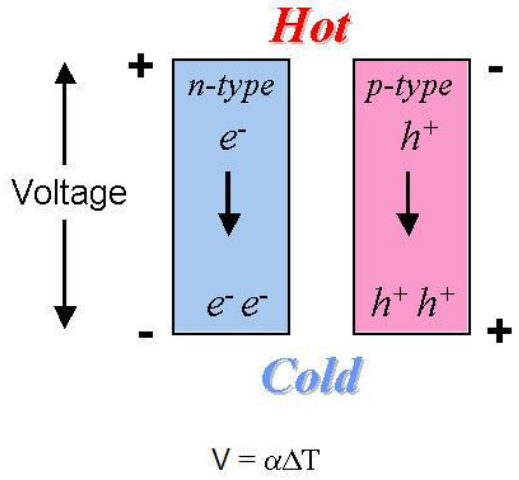
$$V = \int_{T_1}^{T_2} (S_B(T) - S_A(T))dT$$

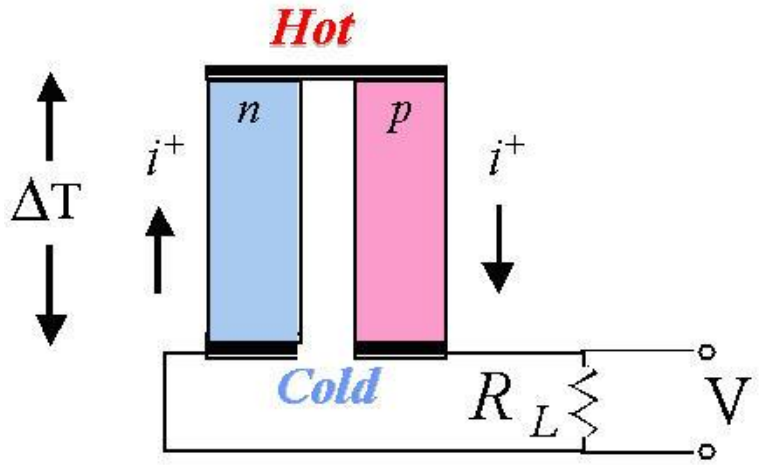
$$V = (S_B - S_A)(T_2 - T_1)$$

Simplify the equation if the Seebeck Coefficients are effectively constant of the measured temperature range

- If the circuit is closed, a current will flow through in the metals, detected by:
  - Magnetic field produced around the wires
  - Joule heating produced by the resistance in the wires
  - Galvanometer or ammeter placed in circuit to measure the current

Causes of the Seebeck Effect





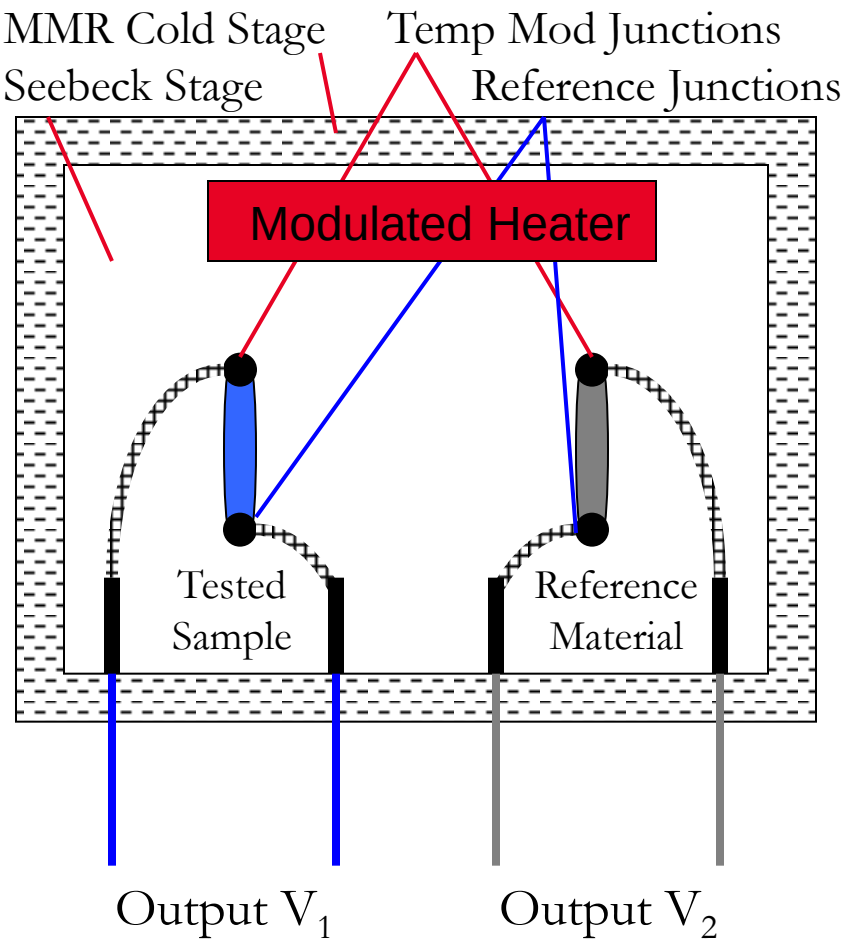
- Charge Carrier Diffusion
  - Charge carriers diffuse when one end of a conductor is at a different temperature than the other
    - Hot carriers diffuse from the hot end to the cold end
    - Cold carriers diffuse from the cold end to the hot end
  - Motion of charge carriers results in an electrical current

Causes of the Seebeck Effect

- Phonon Drag
  - A phonon is a quantized mode of vibration occurring in a rigid crystal lattice
    - Not always in local thermal equilibrium – they move along the thermal gradient
  - Loss of momentum by interaction with carriers and imperfections in the lattice
    - If the phonon-electron interaction is predominant, phonons tend to push electrons to one end of the material
      - Occurs strongly at the Debye temperature
      - Region of thermopower vs. temperature is highly variable under a magnetic field

Taking Measurements

- Two pairs of thermocouples:
  - One based on junctions of Cu-Metal with known properties
  - One based on Cu-Metal of unknown properties
- Computer controlled heater, located close to working junctions, far from reference

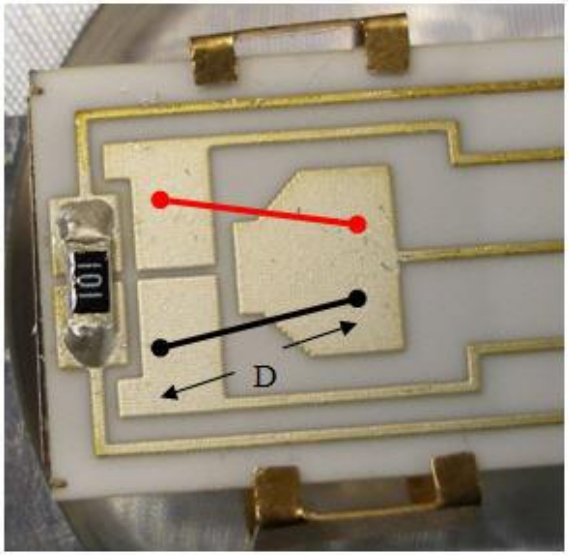


Taking Measurements

- Principle of operation:
  - Assume all four thermocouples have same temperature
    - V_1 and V_2 = zero
  - Apply power to heater to create temperature difference between working and reference junctions
    - Get some non-zero values for V_1 and V_2
    - Assume the temperature difference is the same for both pairs because the sample stage is symmetrical
      - Gives the ratio of the specific thermovoltages equal to the differences in the voltages V_1 and V_2

Taking Measurements

- Difference is very small, so direct measurement will not give high accuracy
  - Eliminate the inaccuracy by taking measurements at two temperature points, and operate with the difference signal
  - Additionally, take multiple measurements at each point and average the results



Reference Wire

Sample "Wire"

Components in a Seebeck System

- Pure high-pressure gas (greater than 1800 psi)
  - Gas Lines, Pressure Gauge, etc
- Filter/Dryer Apparatus
- Refrigerator
- Computer
- Temperature controller
- Circuit Breakout Box
- Vacuum Pump
- Seebeck Vacuum Chamber
- Seebeck Electronics and Software
- Sample Mounting Stage

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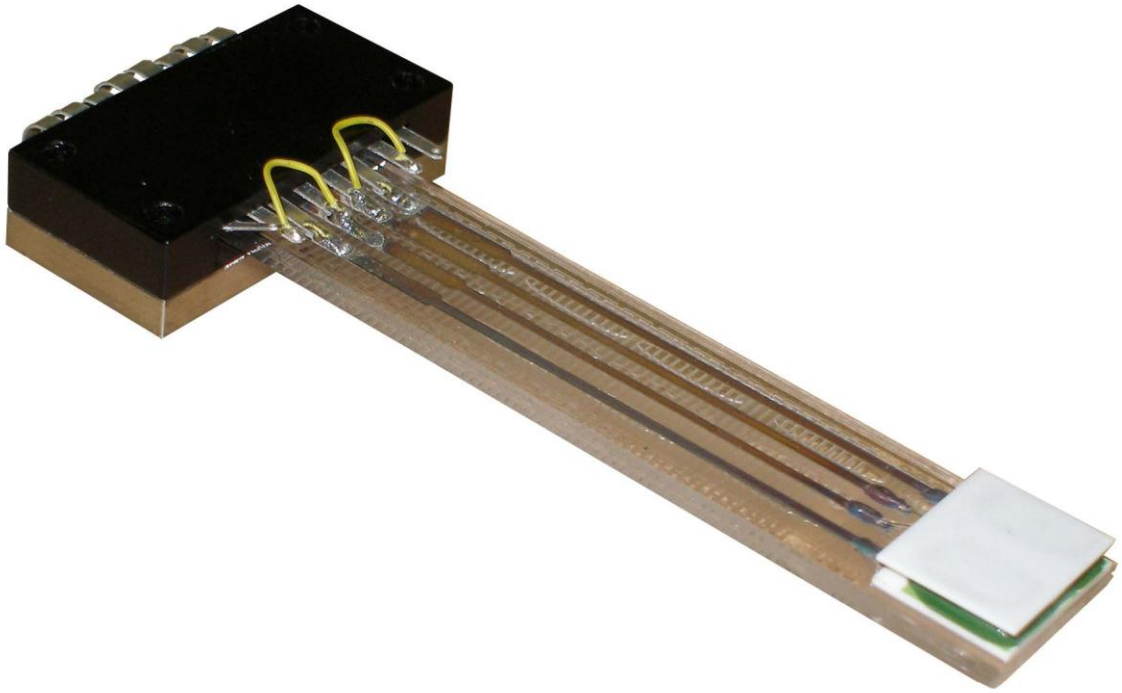
Gas, Lines, Gauges, etc

- 99.998% Pre-purified Nitrogen at 2640 psi or higher
- High Pressure Nitrogen Regulator
- High Pressure Nitrogen Lines (supplied)
- Gas Flow Meter (supplied)

Filter/Dryer Systems

The Joule-Thomson Refrigerators



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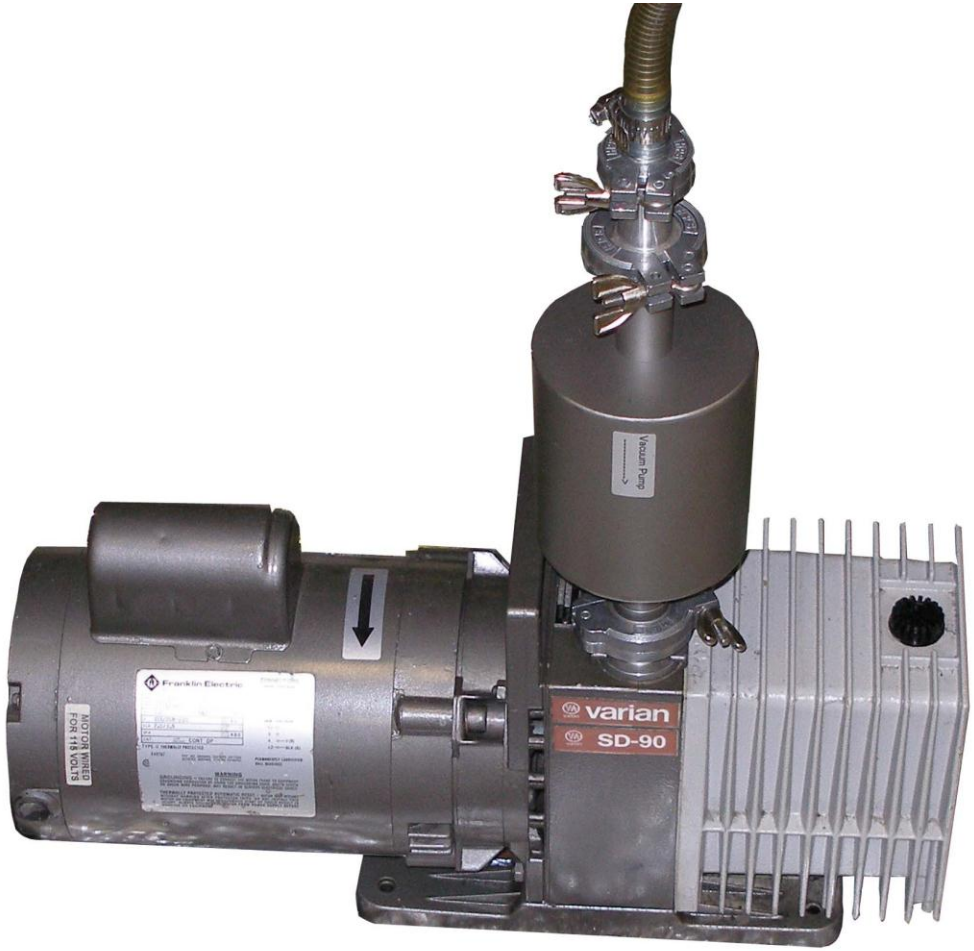
Computer System

- Pentium Processor, 1 GHz minimum
- CD-ROM Drive (4x)
- 250 MB RAM
- 50 MB free on hard drive
- 2 RS232 Serial Ports or USB Ports

Vacuum Pump and Accessory Kit

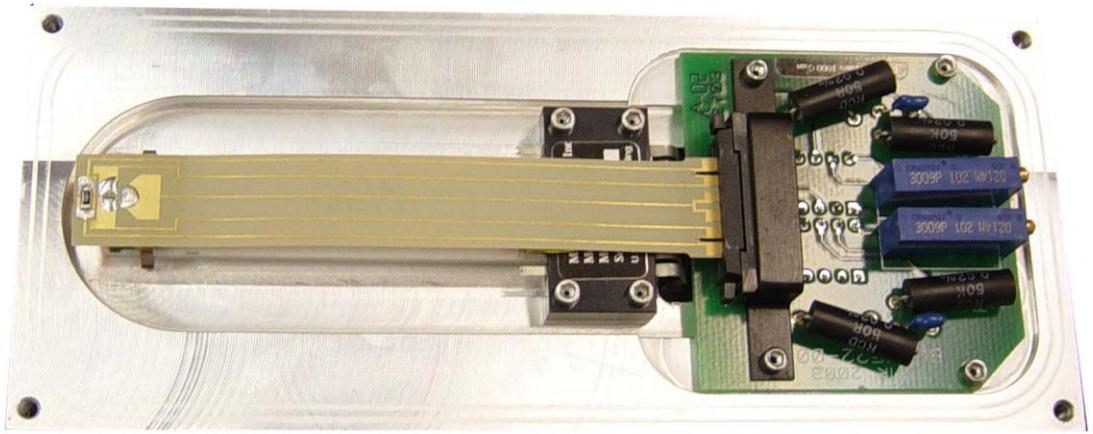


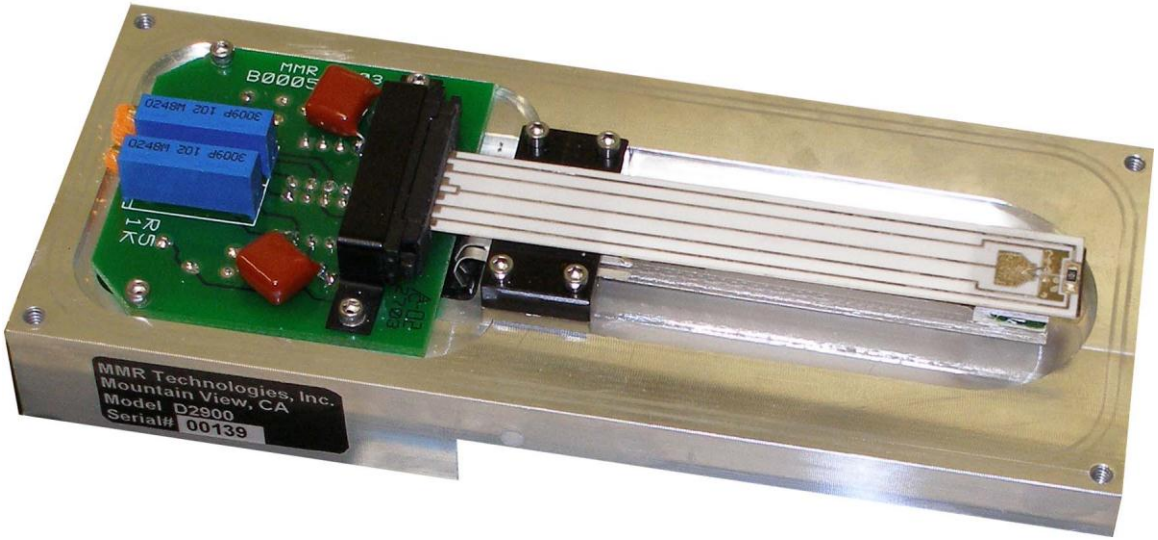
SEEBECK ELECTRONICS

Seebeck Vacuum Chamber

Seebeck Sample Mounting Stage

For Temperatures
below 400 K





For Temperatures
above 400 K

Possible Temperature Ranges

Kelvin Scale	Centigrade Scale
70 K to 580 K	- 200 °C to 305 °C
80 K to 580 K	- 190 °C to 305 °C
70 K to 730 K	- 200 °C to 455 °C
80 K to 730 K	- 190 °C to 455 °C
300 K to 730 K	25 °C to 455 °C

K = °C + 273

Why care about the Seebeck Effect?

- Automobiles and Fuel Consumption
- Energy Efficiency
- Alternate Energy Sources
- Thermoelectric refrigeration

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Potential End-Users for Seebeck

- Semiconductor industry
- Universities
- Energy and environmental engineers
- Thermoelectric Measurement
- Refrigeration industry