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Temperature Sensors

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Outline

- Thermocouples
  - overview, reference junction, proper connections, types, special limits of error wire, time constants, sheathing, potential problems
- RTDs
  - overview, bridges, calibration, accuracy, response time, potentail problems
- Thermistors
- Infrared Thermometry
  - fundamentals, emissivity determination, field of view
- How to Choose
  - Standards, cost, accuracy, stability, sensitivity, size, contact/non-contact, temperature range, fluid type

Thermocouples

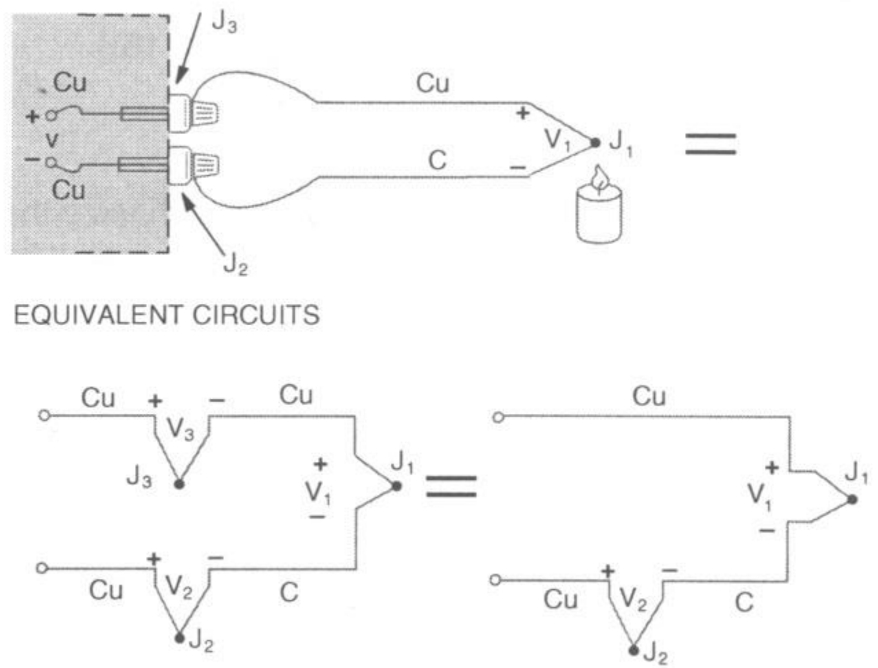
Seebeck effect

- If two wires of dissimilar metals are joined at both ends and one end is heated, current will flow
- If the circuit is broken, there will be an open circuit voltage across the wires
- Voltage is a function of temperature and metal types
- For small temperature difference, the relationship with temperature is linear

$$\Delta V = \alpha \Delta T$$

- For larger temperature difference, non-linearities may occur

Measuring the Thermocouple Voltage



Displayed voltage will be proportional to the difference between J_1 and J_2 (and hence T_1 and T_2).

Note that this is "Type T" thermocouple

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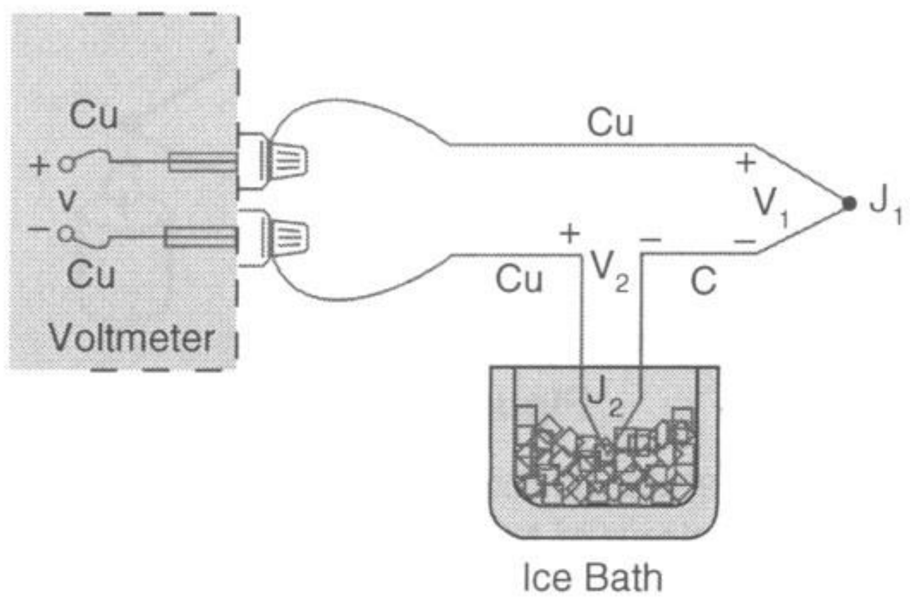
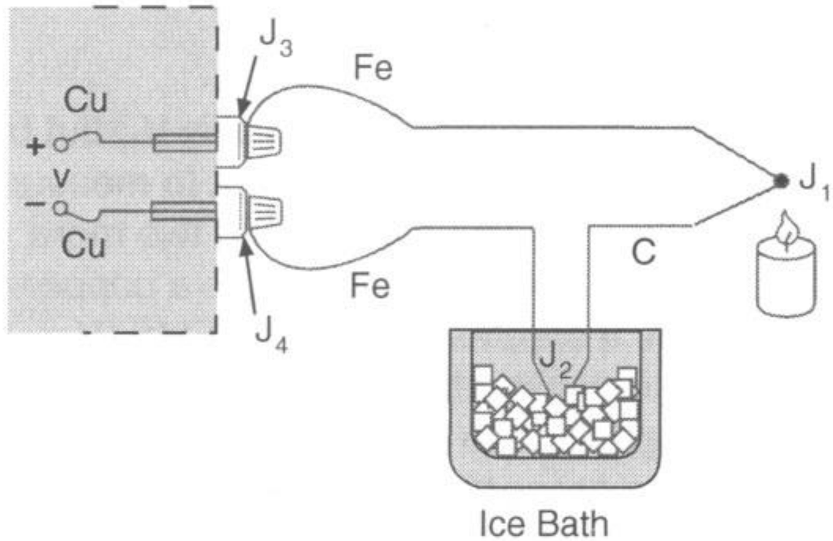
External Reference Junction

A solution is to put J_2 in an ice-bath; then you know T_2, and your output voltage will be proportional to T_1-T_2



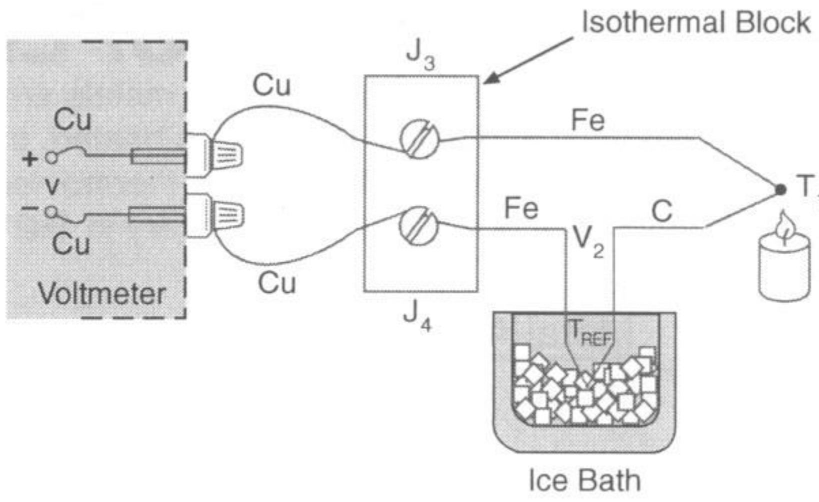
Other types of thermocouples

- Many thermocouples don’t have one copper wire. Shown below is a “Type J” thermocouple
- If the two terminals (J3, J4) aren’t at the same temperature, this also creates an error



Isothermal Block

- The block is an electrical insulator but good heat conductor. This way the voltages for J_3 and J_4 cancel out. Thermocouple data acquisition set-ups include these isothermal blocks.
- If we eliminate the ice-bath, then the isothermal block temperature is reference temperature



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Software Compensation

- How one can find the temperature of the block? Use a thermister or RTD.
- Once the temperature is known, the voltage associated with that temperature can be subtracted off.
- Then why use thermocouples at all?
  - Thermocouples are cheaper, smaller, more flexible and rugged, and operate over a wider temperature range.
- Most data acquisition systems have software compensation built in. To use Labview, you'll need to know if you have a thermister or RTD.

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Hardware Compensation

- With hardware compensation, the temperature of the isothermal block again is measured, and then a battery is used to cancel out the voltage of the reference junction.
- This is also called an "electronic ice point reference". With this reference, one can use a normal voltmeter instead of a thermocouple reader. You need a separate ice-point reference for every type of thermocouple.

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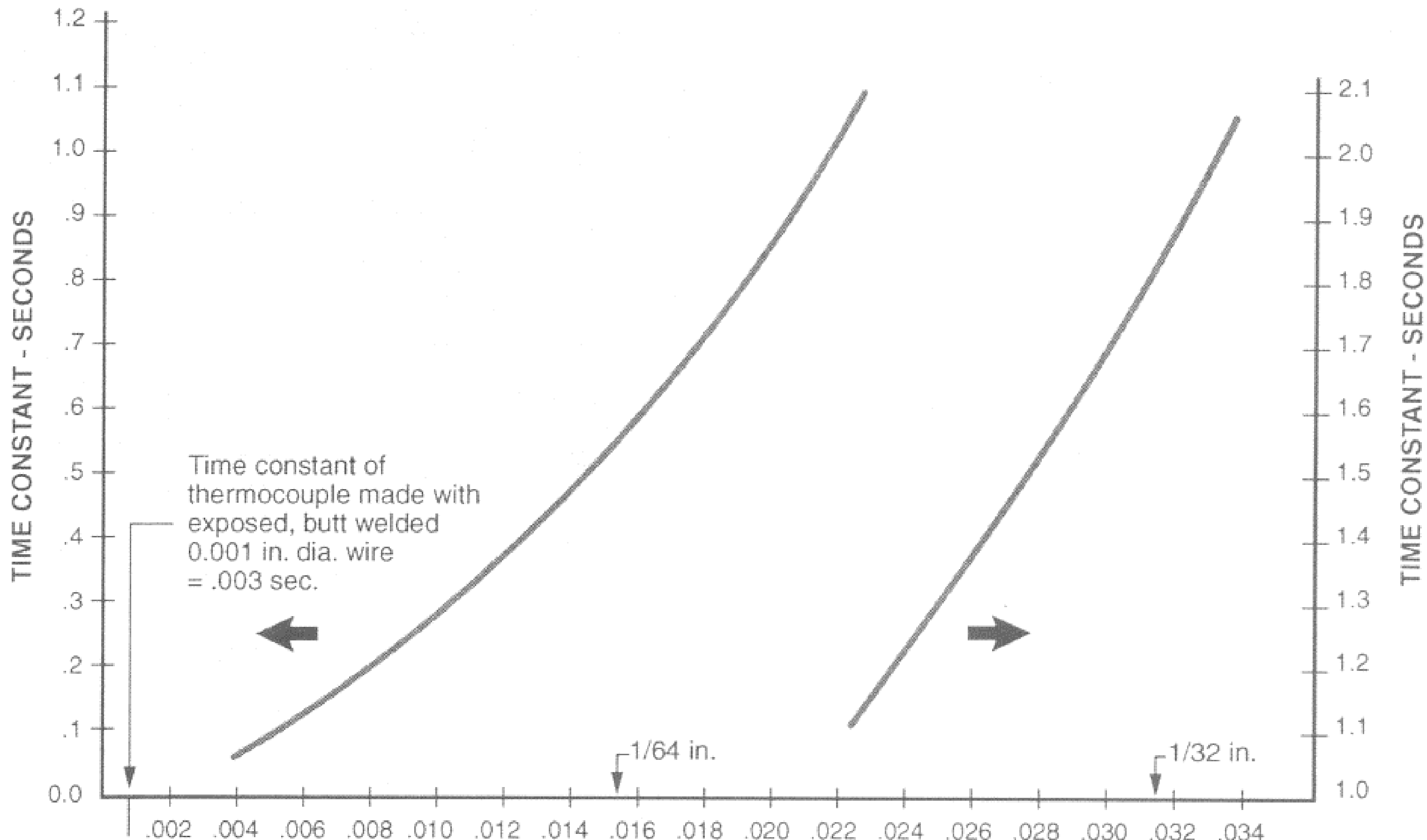
Making Thermocouple Beads

- Soldering, silver-soldering, butt or spot or beaded gas welding, crimping, and twisting are all OK.
- The third metal introduced doesn't affect results as long as the temperature everywhere in the bead is the same.
- Welding should be done carefully so as to not degrade the metals
- It is possible to use a thermocouple welder; the wire ends are placed in the appropriate opening, and welding is performed by pressing a button

Time Constant vs. Wire Diameter



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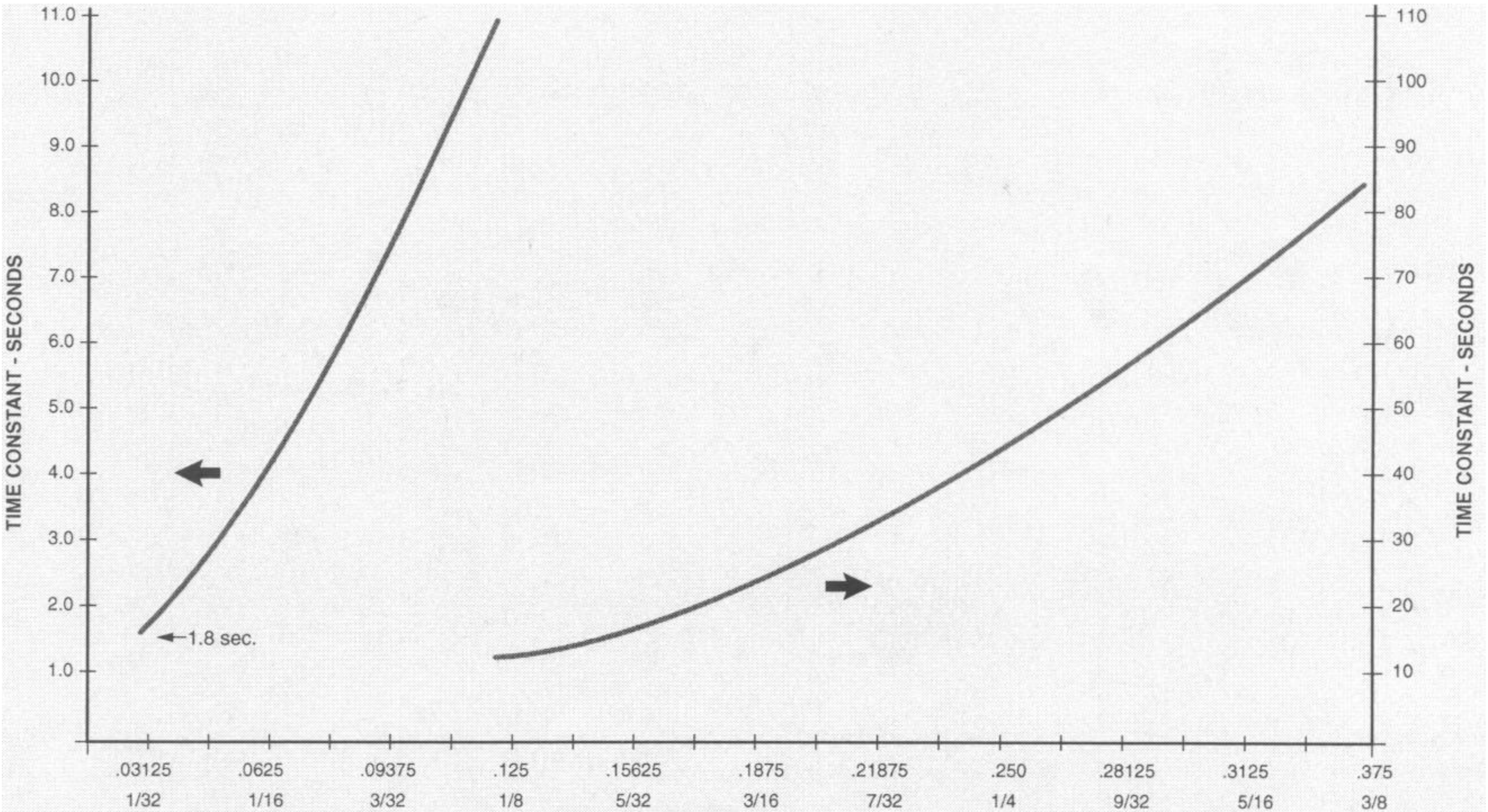
Time Constant vs. Wire Diameter, cont.



Thermocouple Types

Thermocouple Types			
Type	Conductor Combination	Temperature Range	
		°F	°C
B	Platinum 30% Rhodium / Platinum 6% Rhodium	2500 to 3100	1370 to 1700
E	Nickel-chromium / Constantan	32 to 1600	0 to 870
J	Iron / Constantan	32 to 1400	0 to 760
K	Nickel-chromium / Nickel-aluminium	32 to 2300	0 to 1260
N	Nicrosil / Nisil	32 to 2300	0 to 1260
R	Platinum 13% Rhodium / Platinum	1600 to 2640	870 to 1450
S	Platinum 10% Rhodium / Platinum	1800 to 2640	980 to 1450
T	Copper / Constantan	[illegible]	[illegible]

Thermocouple Types

- Type B – very poor below 50 ºC; reference junction temperature not important since voltage output is about the same from 0 to 42 ºC
- Type E – good for low temperatures since dV/dT (a) is high for low temperatures
- Type J – cheap because one wire is iron; high sensitivity but also high uncertainty (iron impurities cause inaccuracy)
- Type T – good accuracy but low max temperature (400 ºC); one lead is copper, making connections easier; watch for heat being conducted along the copper wire
- Type K – popular type since it has decent accuracy and a wide temperature range; some instability (drift) over time
- Type N – most stable over time when exposed to elevated temperatures for long periods

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Sheathing

- Sheathing of wires protects them from the environment (fracture, oxidation, etc.) and shields them from electrical interference
- The sheath should extend completely through the medium of interest. Outside the medium of interest it can be reduced.
- Sometimes the bead is exposed and only the wire is covered by the sheath. In harsher environments, the bead is also covered. This will increase the time constant.
- Platinum wires should be sheathed in non-metallic sheaths since they have a problem with metallic vapor diffusion at high temperatures.

Potential Problems

- Poor bead construction
  - Weld changed material characteristics because the weld temp. was too high.
  - Large solder bead with temperature gradient across it
- Decalibration
  - If thermocouples are used for very high or cold temperatures, wire properties can change due to diffusion of insulation or atmosphere particles into the wire, cold-working, or annealing.
  - Inhomogeneities in the wire; these are especially bad in areas with large temperature gradients; esp. common in iron. Metallic sleeving can help reduce their effect on the final temperature reading.

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Potential Problems

- Conduction along the thermocouple wire
  - In areas of large temperature gradient, heat can be conducted along the thermocouple wire, changing the bead temperature.
  - Small diameter wires conduct less of this heat.
  - T-type thermocouples have more of a problem with this than most other types since one of the leads is made of copper which has a high thermal conductivity.
- Inaccurate ice-point

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Potential Problems

- Galvanic Action
  - The dyes in some insulations form an electrolyte in the water. This creates a galvanic action with a resulting emf potentially many times that of the thermocouple. Use an appropriate shield for a wet environment.
  - “T Type” thermocouples have less of a problem with this.