Meteorology 432

Thermometry

Spring 2013

General

- Temperature impacts every day life.
- Errors of 2-3 ºC are not uncommon in many networks.
  - Bank thermometers or Car thermometers.
- Errors of this magnitude are generally acceptable to the general public.
- Errors of just 1 ºC have been shown to be the deciding factor between no storms initiated, and intense storms in mesoscale models (Crook, 1996)
- Errors as small as 0.2 ºC can change prediction of a global climate model, depending on initial conditions (DeFelice, 1998).

Categories

- Temperature sensors are categorized according to the physical principle they use.

- Mechanical (thermo-expansion)
  - Direct indicating instruments
  - Mercury or Alcohol
  - Bi-metallics

- Electronic (thermo-electric)
  - Thermocouples.
  - Electrical resistance.
  - Thermistors.
  - LM35 or similar integrated circuit device.
  - Designed to work with data loggers.

- Sensing can be passive or remote.

Liquid-in-glass thermometer

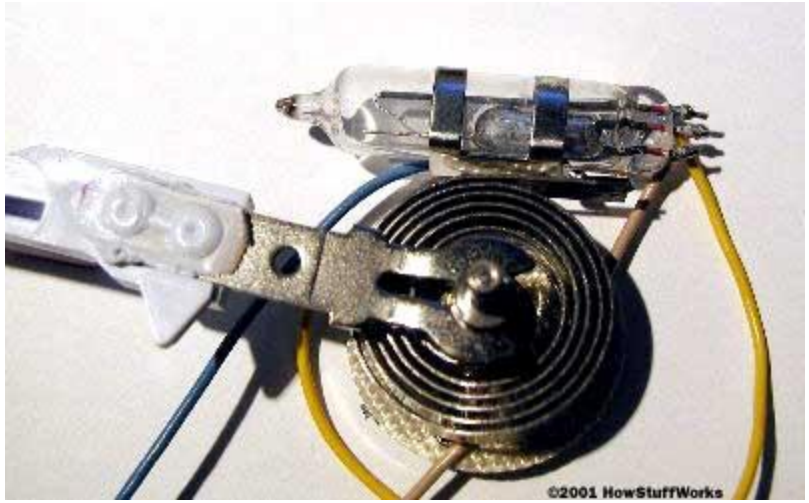
- Glass tube with a bulb at one end filled with liquid and a scale.
  - Usually mercury (-39 ºC freezing point) or alcohol (-62 ºC)
- Raw output is the height of the liquid, h.
- As the temperature increases, both the fluid and the glass expand.

Example

- A mercury-in-glass thermometer has a bulb volume of 150 mm^3 and a capillary tube with a 0.1 mm diameter.
- What is the static sensitivity?
- What is the range of the instrument? What is a reasonable range?

Bi-Metallic Strip

- Pair of metals with different thermal expansion coefficients that are bonded together.
- Temperature at which strip is bonded is the reference temperature of the strip.
- Temperature changes, strip forms an arc.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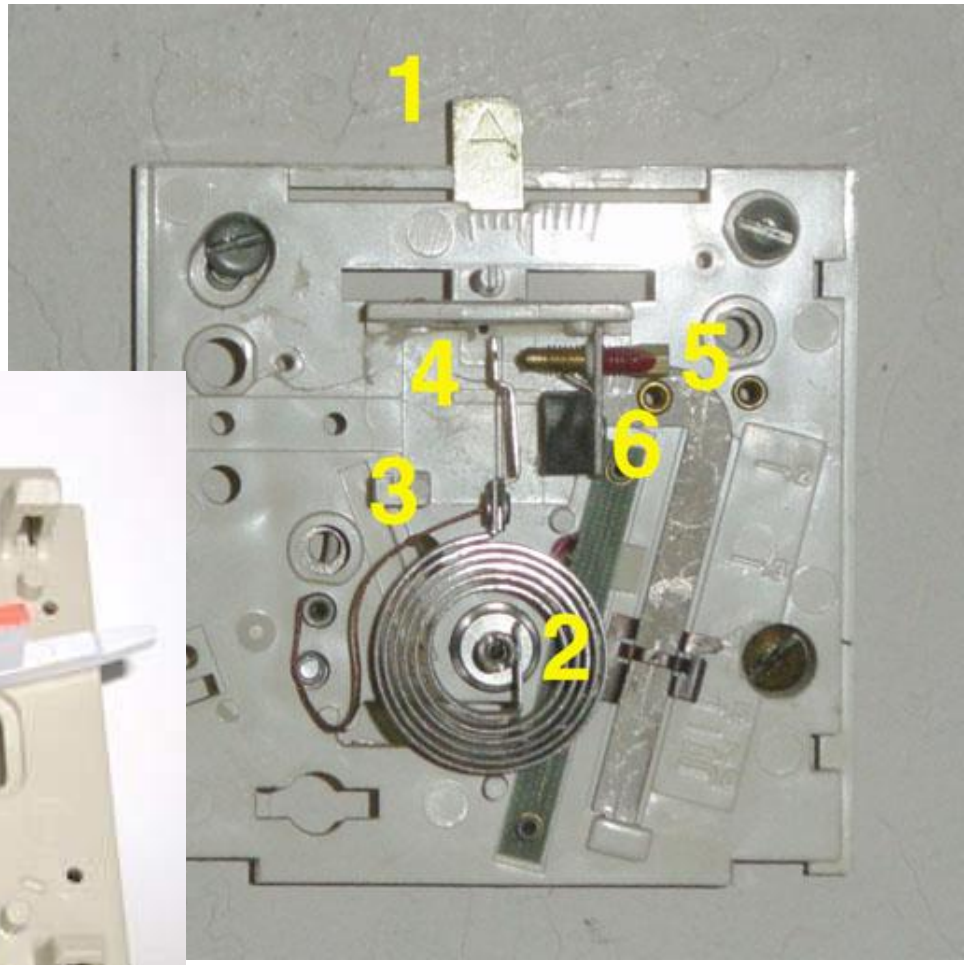
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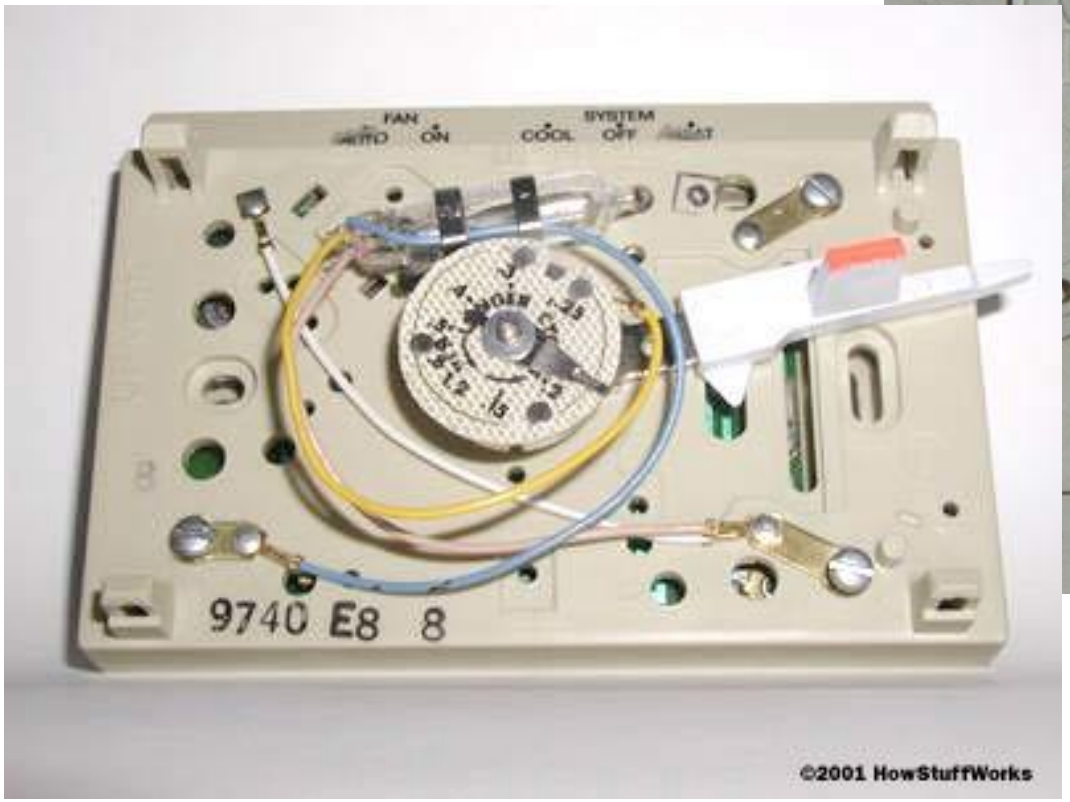
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Thermocouple

- Junction of two dissimilar metals
- Seebeck effect: when the temperature of the two junctions of two dissimilar metals are at different temperatures, a voltage develops between them.
  - Thomas (1821)
- By measuring the voltage difference between the two junctions, the difference in temperature between the junctions can be calculated.
- Alternately, if the temperature of one junction is know and the voltage difference is measured, then the temperature of the second junction can be calculated.
- Want more details? See five “laws of thermocouple behavior” starting on page 67.

Advantages/disadvantages

- Advantages
  - Rugged
  - Reliable
  - Inexpensive

- Disadvantages
  - Very low voltage output (~ 40 μV / ºC) – amplifier needed.
  - Slight non-linearity
  - Need to be calibrated

Key points

- Differential temperature sensor
  - Essentially measures the temperature difference between two junctions.
- Absolute measurements can be made only if one of the junctions is held at a known temperature.
- Typically done with a block of metal
  - Stick reference junction of the thermocouple in the block.
  - Measure the temperature of the block using any appropriate temperature sensor (typically a thermistor).
- Reference junction can also be placed in a block of ice, maintained in an oven, or an electronic reference junction.
- Thermopile: a number of thermocouple connected in series.
  - All junctions are exposed to the same temperature
  - Voltages add up allowing for a large voltage.

Electrical Resistance Sensors

- Resistance varies as a function of temperature.
- Conductive sensors ≡ Resistance Temperature Detectors
  - RTD’s
- Thermistors

RTD's

- Platinum is most common
  - Stable, Resists corrosion, High melting point
  - Simple resistance-temperature relationship

- $R_T = R_o (1 + aT + bT^2)$
  - Sufficient accuracy from -50 ºC to 50 ºC.
  - R_o = resistance at 0 ºC.
  - Coefficients a and b depend on purity of platinum.

- What if b is small?

- Resistance is converted to a voltage.

RTD

The 43347 probe connects to two differential channels and an excitation channel on the datalogger.

Gill Plate Aspiration

FIGURE 3-3. 41003-5 Radiation Shield Mounted to Tripod Mast

Compact Fan Aspiration

RTD Problem

- Self-heating.

- Measurement of resistance typically involves the passage of electrical current.
  - Heats RTD.

- Each RTD comes with a heating specification, or how much power it generates at a given temperature and current ($P = I^2 R_T = V_R^2 R_T / (R_T + R_o)^2$)
  - Resulting heating is then calculated from tolerable temperature error.
  - Take self-heating specification (5.9 mW/ºC) and tolerable temperature error 0.1ºC and get an upper limit of V_R

Thermistors

- Temperature sensitive semiconductors
  - Typically metallic oxides.
- Large and significantly non-linear temperature sensitivity.
- Transfer equation.
  - Most have decreasing sensitivity with increasing temperature.
- Despite their nonlinearity, thermistors are used in a wide variety of applications.
- High resistance (compared to RTD’s)
  - Lead wires

Thermistor

Exposure

- What processes or types of exposure errors is a temperature sensor (without a shelter) exposed to?

- Conduction

- Convection

- Radiation

Reducing Exposure

- Completely isolate the instrument from the atmosphere.
- Conduction: non-heat conductive mounting bracket.
- Convection: Shelter that isolates it from the air flow.
- Radiation: Highly reflective shelter.
- Sensor still needs to be in contact with what you are measuring, i.e., the atmosphere.

No win situation

- If snow is present (or other highly reflective ground surface), the exposure errors will increase.

- Exposure errors are always excluded from laboratory calibrations, so manufacturer performance specifications are not necessarily a good prediction of actual field performance.