Lecture 6
Chapter 6 Temperature

By Hung Nguyen
Maritime Engineering and Hydrodynamics

Chapter 6

- Learning Outcomes
  - pp. 6-3
- Contents:
  - Basic theory
  - Liquid in glass thermometers
  - Filled-system thermometers
  - Bi-metallic thermometers
  - ***Thermocoupes***
  - Resistance: ***RTDs*** and Thermistors
  - Pyrometers (optical and infra-red)

Temperature

- **Basic theory:**
  - Physical variable: Temperature is referred to the "hotness" and the "coldness" of a body
  - Units/Scales: Celsius degree (°C), (SI) Kelvin (K), and Fahrenheit (°F)
  - Relationships:

Celcius - Kelvin $K = C + 273.15$

Celcius - Fahrenheit $F = \frac{9}{5}C + 32$

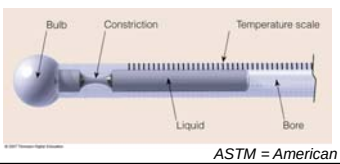
Fahrenheit – Celcius $C = \frac{5}{9}(F - 32)$

Temperature

- **Basic Theory:**
  - Measurement of temperature does not take place directly.
  - Effects of temperature: expansion, thermal conduction, convection and radiation
  - Common methods: expansion, electrical and radiation
- Common temperature instruments: *liquid in glass thermometers*, *filled-system thermometers*, *bi-metallic thermometers*, ***thermocouples***, resistance thermometers (***RDT***, thermistors) and *pyrometers*

Temperature

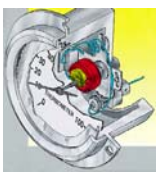
- Liquid-in-glass thermometers:
  - Principle: expansion of fluids (mercury Hg, alcohol)
  - Range: depends on fluids & gas at high pressure
    - Mercury: -30°C to 600°C
    - Alcohol: -80°C to 70°C



ASTM = American Society for Testing and Materials

Temperature

- Filled-system thermometers:
  - Principle: liquid, vapour or gas filled types
  - Construction: bulb, connecting capillary and a Bourdon tube mechanism



Temperature

- Bi-metallic thermometers:
  - Differential expansion of two different materials rigidly joined together

Temperature

- Thermocouples: emf generated if two end junctions at different temperatures

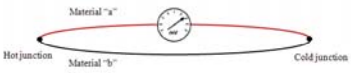
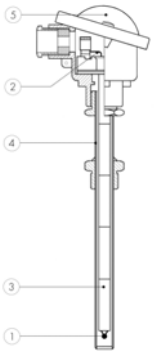


Figure 2.5 A simple thermocouple

Construction

1: Measuring junction
2: Thermocouple wires
3: Ceramic insulators
4: Protective sheath
5: Connection head



Temperature

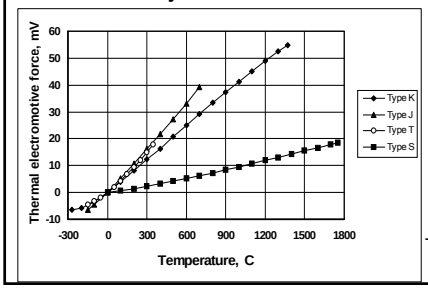
- Thermocouples: different types

Type	Materials	Max. Range (°C)
T	Copper (+) / Constantan (—)	-270 to + 400
E	Chromel (+) I Constantan (—)	-270 to + 1000
J	Iron (+) I Constantan (—)	-210 to +850
K	Chromel (+) / Alumel (—) [also known as T1/T2]	-270 to + 1370
S	Platinum-10% Rhodium (+) I Platinum (-.)	-50 to +1760
R	Platinum-13% Rhodium (+) / Platinum (—)	-50 to +1760
B	Plat.-30% Rhodium (+) / Plat.-6% Rhodium (—)	-50 to +1 820

Temperature

- Thermocouples: sensitivity

$$K = \frac{\text{change in output}}{\text{change in input}}$$



- **Example 1**

Thermocouple Tables

Temperature

- Thermocouples:
  - Compensating (extension) leads
  - Cold conjunction compensation
  - Basic thermocouple circuit

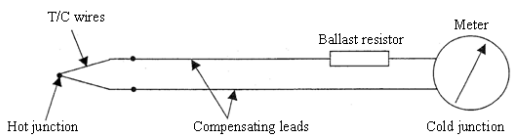


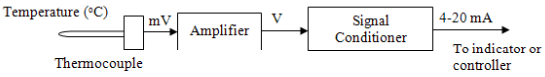
Figure 6 An illustration of basic thermocouple circuit

Temperature

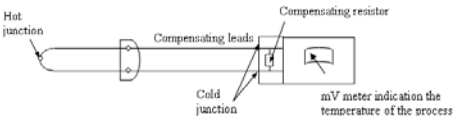
- Thermocouples: Use of thermocouple tables
  - **Example 2**
  - **Example 3**

Temperature

- Thermocouples:
  - Thermocouple interfacing



  - A mVmeter: indication



Chapter 6

- Thermocouples: interfacing

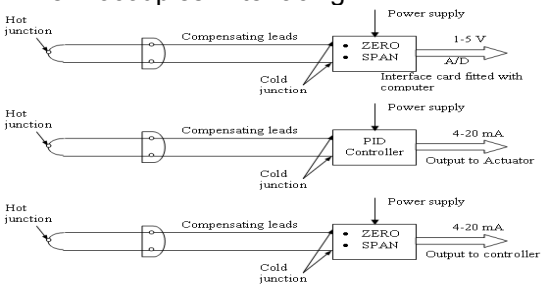


Figure 8 Thermocouple interfacing to other devices

Chapter 6

- Thermocouples
  - K-type:
    - Multimeter
    - PC + USB 6009 (LabVIEW)

Temperature

- **Theory of RTD:**
  - Resistance at temperature T

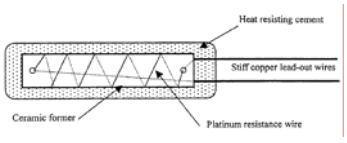
$$R_T = R_0\left[1+\alpha T+\beta T^2\right]$$

  - For a limited range of temperature

$$R_T = R_0\left[1+\alpha T\right]$$

Chapter 6

- **RTD:**
- construction



Temperature

- **RTD:**
  - Platinum RTD 100 (data sheet)
  - **Example 4: pp. 6-13**
  - Three-wire system:

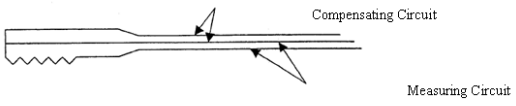


Figure 11 Three-wire system

Temperature

- RTD:
  - Measuring system

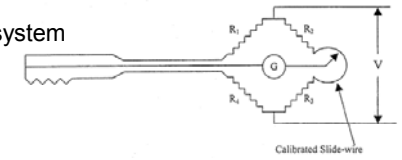


Fig. 12 Null balance system with Wheatstone bridge

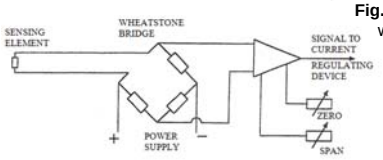
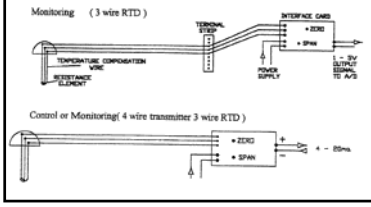


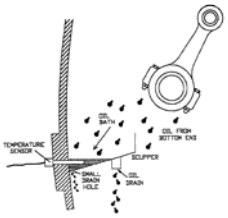
Fig. 13 An electronic resistance thermometer

Temperature

- RTD:
  - RTD interfacing (to indicator, recorder or controller or PCs)



- RTD:
  - An example of RTD application



Chapter 6

- Thermocouples: Activities
  - **Activity 1:** Determine the 'Sensitivity' of a 'J-type' thermocouple in the range of 0ºC to 100ºC and compare it with the 'Sensitivity' of a 'J-type' thermocouple in the range of 100ºC to 200ºC.
  - **Activity 2:** Determine the 'Sensitivity' of a 'T-type' thermocouple in the range of 0°C to 100°C and compare it with the 'Sensitivity' of a 'T-type' thermocouple in the range of 100°C to 200°C.

Chapter 6

- Thermocouple: Activities
- **Activity 3:** Plot a graph of output in millivolts against temperature, for a 'J-type' thermocouple which has its cold junction maintained at 0°C.
  - On the same graph, plot a graph of output in millivolts against temperature, for a 'J-type' thermocouple which has its cold junction maintained at 20°C.

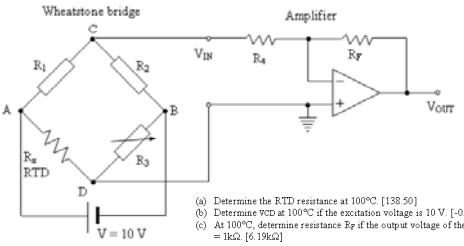
Temperature

- RTD: Activities
  - **Activity 4:** An RTD-100 Platinum resistance thermometer is tested at a temperature of 160ºC and found to have a resistance of 162.1 Ω. Determine the temperature being measured at a time when the resistance of this thermometer is 150 Ω.

Chapter 6

- RTD: Activities
- Activity 5

The following figure shows an amplifying circuit for a temperature measuring system (transmitter) employing an RTD to measure temperature in range of 0ºC to 100ºC. The RTD has a resistance of $R_\alpha = 100\Omega$, and $\alpha = 0.00385$ /ºC (at 0ºC), $R_1 = R_2 = 100\Omega$ and R_3 is a variable resistor used to null the bridge at 0ºC.



(a) Determine the RTD resistance at 100ºC. [138.50]
(b) Determine VCD at 100 ºC if the excitation voltage is 10 V. [-0.80712 V]
(c) At 100ºC, determine resistance RF if the output voltage of the amplifier is 5 V and R_4 = 1kΩ. [6.19kΩ]

Temperature

- Summary of temperature measurement:
  - Common methods: expansion, electrical and radiation
  - Common temperature instruments:
    - liquid in glass thermometers
    - filled-system thermometers
    - bi-metallic thermometers
    - ***thermocouples***
    - ***RTDs: resistance temperature detectors***
  - Applications: indication and control of temperature

Any Questions?