

CH0302 Process Instrumentation


Lecture 6 – Temperature Measurements



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Introduction – Temperature Measurements

 Thermal Expansion

 Thermoelectric

 Resistance

 Radiation


Introduction – Temperature Measurements

- Temperature
- Temperature scale
- Temperature Measurement instruments

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- Temperature
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Introduction – Temperature Measurements Instruments

 Thermal Expansion

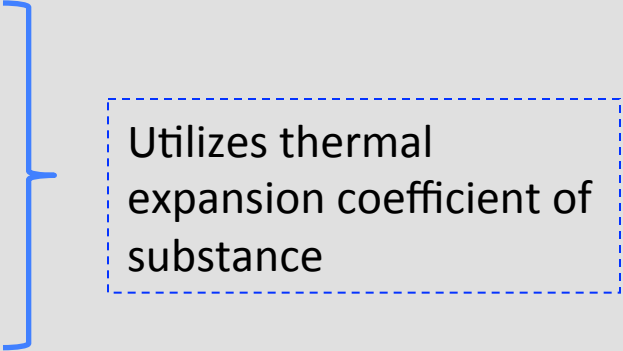
 Thermoelectric

 Resistance

 Radiation

Introduction – Thermal Expansion type

- Constant Volume gas thermometers
- Mercury in glass thermometers
- Bi metal thermometers
- Pressure spring thermometers




Utilizes thermal expansion coefficient of substance

The temperature range between -459.7°F and 212°F
i.e. -273.2°C and 100°C

Thermocouples

- Copper – Constantan
- Iron - Constantan
- Chromel – Constantan
- Platinum – Rhodium



Uses the e.m.f. generated in a wire the temperature difference between the ends of the wire

The temperature range between -300°F and 3000°F
i.e. -184.4°C and 1648.8°C

Resistance Thermometers

- Simple wheat stone bridge circuit
- Double slide wire bridge circuit
- Capacitance bridge
- Null bridge and deflection type

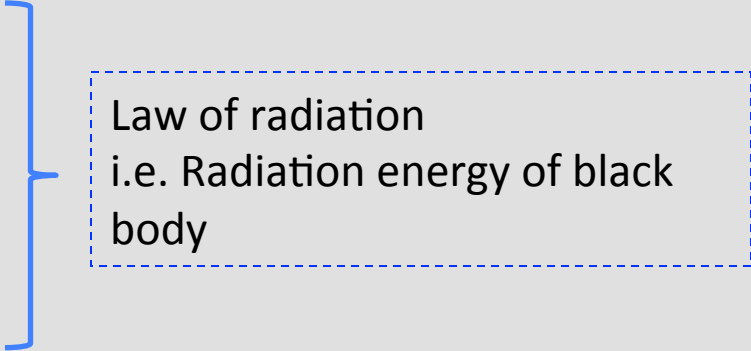
Change in electrical resistance is used of a substance with temperature

The temperature range between i.e. - 190 °C and 660 °C

Introduction – Radiation type

Radiation Thermometers

- Lens type
- Mirror type
- Photo electric type
- Optical pyrometers



Law of radiation
i.e. Radiation energy of black
body

The temperature range between -200°F and 2000°F
i.e. -93°C and 1100°C

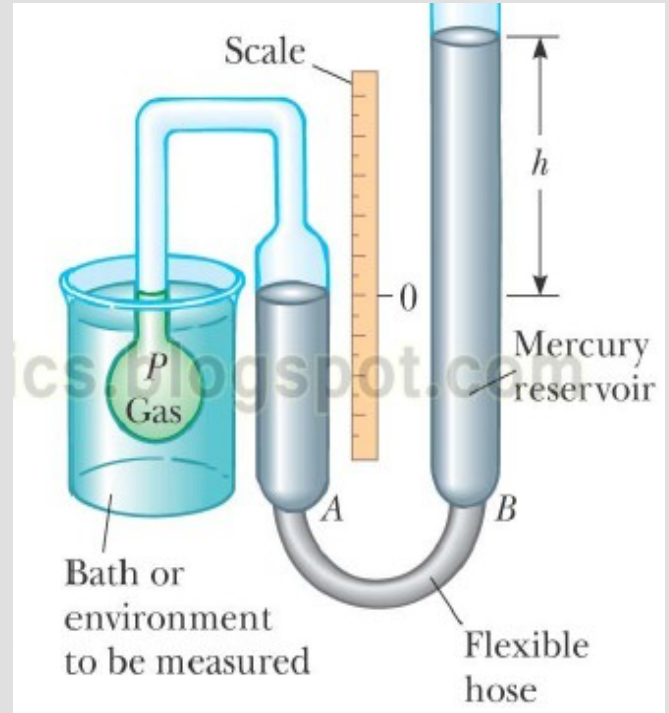
Introduction – Thermal Expansion Type

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- Bi metal thermometers
- Pressure spring thermometers

Thermal Expansion type

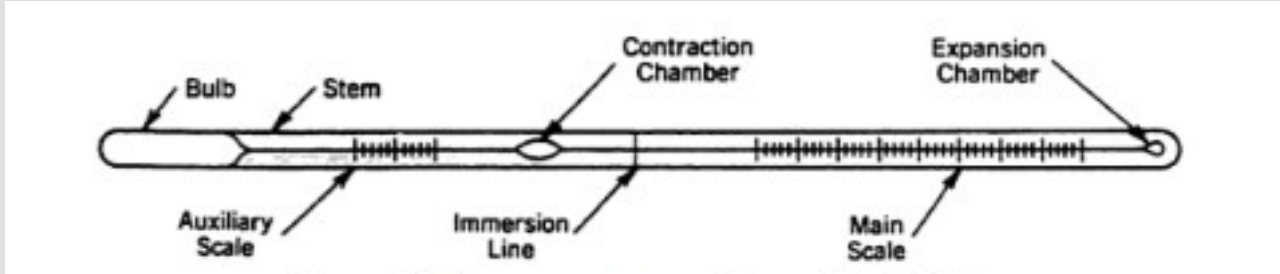
Constant Volume gas thermometers

- Widely used in laboratories for comparison calibration of other thermometers.
- the gas is maintained at constant volume and by ideal gas law, the pressure is directly proportional to the temperature.
- the pressure reading of the thermometer can be related to ideal thermodynamic temperature scale.
- the gases used in this type thermometer are
- helium, hydrogen and nitrogen.

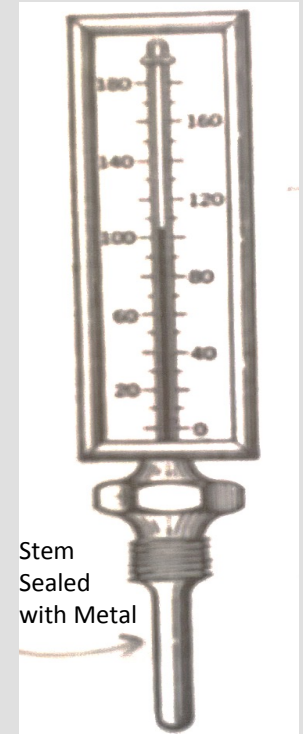


Thermal Expansion type

Mercury-in-glass thermometer



Ordinary Mercury-in-glass thermometer

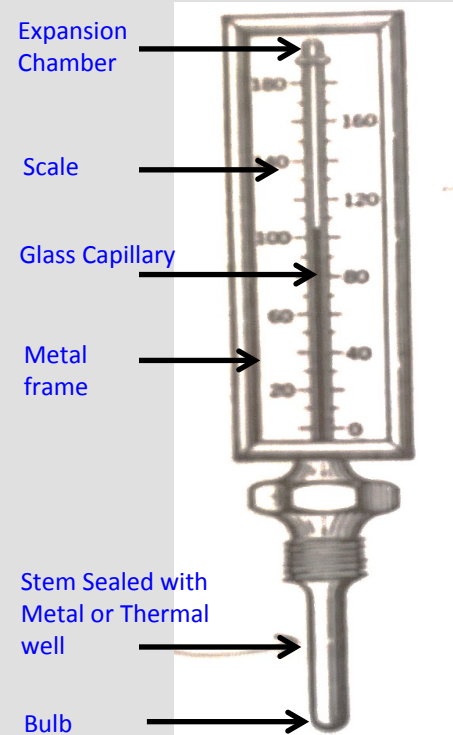


A typical industrial thermometer

Thermal Expansion type – A typical Industrial thermometer

Bimetallic thermometer (Constructional Features)

Parts	Function
Bulb	It is the liquid (Hg) reservoir. The liquid in this reservoir expands or contracts in volume
Thermal well	Thermal well is provided for the purpose of preventing breakage and providing a sealing means at the point of installation
Metal frame	Metal frame provides the complete protection for the thermometer
Glass capillary or Envelope	Glass tube containing a tiny capillary connected to the bulb. The change in volume of the liquid in the bulb causes liquid to expand or contract in the capillary
Scale	Graduated region to read degrees of temperature Metal scale provides the complete protection for the thermometer
Expansion chamber or reservoir	To protect the mercury when it is subjected to over range of temperatures.

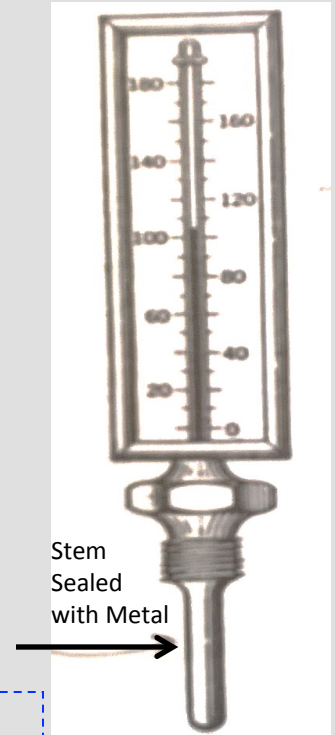


Thermal Expansion type

Working Principle

- As the **heat** is transferred through the **metal stem and into the mercury**, the **mercury expands pushing the column higher in the capillary**.
- That is, **first** the **glass envelope** of the thermometer **expands and contracts** with **temperature changes**. This **changes the volume** of the **mercury** inside the thermometer.
- **Second**, the **coefficient of cubical expansion** for mercury **varies with temperature**.
- **Third**, As the mercury expands past the highest calibrated point, it slowly fills in a small reservoir at the top where **dry nitrogen** is filled in to elevate the **boiling point** of the mercury **when the thermometer is used at higher temperature**.

Note: Boiling point of commonly used thermometer is about 357°C .

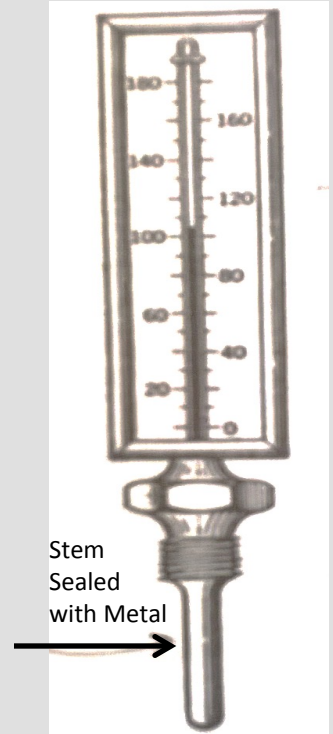


A typical industrial thermometer

Thermal Expansion type

- The **time constant** of the industrial thermometer response will range from **0.01 min to 1 min** depending upon the conditions of use.
- **Ethyl alcohol, pentane and toluene** are some of the other medias as mercury used in thermometers to measure the temperature
- The industrial applications :
 - (i) **Cooking kettles**
 - (ii) **Molten metals**
 - (iii) **Steam lines**
 - (iv) **Air ducts**
 - (v) **Pipe lines** for fluid flow and so on

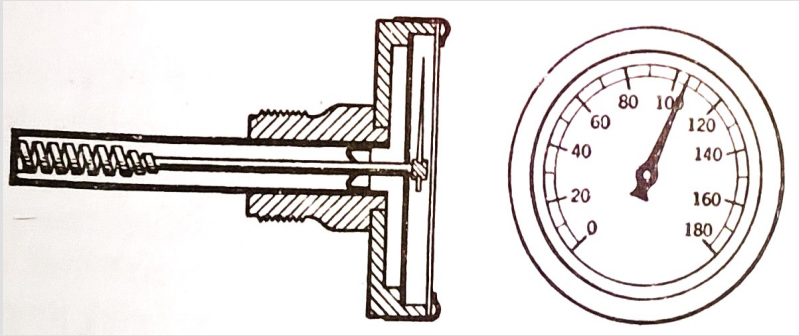
Note: The accuracy of the industrial thermometer, when properly installed and used, is about ± 1 percent



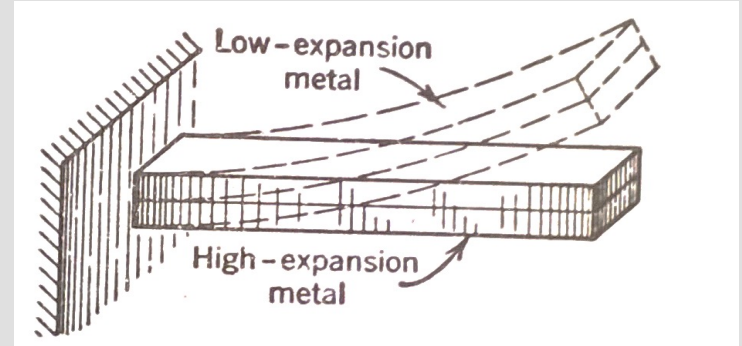
A typical industrial thermometer

Thermal Expansion type

Bimetallic Thermometer



Front cut sectional view



Bimetallic strip

Thermal Expansion type

- A **bimetal** is composed of **two strips of metal** welded or fused together, each **strip is made from metal** having a **different coefficient of thermal expansion**.
- **Invar** is universally employed as the low expansion metal
- **Brass** is widely used as the high expansion metal
- Invar is an **iron-nickel** alloy containing about 36% of nickel

Various Values of Thermal coefficient (α)

$10^{-6}/^{\circ}\text{C}$

Copper

17

Brass

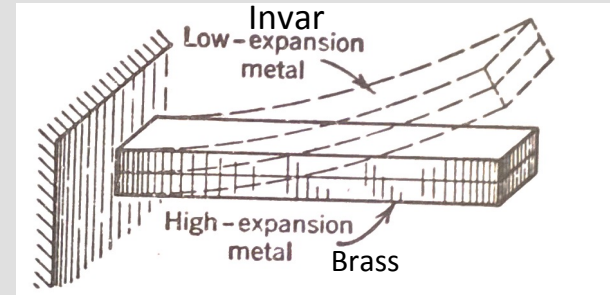
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Invar

0.9

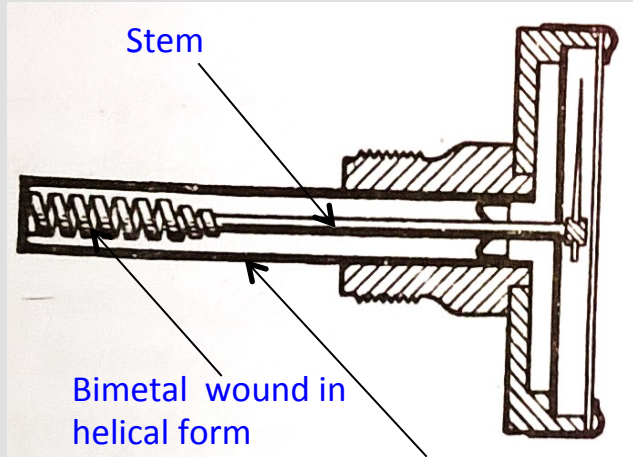
Steel

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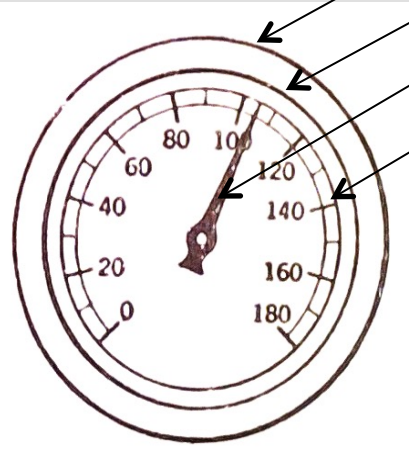


Introduction – Thermal Expansion type

Bimetallic Thermometer (Construction)



Cut sectional view



Front View

- Metal Case
- Glass Dial
- Pointer
- Scale

Introduction – Thermal Expansion type

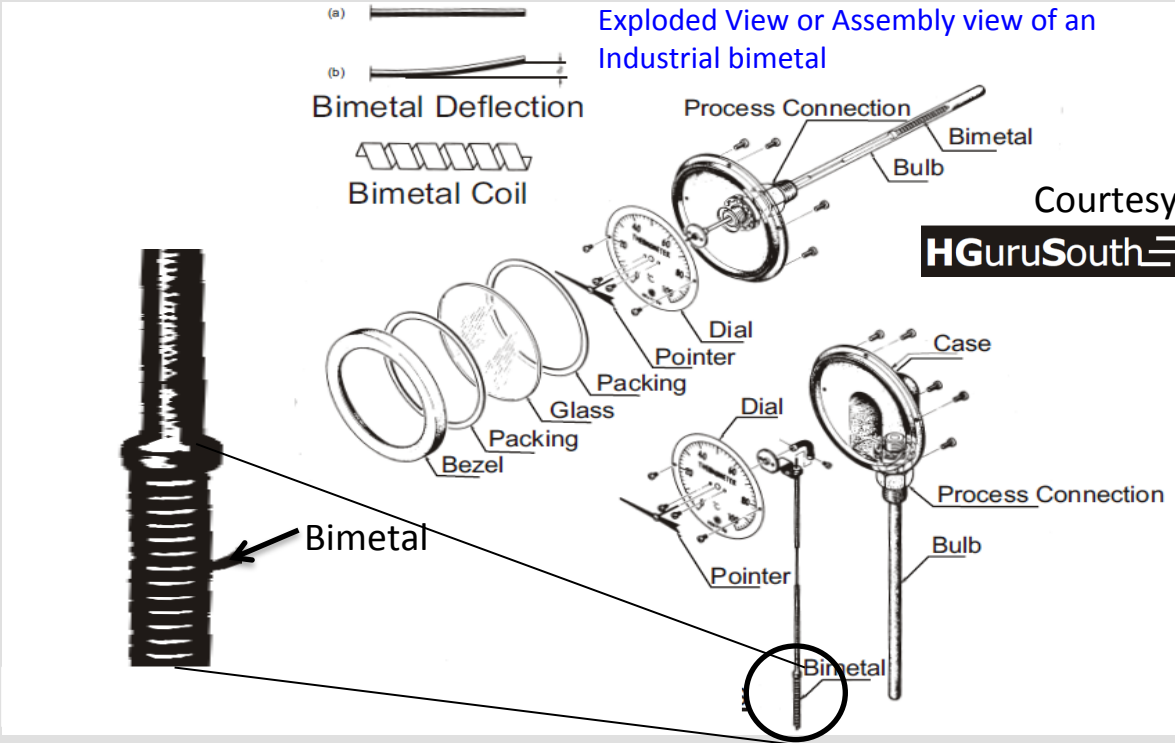
Parts	Functions
Metal Case/ Frame with glass	Provides the complete protection for the thermometer from temperature, humidity and vibrations.
Glass Dial	Provides a controlled interface between the scale and metal frame
Pointer	Deflects and indicates the temperature scale.
Scale	Graduated region to read degrees of temperature usually in the eccentric style.
Stem	Connects the bimetal and the pointer and serves as the manipulating element
Helical Coil	Primary element that utilizes the heat energy to expands and contract
Thermal Well	Thermal well is provided for the purpose of preventing corrosion, breakage and providing a sealing means at the point of installation

Introduction – Thermal Expansion type

Working Principle

- In industrial bimetallic thermometer, bimetal is wound in the form of a helix or spiral with one end fastened permanently to the outer casing and the other end is connected to the pointer.
- The pointer is attached to the upper end of the stem and rotates (or sweeps) over a circular dial to indicate the temperature.
- When the temperature surrounding the whole stem changes, the bimetal expands and rotates at its free end, thus turning inside the stem and the pointer to a new position on the dial .
- The thermal well made up of brass, steel or stainless steel may be used to protect the thermometer against corrosion and breakage

Thermal Expansion type



1. Donald P. Eckman, (2004) *Industrial Instrumentation*, CBS Publishers, Pp. 1- 27.

Thank You