Exposure of Temperature Sensors

Dr. Christopher M. Godfrey
University of North Carolina at Asheville

Exposure and atmospheric coupling

- There are two important questions regarding the exposure of any sensor to the atmosphere:
  - What do we want the sensor to measure?
  - What is the sensor really measuring?
- We want the temperature sensor to be in equilibrium with the atmosphere
  - Quickly and under rapidly changing conditions

Significant coupling errors

- There are at least three errors associated with the placement of the sensor in the atmosphere:
  - Radiation errors (most important)
  - Conduction errors (usually a bad effect)
  - Wind speed errors (i.e., convection/air flow over the sensor; usually a good effect)

Significant coupling errors

- For accurate temperature measurements, the sensor must be in good thermal contact with the air, which requires:
  - Air circulation to promote heat transfer by convection (but not too much air or else we can get wind speed errors due to friction!)
  - Protection from conductive heat flow along the mechanical sensor support
    - Solution: Use mounting brackets that are good insulators
  - Protection from radiative heat transfer
    - Solution: Use a small sensor with a high reflectivity

Conduction Errors

- Thermal energy is conducted to or from the sensor
- Conduction paths:
  - Electrical lead wires
  - Sensor support structures
  - Protective shells around the sensor

Radiation Errors

- Most important factor in temperature measurements
- Types of radiation to worry about
  - Direct solar radiation
  - Reflected solar radiation (diffuse)
  - Emitted IR radiation
  - Reflected IR radiation
- We use radiation shields to reduce these errors

Radiation Shields

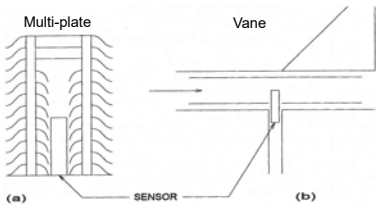
- Two basic types of radiation shields:
  - Aspirated
  - Unaspirated
- Aspirated shields
  - Force air to move over the sensor
  - WMO recommends a wind flow of 2.5 m s^{-1}
- Unaspirated shields
  - Assume that the ambient wind maintains the sensor at the air temperature

Radiation Shields–Stevenson Screen

Source: http://www.fairmountweather.com/products_bottom.php?cat=5&pid=36

Source: http://www.bom.gov.au/weather/qld/townsville/photos.shtml

Radiation Shields–Multi-Plate and Vane



Radiation Shields–Multi-Plate

Photo: C. Godfrey

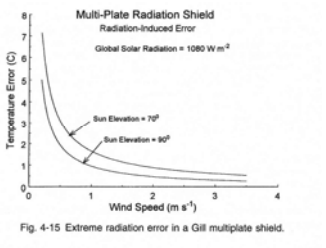


Fig. 4-15 Extreme radiation error in a Gill multiplate shield.

- In this example:
  - Maximum solar radiation
  - Light winds
  - Over snow

Aspirated Radiation Shields

Photo: C. Godfrey

Source: NWS

Advantages and Disadvantages of Radiation Shields

- Aspirated
  - Expensive
  - High power consumption (not a problem where AC is available)
  - May be the most effective method of aspiration
- Unaspirated
  - Low cost
  - Zero power consumption
  - May induce large temperature errors
- No radiation shield
  - Very low cost
  - Zero power consumption
  - Precipitation effects (measures wet-bulb temperature when wet)
  - Reflectivity degrades with time
  - Sensor is typically small and fragile