Calibration Checks of Dry- and Wet-Bulbs
Observations From Kiln Audits

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New England Kiln Drying Association
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Presentation Plan

1) Types of temperature sensors in kilns

2) Results of calibration checks from kiln audits

3) Calibration checks methods

4) Conclusions
Main types of temperature probes in kilns

1) Dry-Bulb Temperature
   ▫ Resistance Temperature Device (RTD) Sensors
   ▫ Transistor Sensors

2) Air Humidity
   ▫ Dry- and Wet-Bulbs Psychrometer
   ▫ Electronic Dry- and Wet-Bulbs or Electronic RH Sensors
   ▫ Paper Wafer Electric Resistance Sensors
Dry-Bulb Temperature Sensors

1) RTD Sensors

- RTD = «Resistance Temperature Device»
- Based on the fact that the electrical resistance of platinum is dependent of its temperature
Dry-Bulb Temperature Sensors

2) Transistor Sensors

- Used mainly by European kiln controllers
  - At constant current, the voltage measurement is a linear function of the temperature
  - Advantage of being simple to manufacture and implement, inexpensive and very linear
  - Correct measurement range for kilns (-50 °C, 150 °C)
Air Humidity Sensors

1) Dry- and Wet-Bulbs Psychrometer
   - Wet-Bulb Temperature
     - It is defined as the air temperature obtained by any temperature measuring device whose sensitive portion is kept wet by means of a cotton wick soaking in water the whole being placed in a stream of air

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Air Humidity Sensors

1) Dry- and Wet-Bulbs Psychrometer

- The temperature difference between the dry bulb and wet bulb thermometers is a function of air relative humidity
Air Humidity Sensors

2) Electronic Dry- and Wet-Bulbs Temperature Sensors

- VAISALA brand are the most used for dry kilns
- Doesn’t require water in the kiln
- Expensive
Air Humidity Sensors

3) Paper Wafer Electrical Resistance

- Used mainly by European kiln controllers
  - The paper wafer absorbs or releases moisture depending on the humidity of the air
  - The electrical conductivity of the paper varies according to its moisture
  - Does not require water in the kiln
Presentation Plan

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FPInnovations Kiln Audit Program

- Standardized Audits (Keep It Simple and Short)

1. Kiln Tightness
2. Mechanical Components
3. Controller (calibration check)
4. Airflow
5. Temperature Distribution
Results from Kiln Audits

1) Example of Dry-Bulb Sensors Calibration Check
Results from Kiln Audits

1) Example of Dry-Bulb Sensors Calibration Check
Results from Kiln Audits

1) Example of Dry-Bulb Sensors Calibration Check
Results from Kiln Audits

1) Example of Wet-Bulb Sensors Calibration Check
Results from Kiln Audits

1) RTD Sensors

- PT100
  - PT = Platinum (most linear, stable, repetitive et precise)
  - 100 = Electrical resistance value in ohms at 0°C

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Tolerance Class B</th>
<th>Tolerance Class A</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°C (32°F)</td>
<td>±0.3°C (±0.5°F)</td>
<td>±0.15°C (±0.3°F)</td>
</tr>
<tr>
<td>100°C (200°F)</td>
<td>±0.8°C (±1.4°F)</td>
<td>±0.35°C (±0.6°F)</td>
</tr>
</tbody>
</table>
Results from Kiln Audits

- RTD Sensors

![Diagram showing frequency of reading offsets for RTD probes]

- Faster Drying (more heating): 64%
- Slower Drying (less heating): 4%
- 32% of probes fall within the range of -10 to -5°F.
Calibration Checks

1) RTD Sensors

a) Ice Water and Boiling Water Method
   - Only the sensing part of the probe is heated

Laboratory method, hard to do in a dry kiln!

Necessary equipment:
- Hot plate
- Agitator
- Reference thermometer
Calibration Checks

1) RTD Sensors
   
   b) Hot water in a insulated bottle
      
      ▪ Only the sensing part of the probe is heated

   Necessary equipment:
   - Insulated bottle
   - Reference thermometer (calibrated) to tell water temperature in the bottle
Calibration Checks

1) RTD Sensors
   
c) RTD dry-wells
     - Only the sensing part of the probe is heated
Calibration Checks

1) RTD Sensors

d) In operation with a thermocouple
   • Allows to check the cable and junctions

Make sure your thermocouple meter has been calibrated lately!
Results from Kiln Audits

- Transistor Sensors

<table>
<thead>
<tr>
<th>Reading offset (°F)</th>
<th>Frequency (# of probes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; -10</td>
<td>2</td>
</tr>
<tr>
<td>-9</td>
<td>1</td>
</tr>
<tr>
<td>-8</td>
<td>1</td>
</tr>
<tr>
<td>-7</td>
<td>1</td>
</tr>
<tr>
<td>-6</td>
<td>2</td>
</tr>
<tr>
<td>-5</td>
<td>2</td>
</tr>
<tr>
<td>-4</td>
<td>2</td>
</tr>
<tr>
<td>-3</td>
<td>1</td>
</tr>
<tr>
<td>-2</td>
<td>1</td>
</tr>
<tr>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>&gt;= 10</td>
<td>2</td>
</tr>
</tbody>
</table>

- 27% Faster Drying (more heating)
- 65% Slower Drying (less heating)
- 8%
Calibration Checks

2) Transistor Sensors

a) In operation with a thermocouple
   - Allows to check the cable and junctions
   - Hard to reach adjustment potentiometer

Make sure your thermocouple meter has been calibrated lately!
Results from Kiln Audits

- Wet-bulb using a RTD and a wick

![Graph showing frequency of reading offsets for RTDs with wicks, indicating percentages of slower and faster drying conditions.](image)
Calibration Checks

1) Wet-bulbs using a RTD and a wick
   a) Same methods dry-bulb RTD can be used if you remove the wick
   b) In operation a portable wet-bulb
      o Allows to check the cable and junctions
      o Allows to check water and wick
Calibration Checks

1) Wet-bulbs using a RTD and a wick

   b) In operation with a portable wet-bulb
Results from Kiln Audits

- Electronic Wet-Bulbs

![Bar Graph showing frequency of readings]

- **20** Electronic Wet-Bulbs

- **Frequency (# of probes):**
  - Slower Drying (less venting)
    - 20%
  - Faster Drying (more venting)
    - 75%
  - 5%

- **Reading offset (°F):**
  - <=-10
  - -9
  - -8
  - -7
  - -6
  - -5
  - -4
  - -3
  - -2
  - -1
  - 0
  - 1
  - 2
  - 3
  - 4
  - 5
  - 6
  - 7
  - 8
  - 9
  - >=10
Calibration Checks

2) Electronic Wet-Bulbs

a) In operation with a portable wet-bulb
   - Allows to check the cable and junctions
   - If readings are not acceptable, the probe must be send to the supplier for calibration = expensive
Results from Kiln Audits

- Paper Wafer Electrical Resistance

![Bar Chart]

- 20 Paper Wafer Sensors
  - Slower Drying (less venting): 63%
  - Faster Drying (more venting): 33%
  - 4%
Results from Kiln Audits

- Impact on wet-bulb temperature of the variation of EMC of 1%

<table>
<thead>
<tr>
<th>Dry-Bulb (°F)</th>
<th>Wet-Bulb (°F)</th>
<th>Depression (°F)</th>
<th>Equilibrium MC (%EMC)</th>
<th>Variation of Wet-Bulb Temperature in Function of EMC</th>
</tr>
</thead>
<tbody>
<tr>
<td>190</td>
<td>186</td>
<td>4</td>
<td>16.0</td>
<td>1°F / %HE</td>
</tr>
<tr>
<td>190</td>
<td>180</td>
<td>10</td>
<td>11.0</td>
<td>2°F / %HE</td>
</tr>
<tr>
<td>190</td>
<td>174</td>
<td>16</td>
<td>9.0</td>
<td>4°F / %HE</td>
</tr>
<tr>
<td>190</td>
<td>160</td>
<td>30</td>
<td>6.0</td>
<td>8°F / %HE</td>
</tr>
<tr>
<td>190</td>
<td>135</td>
<td>55</td>
<td>3.0</td>
<td>12°F / %HE</td>
</tr>
</tbody>
</table>
Calibration Checks

3) Paper Wafer Electrical Resistance
   
   a) By applying a known electrical resistance between connectors
      o If readings are not acceptable, the service technician adjust a potentiometer on controller I/O cards
   
   b) In operation with a portable wet-bulb
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Conclusions

- In average, one sensor out of three in a dry kiln is outside its accuracy specification
  - This tells that calibration check frequency and/or calibration check methodology and/or calibration methodology has to be reconsidered by many of you

- Reading Offsets are not normally distributed along Normal Law. Two hypothesis to consider:
  - Aging of sensors, cables, junctions, etc.
  - In operation, it is harder to detect:
    - RTDs, Transistor Sensors or Electronic Wet-Bulbs that under-estimate temperature
    - Paper Wafer Sensors that over-estimate EMC