Measurement Uncertainties of Organic Liquid-in-Glass Thermometers

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Abstract

The National Institute of Standards and Technology (NIST) Industrial Thermometer Calibration Laboratory (ITCL) investigated the viability of organic liquid-in-glass thermometers as possible replacements to mercury liquid-in-glass thermometers.

- mercury is a powerful neurotoxin, both national and international standards and regulations to eliminate mercury from the environment are becoming common
- standards and regulations are making the use and purchase of mercury thermometers for use in the industrial environment problematic
- NIST stopped calibrating mercury thermometers on 01 March 2011

We present the calibration and in-use uncertainties the organic thermometers over the temperature range from –196 °C to 250 °C. Measurements capabilities of the organic thermometers are compared to that of mercury thermometers.

Organic Thermometers Tested

<table>
<thead>
<tr>
<th>Thermometer Type</th>
<th>Graduation Interval</th>
<th>Maximum Range, °C</th>
<th>Number of Thermometers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial</td>
<td>0.5</td>
<td>0 to 250</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>0.2</td>
<td>0 to 100</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>-200 to 210</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>-20 to 500</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>0.2</td>
<td>0 to 100</td>
<td>3</td>
</tr>
</tbody>
</table>

- Pentane-filled total immersion marked –200 °C to 30 °C with 1 °C increments for below 0 °C
- Organic-filled partial and total immersion LIG’s thermometers over the range from –20 °C to 250 °C

Measurement Protocols

Parameters
- Temperature range for Organic LIGs: –196 °C to 250 °C
- 6 measurement cycles

Order of measurement:
- Ice MP, –196 °C to –25 °C, Ice MP, 5 °C to 250 °C, Ice MP

Several inherent limitations of organic LIG thermometers investigated to quantify both the calibration and in-use measurement uncertainties
- Short and long-term repeatability
- Thermal cycling
- Drain time of the fluid in the capillary

Special measurements of pentane-filled LIGs made at –196 °C (LN₂)
- Investigate re-insertion time interval (cryogenic thermal cycling)
- Drain time required for pentane fluid

Measurement Uncertainties of Organic Liquid-in-Glass Thermometers

<table>
<thead>
<tr>
<th>Thermometer Type</th>
<th>Graduation Interval</th>
<th>Range, °C</th>
<th>Organic U (k=2), °C</th>
<th>Mercury U (k=2), °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial</td>
<td>0.5</td>
<td>0 to 250</td>
<td>0.5 to 5.4</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>0.2</td>
<td>0 to 100</td>
<td>0.2 to 1.2</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>-196 to 0</td>
<td>6.4 to 2.0</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>-20 to 50</td>
<td>0.4 to 0.7</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>0.2</td>
<td>0 to 100</td>
<td>0.4 to 0.2</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Future Directions

NIST will explore the measurement uncertainty and feasibility of using hand-held and data-logger digital thermometers as replacements for mercury thermometers

Conclusions

Based on the results of our set of organic LIG thermometers, Organic LIGs are not suitable replacements for mercury LIGs

- Uncertainties
  - Larger than that of Hg
  - Can be expressed with simple linear or quadratic functions
- Corrections are often greater than the graduation interval (scale division)
- Organic fluid wets the column causing fluid to stick to capillary
- Long drain time: 10 min at ≤ –90 °C and 30 min at –196 °C
- Separation of fluid column unpredictable
- Pentane required warming to ambient before re-insertion into ≤ 0 °C environments to achieve repeatable results

A new NIST Temperature and Humidity Group Alternative Thermometer Webpage will act as an information portal for NIST to disseminate scientific-based findings to support the transition away from Hg

Notes and Disclaimer:
- thanks to those companies who donated thermometers (analog and digital) for this work
- any commercial products identified in this poster do not constitute endorsement by NIST