MSL Technical Guide 2

Infrared Thermometry
Ice Point

Introduction and Scope

In recent years, radiation thermometers have become widely used in processing, plant maintenance, and food industries. Their ability to measure temperature without contact has obvious advantages where process materials are moving, or where contamination must be avoided. Like all measuring instruments, radiation thermometers are prone to errors arising from drift with age and accumulated damage. Where measurements are required to satisfy health and safety regulations, such errors can have serious health and safety or economic consequences. This technical guide describes how to make a 0 °C temperature reference using ice, and ensure that your radiation thermometer is operating correctly.

An ice-point check is a simple and effective method to check the operation of any thermometer designed to work near 0 °C. It should be carried out regularly and readings recorded – a sudden change or persistent drift in the ice-point reading is often the first indication of a fault in the instrument.

Emissivity and Blackbodies

All objects emit infrared radiation characterised by intensity and wavelength, which are both temperature dependent. Most handheld low-temperature radiation thermometers operate over a single band, typically near 4 µm, or in the range 8–14 µm. The temperature of an object is found by measuring the intensity of the radiation emitted by the object over this wavelength band.

The ability of objects to emit and absorb infrared radiation is described by a property called emissivity, and many radiation thermometers have an adjustment to compensate for the emissivity of the surface. Values of emissivity range from zero for poorly emitting surfaces, approaching 1.0 for objects that are good emitters of radiation.

Emissivity and reflectivity are complementary properties. Surfaces with a low emissivity are good reflectors of radiation, and vice versa. For opaque objects (non-transparent), the emissivity plus the reflectivity equals 1.0. An object with an emissivity of 0.9 has a reflectivity of 0.1, and therefore reflects 0.1 (10%) of all of the radiation that falls on the surface.

A good temperature reference for radiation thermometers requires a surface with a high emissivity (low reflectivity) maintained at a controlled temperature. Melting ice has both properties.

While ice is transparent at visible wavelengths, at infrared wavelengths longer than about 2 µm, both ice and water become increasingly opaque. At these wavelengths water also has an emissivity of about 0.96. In other words, if we could see in the infrared, ice would appear black.

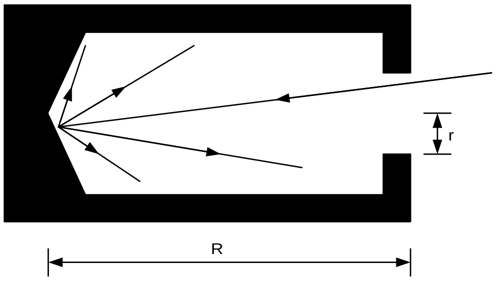

Figure 1. A simple representation of a blackbody cavity. The greater the ratio of the cavity size, *R*, to the aperture, *r*, the greater the emissivity of the cavity.

We can improve the emissivity of objects by making so-called blackbody cavities, as shown in Figure 1. The principle is to make sure any radiation entering the cavity is absorbed; then, since there are no reflections, the emissivity of the cavity must be 1.0. The ideal blackbody cavity is a perfect emitter and absorber of radiation.

The Ice Point

Figure 2 shows the phase diagram for water; this illustrates the different temperatures and pressures where water exists as ice, water, or water vapour. Remarkably, the melting point of water (the boundary between the solid and liquid phases) is very near 0 °C for all normal atmospheric pressures.

In fact, for the normal range of atmospheric pressures, the melting point of pure ice is very near 0.0025 °C. An additional 'error' caused by dissolved gas in the water and ice causes the melting point to be very near 0 °C. Historically, the ice point was the defining point for many temperature scales until the more precise triple-point cells (0.01 °C) were developed. However, the

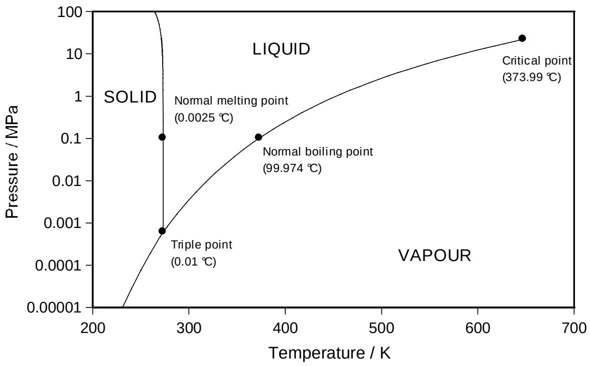

Figure 2. The phase diagram for pure water showing the different temperatures and pressures at which water exists as liquid, solid (ice), and vapour.

ice point still has a major role in thermometry since it is a fixed point that can be readily achieved by any laboratory for minimal outlay of resources. So long as the basic principles described here are followed, it is relatively straightforward to realise a 0 ℃ reference temperature with an accuracy of ±0.1 ℃. or better.

The Equipment

To assemble an ice point for radiation thermometers you will need:

An **insulating container**, such as a vacuum-insulated, expanded polystyrene or yoghurt-making flask of approximately 120 mm to 140 mm in diameter. It should be deep enough so that you can form a hole in the ice with a depth about five times the field of view diameter of the infrared thermometer (see Figure 3). There should be 50 mm to 100 mm extra depth to accumulate melt-water.

A **siphon tube** (see Figure 3) is placed in the flask to enable the removal of excess water, which should be kept to a minimum, as the ice melts. You need to make sure that the water level does not rise above the bottom of the cavity, otherwise the bottom of the cavity may rise above 0 ℃.

Clean, shaved ice that is free of impurities, and ideally made from distilled or de-ionised water. Because freezing is also a purification process, food-grade ice made in freezers that employ a washing process is also satisfactory. Good, clean tap water is often satisfactory but should be avoided as it will occasionally be contaminated or have a high concentration of additives from the water treatment process.

The ice must be shaved or crushed, ideally into small chips using a commercial ice shaver. A low-cost alternative, which is satisfactory for infrequent use, is a food processor with a grating disc. Note that discs with blades or knives are not suitable because they do not cut ice very effectively and the processor will be quickly damaged.

Approximately 300 mL of clean cold water is required. Distilled water or de-ionised water is ideal, as is the melt water from the ice.

The Procedure

First, one-third fill the flask with clean water. Freshly shaved ice is quite often colder than 0 ℃; wetting the ice, however, ensures that it is melting. The difference in the condition of the ice is readily visible since cold ice freezes water vapour from the atmosphere giving it a white frosty appearance. Wet ice has a clear translucent appearance.

Siphon off the excess water and compress the ice to form a tightly packed slush. Then carve or press a cavity into the remaining ice, ensuring that the bottom of the ice cavity is sufficiently wide to fill the entire field of view of the thermometer. The walls of the ice cavity should be rough so that the radiation is scattered randomly inside the cavity to ensure uniformity.

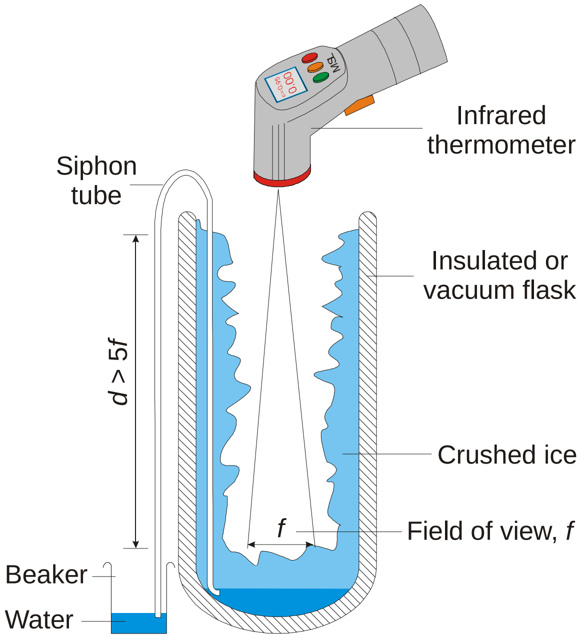

Figure 3. An ice-point blackbody cavity.

Read the thermometer several times at intervals of a few minutes to be sure that the walls of the flask have reached equilibrium with the ice. Note that for radiation thermometers whose emissivity is less than 1.00 (e.g., many thermometers have a fixed emissivity setting of 0.95), the reading when measuring the ice point is not expected to be 0.0 ℃, but rather somewhat less. See MSL Technical Guide 22: “Calibration of Low-Temperature Infrared Thermometers” for a discussion on this, and methods and graphs for determining the expected reading for a given emissivity value.

References

J V Nicholas and D R White, *Traceable Temperatures* Second Edition, John Wiley and Sons, Chichester, 2001.

MSL Technical Guide 1: “The Ice Point”, http://msl.irl.cri.nz.

MSL Technical Guide 22: “Calibration of Low-Temperature Infrared Thermometers”, http://msl.irl.cri.nz.

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