Measurement Standards Laboratory of New Zealand

MSL Technical Guide 44

Shipping Triple Point of Water Cells

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Introduction

Triple-point-of-water (TPW) cells are delicate, glass, water-filled cells used as a temperature reference at 0.01 °C, with uncertainties in the realised temperature that may be less than 30 µK for the best cells. Before May 2019, when the International System of Units (SI) was updated, the triple point of water was used to define the kevin, but now is the main reference point for standard platinum resistance thermometers used to define the ITS-90 temperature scale. Figure 1 shows a cell in its frozen state with all three phases of water – solid, liquid, and vapour – present. See reference [1] for more details on the realisation of ITS-90 and the use of TPW cells.

For verification of cells, or for comparisons and proficiency tests, it is occasionally necessary to ship the cells. If possible, they should be hand-carried in a hard foam lined case, such as a camera case (see Figure 2). However, there are occasions when hand carriage is not warranted or practicable, and in that case, a reliable method of shipment is required. The purpose of this guide is to describe a method of shipment that MSL has found to be reliable. The method is suitable for cells like that shown in Figure 1, where the two seal-off tubes at the top of the cell are relatively short and parallel to the cell axis. The method is not suited to the Jarret-style cells that have a prominent right-angled extension on the cells. The purpose of the extension is to measure the residual air pressure in the cell, in the manner of a McLeod gauge, but looks like a handle.

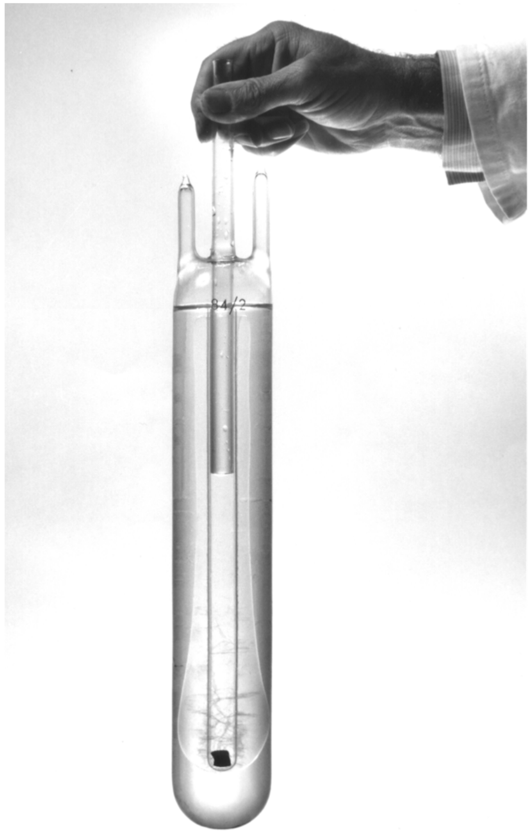

Figure 1. The triple-point-of-water cell in its frozen state ready for use. The ice mantle is just visible around the thermometer well. The thermometer well also contains some water, to improve thermal contact with the thermometer, and a sponge to isolate the thermometer from the cold spot at the bottom of the well.

Figure 2. A pair of cells in a hard camera case. Note that the cells are placed along the vertical and horizontal diagonal to prevent water hammer effects.

Modes of Failure

There are three main modes of breakage for the TPW cells: crushing, water hammer, and lateral or torsional acceleration.

The crushing mode is obvious and occurs when a heavy load is placed on the cell wall or where the seal-off tubes and thermometer well protrude from the cell body.

The water hammer mode occurs when the cell is subjected to rapid axial accelerations, which cause the water to slam hard against the top or bottom of the cell. Because, ideally, all the gas in the cell is just water vapour, there is no air to cushion the impact of the water on the glass. If the water slams into the glass with enough force, it will break the cell.

Finally, there are two situations that may cause the internal section of the thermometer well to break away from the cell body. This occurs with rapid lateral acceleration, and with rapid rotational accelerations around axes at right angles to the axis of the cell.

The Cell Carrier

Figures 3 and 4 show the components and assembly of the TPW cell carrier, made from 80 mm PVC drainage tubing and fittings, including a section of 80 mm tube, an end cap, a joiner section, and an inspection cap and its mounting ring. The end cap, joiner, and mounting ring are glued together using PVC adhesive to form a cylindrical container that can be sealed with the inspection cap. The components here are as sold in New Zealand, but similar components should be available in most countries. Note that the inspection cap has an interlocking 1/8th-turn closing mechanism that traps very little air when the tube is closed. This type of locking mechanism is better than end caps with screw threads. Note too, the O-ring to provide a water-tight seal.

Additional components include a small rubber bung to block the thermometer well of the cell, and sections of sponge cloth, such as that commonly used for household cleaning. The sponge should be very open-pored and soft – it is used to constrain the movement of the cell.

It is helpful to have two thicknesses of sponge, one about 10 mm thick for the sections at the ends of the cell, with appropriate perforations, and sections of large flat 5 mm thick sponge to wrap the cell.

Finally, the cell carrier is shipped in a large cube of sponge in a closed cloth carry bag, as shown in Figure 5.

Figure 3. The assembled cell carrier and some of its component parts, including the endcap, the joiner section, and the inspection cap and mounting ring. Note the O-ring and the 1/8th-turn locking mechanism of the inspection cap.

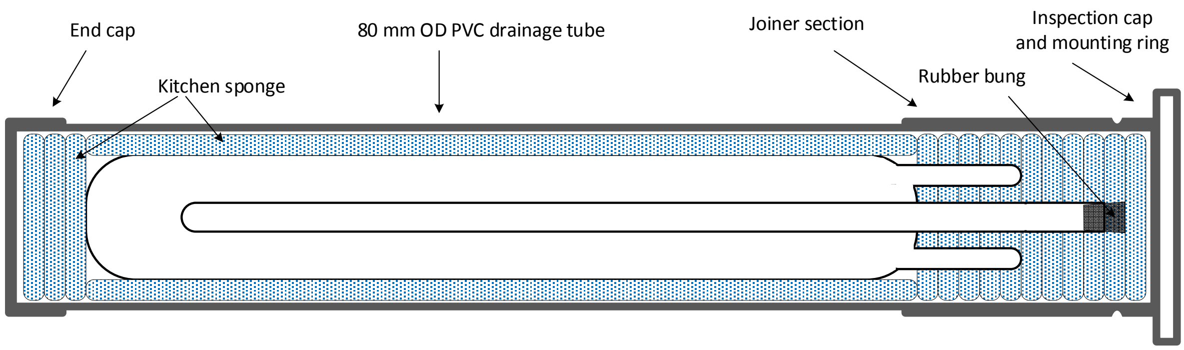

Figure 4. Schematic drawing of the TPW cell carrier with the TPW cell within. The cell is surrounded by soft sponge fully saturated with water. Note also the bung in the entrance of the thermometer well.

Loading the Carrier

In operation, the cell carrier should be filled with water with all the air excluded, so all of the sponges should be fully saturated. The only place where air is allowed is in the thermometer well. Loading proceeds as follows:

1. Empty and drain the thermometer well of the TPW cell, and firmly insert the rubber bung.
2. Empty the tube carrier of water, and place three of the thick sponges in the bottom of the carrier.
3. Cover the sponges with water and tamp them to remove air bubbles.
4. Wrap the TPW cell in two layers of the dry thin sponge. Once wrapped, tape the sponge ends so the cell stays wrapped.

5. Lower the wrapped TPW cell into the carrier.
6. Fill the carrier tube slowly, allowing the water to seep into the sponge without trapping air.
7. Slowly lower the sections of perforated sponge over the top of the cell and around the seal-off tubes and thermometer well, again avoiding trapping bubbles of air.
8. Top up the carrier tube with water.
9. Seat the O-ring into the top of the tube.
10. Turn the inspection cap upside down and fill with water. Then place a waterproof card over the cap to trap the water.
11. Lower the cap onto the top of the tube, remove the card, and lock the inspection cap down. There should now be very little air trapped in the carrier.
12. Place the carrier tube in the sponge carry bag. It is now ready for shipping.

Figure 5. The sponge carry bag for shipping the cells. This bag has positions for two of the tubular cell carriers.

Explanation

There are several aspects of the carrier critical to its performance. Firstly, the hard PVC tubing, stiffened by the end caps, provides protection against crushing. The layers of open-pore sponge between the tube walls and the TPW cell provide extra protection.

Secondly, shipping the cell fully immersed in water provides protection again axial acceleration and water hammer. Normally, when the water slams into the cell wall, the mismatch in the acoustic impedance of the glass and air means that the energy of the water hammer is reflected by the glass, resulting in large forces on the glass. Placing water on both sides of the glass means that the acoustic impulse from the water hammer is propagated through the glass to the water on the outside of the cell. In effect, the better impedance match of the water to the glass means that the acoustic reflection at the glass and the accompanying forces are much reduced. The effectiveness of the fix can be felt in the hands when the filled carrier tube is gently shaken.

Thirdly, trapping air within the thermometer well means that the effective density of the empty thermometer well is a close match to water. When the cell is accelerated laterally, the buoyancy pressure from the water balances the inertial force on the thermometer well, greatly reducing the risk of breakage. If water is allowed to fill the thermometer well, the inertial forces will certainly break the cell.

The soft sponge carrier bag reduces the g forces experienced by the cell during shipping, and the bright red cloth outer covering encourages couriers to treat the package gently.

References

[1] "Guide to the realization of the ITS-90", https://www.bipm.org/en/committees/cc/cct/guide-its90.html.

Prepared by Rod White and Ross Mason.

Contact Details

Postal address: Measurement Standards Laboratory, Callaghan Innovation, PO Box 31-310, Lower Hutt 5040, New Zealand.
Website: www.measurement.govt.nz
E-mail: info@measurement.govt.nz

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