Triple point of water cells

- Easy-to-use, inexpensive standard with uncertainty better than ± 0.0001 °C
- Four sizes and two shells (glass and quartz) to choose from
- Isotopic composition of Vienna Standard Mean Ocean Water

The triple point of water (TPW) is not only the most accurate and fundamental temperature standard available, it's also one of the least expensive and simplest to use.

Water cells are essential!

Triple point of water cells fill four critical purposes. First, they provide the most reliable way to identify unacceptable thermometer drift between calibrations—including immediately after a calibration if the thermometer has been shipped. Interim checks are critical for maintaining confidence in thermometer readings between calibrations. Second, they provide a critical calibration point with unequaled uncertainties.

Third, for users who characterize probes using ratios (that is, they use the ratios of the resistances at various ITS-90 fixed points to the resistance of the thermometer at the triple point of water, indicated by "W"), interim checks at the triple point of water allow for quick and easy updates to the characterizations of critical thermometer standards, which can be used to extend calibration intervals.

And lastly, the triple point of water is where the practical temperature scale (ITS-90) and the thermodynamic temperature scale meet, since the triple point of water is assigned the value 273.16 K (0.01 °C) by the ITS-90 and the Kelvin is defined as 1/273.16 of the thermodynamic temperature of the triple point of water.

Good triple point of water cells contain only pure water and pure water vapor. (There is almost no residual air left in them.) When a portion of the water is frozen correctly and water coexists within the cell in its three phases, the "triple point of water" is realized. Hart water cells achieve this temperature with expanded uncertainties of less than 0.0001 °C and reproducibilities within 0.00002 °C.

In simple terms, water cells are made from just glass and water, but there's much more to it than that! For starters, that's not just *any* water in there.

Heavy water

Hart cells contain carefully and repetitively distilled ocean water and are meticulously evacuated and sealed to maintain an isotopic composition nearly identical to the international standard, "Vienna Standard Mean Ocean Water," or "VSMOW."

The oxygen atoms found in most water are predominantly comprised of eight protons and eight neutrons (^{16}O). Some oxygen atoms, however, have an extra neutron (^{17}O) or two (^{18}O). Similarly, the hydrogen atoms in water normally contain only a single proton (^{1}H), but sometimes contain a neutron also (^{2}H), resulting in "heavy" water. These isotopes coexist in varying proportions in ocean water, polar water, and continental water, with ocean water being the heaviest.

The ITS-90 recommends that water cells be made from water with "substantially the isotopic composition of ocean water." Research has shown that TPW errors associated with isotopic composition can be as large as 0.00025 °C. The uncertainty contribution due to the effect of deviation from VSMOW in Hart cells is less than ± 0.000007 °C. That's seven microkelvin!

Hart offers two options for verifying the isotopic composition of any purchased water cell, both at nominal costs. We can submit a sample of water taken from your own cell to a testing laboratory (*after* it was completely manufactured, so you get a valid comparison) and give you the test report. Or, we can send that water sample to you in a sealed ampoule for you to conduct your own tests. We can even provide multiple samples from the same cell (virtually as many as you'd like) so you can check for changes over time.

Impurities

Further, the potential for errors due to water impurity is even greater than the errors from isotopic composition. Hart cells undergo multiple distillation processes and utilize special techniques to retain water purity. Among other things, our primary

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standards scientists are able to connect quartz cells directly to the glass distillation system without using coupling hardware that may invite contamination.

Glass vs. quartz

Most Hart water cells may either be purchased with borosilicate glass or with fused silica ("quartz") housings. What's the difference? Glass is less expensive than quartz, but it's also more porous, allowing impurities to pass through it over time. Research indicates that glass cells generally drift about 0.000006 °C per year while quartz cells drift less.

Many sizes

Hart cells come in four general sizes. Models 5901A, 5901C, and 5901D each come in either quartz or glass shells and include 265 mm of thermometer immersion depth. The primary difference between these models (other than the arm on the 5901A) is the inside diameter of the probe well. (See chart on page 16 and note that the inside diameter of the 5901C cells varies with the shell material). A variety of baths is available, which can maintain the triple point within these cells for many weeks. Accredited (NVLAP) test certificates are available with any cell under our Model 1904-TPW.

5901A cells include an arm that can be used as a handle, a hook, or a McLeod gauge to demonstrate how much residual air is trapped in the cell. Carefully developed manufacturing processes at Hart keep the air bubble in a quartz cell as small as the air bubble in glass cells.

A fourth size, the 5901B cell, comes in a glass version and is significantly smaller than the other cells. It is designed for use in our Model 9210 Maintenance Apparatus, which automates the realization and maintenance of the TPW. The 9210-5901B combination is perfect for both calibrating thermometers and providing periodic checks of sensor drift.

Accessories

For simplest realization of the TPW in our larger cells, the Model 2031A "Quick Stick" Immersion Freezer uses dry ice and alcohol to facilitate rapid formation of an ice mantle within the cell without requiring constant intervention while the mantle forms.

For best results, use a 3901 bushing with your triple point of water cell. A bushing is used to improve the thermal contact between your SPRT and the ice mantle of your water triple point cell. Be sure to choose a bushing that matches the inner diameter of the reentrant well of the cell and the outer diameter of the SPRT. Additionally, a small piece of foam (<0.5 cm) may be placed beneath the bushing to isolate it from the bottom of the cell which research has shown is slightly colder than the rest of the cell.

Insurance is also available for each water cell purchased from Hart. Water cells are not difficult to handle nor is the TPW difficult to realize, but they are delicate and accidents do happen. For a nominal fee, we'll insure your cell in one-year increments. If something goes wrong, just let us know and we'll replace your cell. No questions asked.

The 2028 Dewar has inside dimensions of 20 cm by 50 cm (7.75 in x 19.5 in), and outside dimensions of 25 cm by 61 cm (9.75 in x 24 in).

Accessories like the "Quick Stick" Immersion Freezer and 3901 bushings add simpler realization and improved thermal contact.

Ordering Information

5901A-G	TPW Cell, 12 mm ID with handle, glass shell
5901A-Q	TPW Cell, 12 mm ID with handle, quartz shell
5901C-G	TPW Cell, 13.6 mm ID, glass shell
5901C-Q	TPW Cell, 14.4 mm ID, quartz shell
5901D-G	TPW Cell, 12 mm ID, glass shell
5901D-Q	TPW Cell, 12 mm ID, quartz shell
5901B-G	TPW Cell, mini, glass shell
7012	TPW Maintenance Bath (maintains four cells)
7312	TPW Maintenance Bath (maintains two cells)
9210	TPW (5901B-G) Maintenance Apparatus
2028	Dewar (for TPW ice bath)
2031A	"Quick Stick" Immersion Freezer
1904-TPW	Accredited Cell Intercomparison
INSU-5901	TPW Cell Insurance, one-year
5901-ITST	Isotopic Composition Analysis, TPW Cell
5901-SMPL	Water Sample, TPW Cell (comes in a sealed glass ampoule)
3901-11	TPW Bushing, 5901/5901A to 7.5 mm
3901-12	TPW Bushing, 5901/5901A to 5.56 mm (7/32 in)
3901-13	TPW Bushing, 5901/5901A to 6.35 mm (1/4 in)
3901-21	TPW Bushing, 5901C to 7.5 mm
3901-22	TPW Bushing, 5901C to 5.56 mm (7/32 in)
3901-23	TPW Bushing, 5901C to 6.35 mm (1/4 in)

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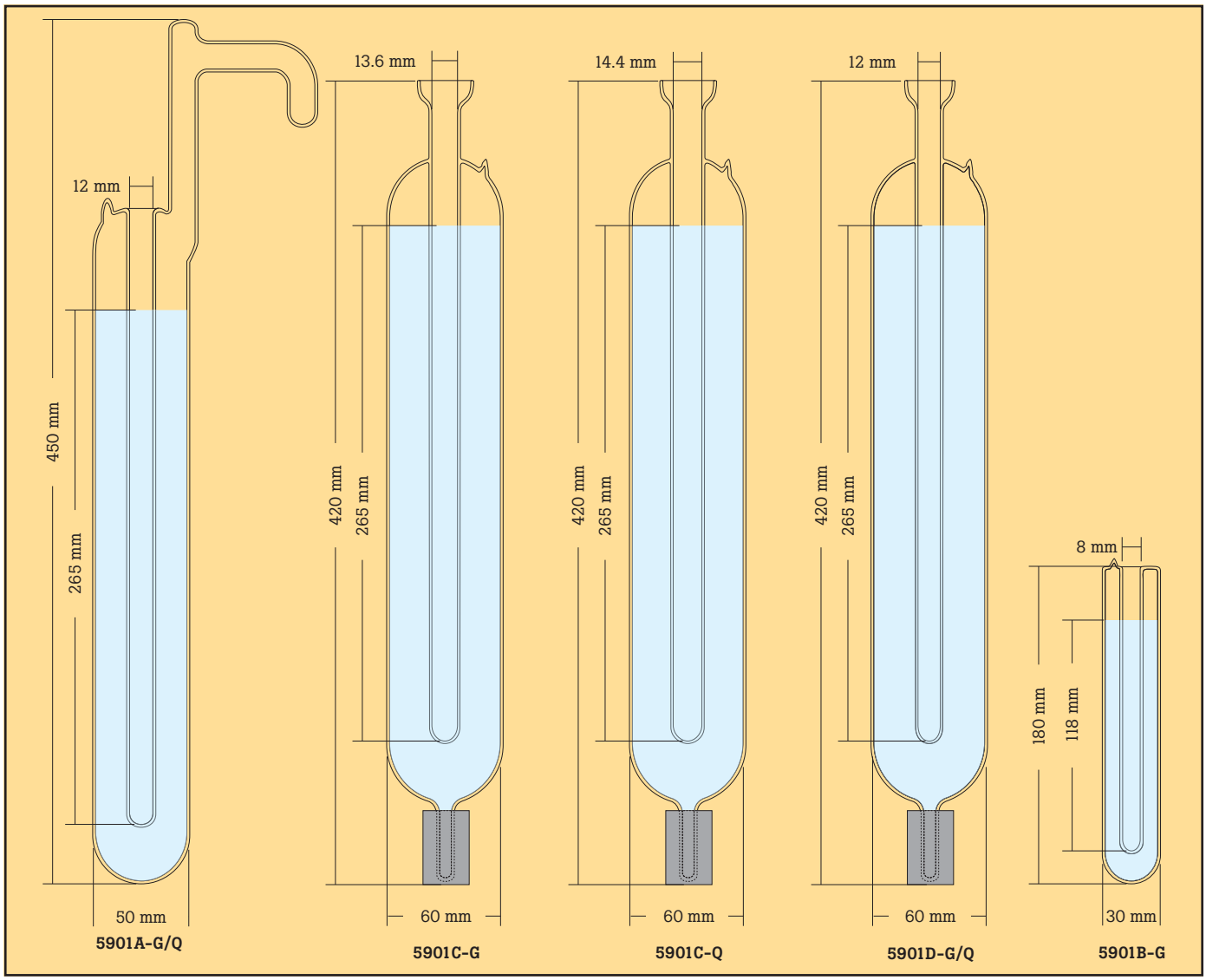

Specifications

	5901A-G	5901A-Q	5901C-G	5901C-Q	5901D-G	5901D-Q	5901B-G
Expanded Uncertainty (k=2)	< 0.0001 °C						< 0.0002 °C
Reproducibility	0.00002 °C						0.00005 °C
Dimensions	50 mm OD 12 mm ID 450 mm long		60 mm OD 13.6 mm ID 420 mm long	60 mm OD 14.4 mm ID 420 mm long	60 mm OD 12 mm ID 420 mm long		30 mm OD 8 mm ID 180 mm long
Immersion Depth (water surface to well bottom)	265 mm						118 mm
Material	Borosilicate Glass	Fused Silica (Quartz)	Borosilicate Glass	Fused Silica (Quartz)	Borosilicate Glass	Fused Silica (Quartz)	Borosilicate Glass
Water Source	Ocean						
δD_{VSMOW}	± 10 ‰ (± 1 %)						± 20 ‰
$\delta^{18}O_{VSMOW}$	± 1.5 ‰ (± 0.15 %)						± 3 ‰
Effect of Deviation from VSMOW	± 7 µK						± 14 µK