THE INTERESTING LIFE AND TIMES OF 108462/S/002 THERMOMETER

Introduction

This novel design of thermometer uses alumina, not quartz as the sheath material because quartz is ‘soft’ at 1085°C. Alumina is slightly porous and so the sheath is pressurised by 1 or 2” water gauge of filtered air, so that any leakage would be outward, and the internals have access to oxygen. (Platinum likes an oxygen-rich atmosphere).

The 0.25ohm bifilar winding is wound onto a sapphire spade shaped support with notches along the edges. The 4 platinum lead wires are separated by quartz spacers and insulated with quartz capillaries.

The complete platinum circuit was biased to +9V DC.

Purpose

The objective of the thermometer is to measure melts and freezes of metal clad copper cells. The metal cladding is Inconel 600 or Haynes 230.

It must perform its task without drift (less than 0.1mK per hour at 1084.62°C) and without contamination. R_{TPW} must also be stable.

There will be no protective material such as platinum between cell and thermometer.

Pre-Conditioning

There is no-preconditioning or annealing of the thermometer it is used just as it came from production.

Gauging Performance

4 graphs are plotted of R_{Cu} W_{Cu} R_{tp} W_{ga} with the number of hours at 1084.62°C as the horizontal axis.

In addition, the liquidus and solidus resistance are tabulated for the 2011 sequence of melts and freezes together with R_{TPW}, W_{ga} and W_{Cu}.

The Graphs

Four graphs are presented:

The First Plots	R_{TPW}
Second	W_{ga}
Third	R_{Cu}
Fourth	W_{Cu}

They can be considered in two parts. The first part comprises the measurements made during the first 3 months of 2010[+]. The second parts are measurements made in April/May 2011.

[+]See “A New Thermometer for the Copper Point” Tempmeko 2010.

Graph 1 R_{TPW}

R_{TPW} remains the same throughout the complete investigation with the exception of the strange dip in R_{TPW} (accompanied by an exceptionally high W_{ga}. Measurements were repeated but after annealing the thermometer reverted to its original values). Oxygen in Cu is known to depress the transition temperature (5mK per 1ppm). During testing the Cu Cell was exposed to 1100°C for 100 hours under vacuum to remove any oxygen. This made no difference to the copper cells temperature (less then 1mK).

Graph 2 W_{ga}

Excepting the strange result, W_{ga} increases slightly and then stabilises.

Combined with graph 1 these results show an exceptionally stable thermometer with no signs of contamination after 800 hours of temperatures from 1084 to 1100°C.

Graph 3 R_{Cu}

Unlike RTPW and W_{ga} R_{Cu} drops like a stone during its first 100 hours at 1085°C, then drifts downwards slowly for the rest of the 2010 testing.

Examining the results showed the shifts occurred during the time the thermometer was removed for cold rodding, and so the 2011 melts and freezes were done by adjusting the furnace temperature rather than cold shocking the thermometer during the 400 hours testing in 2011 the R_{Cu} remained stable.

Graph 4 W_{Cu}

As could be predicted W_{Cu} came down in sympathy with R_{Cu} and stabilised with R_{Cu} during the 2011 testing.

Table 1 shows two 'runs' made in May 2011

Run 1 comprises 3 melts and 3 freezes.
Run 1 was performed over 216 hours.
R_{TPW} shifted up by 0.8mK
R_{Cu} shifted around between 1.092,275 and 1.092,259Ω
Run 2 comprises 3 melts and 2 freezes
Run 2 took 170 hours.
R_{TPW} shifted down by 0.3mK.
R_{Cu} shifted around between 1.092,275 and 1.092,270Ω
In Run 2 the procedure was changed to give more consistent freeze plateaus.
W_{ga} changed from 1.118133 to 1.1181314 over the 386 hours of the 2 runs.

Discussion and Speculation

Physics works, so what's happening inside my new thermometer?

R_{TPW} and W_{GA} are remarkably stable and so the platinum is remaining pure and without contamination.

R_{Cu} reduces; this could be because the parallel resistances of the sapphire/quartz glass are changing. These effects would show up more at high temperature as the resistance of every insulator reduces with temperature.

This cannot be the full explanation, because most of the changes occur during cold rodding, and 100 hours at 1100°C made no change to R_{Cu}.

So what happens when the thermometer is removed?

Being alumina sheathed, the thermometer is removed slowly to avoid thermal shock and so the top containing the winding is hottest. This is known to be bad for thermometers as any volatiles in the thermometer will move toward the hottest part where they will eventually condense.

By keeping the thermometer in the apparatus large gradients along the thermometer are avoided.

Where are the volatiles originating?

Possibly from the quartz spacers and capillaries along the thermometer.

To test this proposition another thermometer with alumina capillaries and no spacers could be produced and tested.

How good is W_{Cu}?

Searching the literature there are few authors who list W_{Cu}.

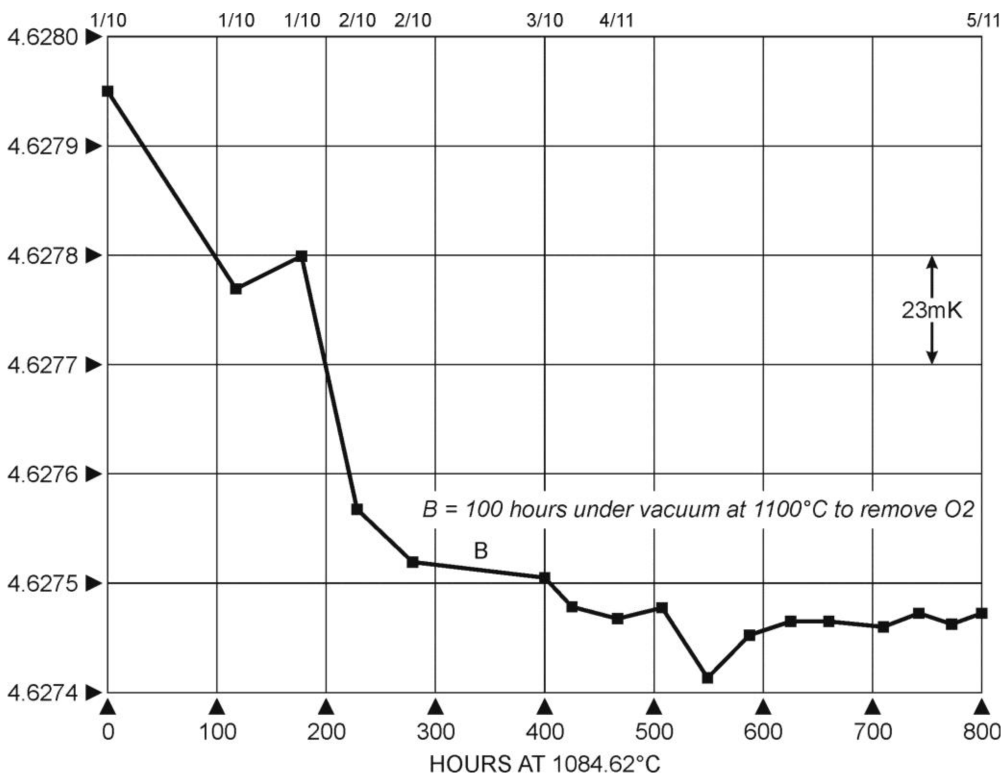
McLachlin lists W_{Cu} for his 3 thermometers. These are 4.62708, 4.62692 and 4.62724. This compares with the final stable value of 108462/S/002 of 4.62745 so even with its parallel resistance creep, W_{Cu} remains high.

Conclusion

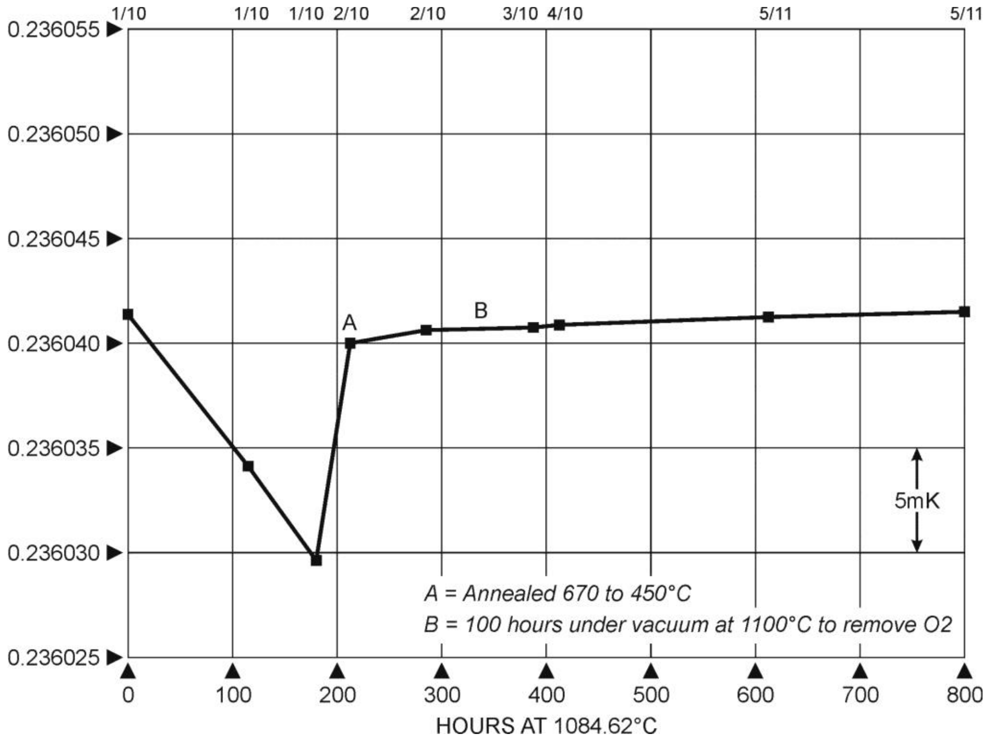
The purpose of the thermometer is to characterise copper cells by measuring their freeze and melt curves.

Once it was realised that the small changes in the thermometer were cause by thermal shocking the thermometer during the cold-rod process and this was illiminated, the thermometer was able to measure the cells melt and freeze without drift.

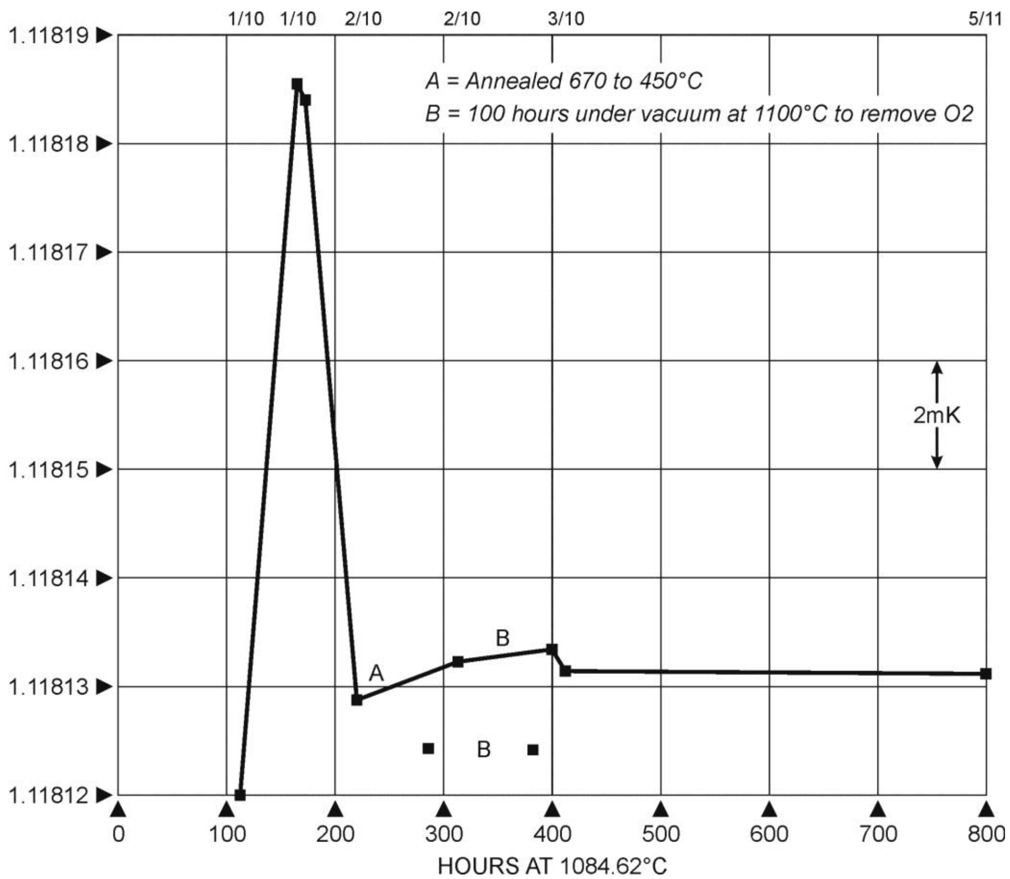
W_{Cu} 108462/S/002



Changes in R_{TPW} 108462/S/002



Changed in W_{ga} 108462/S/002



R_{Cu} ohms 108462/S/002

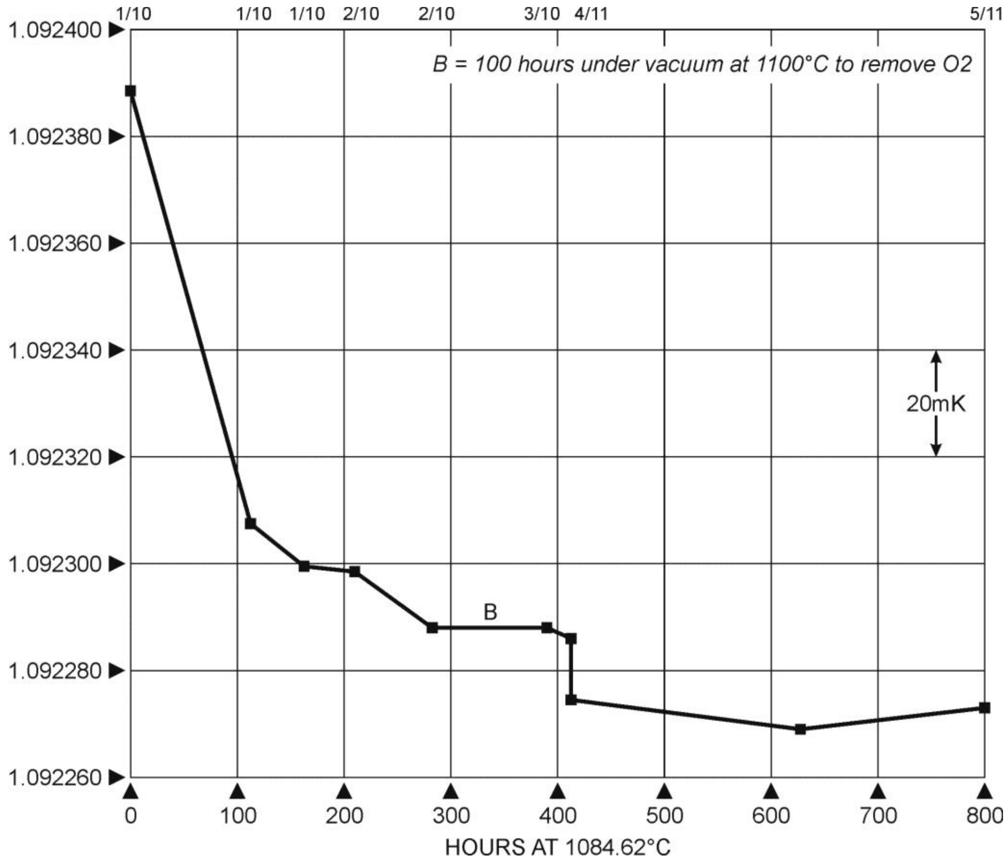


Table 1: Performance of 108462/S/002

Date	R_{TPW}	W_{ga}		108462/S/002	W_{Cu}
??/02/2010	1.2360,408	1.118,133	F	1.092,283	
09/04/2011			M	1.092,275	4.627,470
10/04/2011			F	1.092,272	4.627,458
11/04/2011			M	1.092,275	4.627,470
12/04/2011			F	1.092,259	4.627,402
26/04/2011			M	1.092,270	4.627,449
27/04/2011			F	1.092,268	4.627,467
28/04/2011	0.2360,415				
216 hours					
10/05/2011			M	1.092,273	4.627,467
11/05/2011			F	1.092,270	4.627,455
12/05/2011			M	1.092,275	4.627,470
13/05/2011			F	1.092,270	4.627,455
16/05/2011			M	1.092,273	4.627,467
17/05/2011	0.2360,412	1.118,1314			
170 hours					