CALIBRATING THERMOMETERS IN BOILING WATER:

Boiling Point / Atmospheric Pressure / Altitude Tables

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In some literature that I received from Taylor a few days ago, I saw that the calibration point that they use for the standard grade bimetallic coil thermometers is 100F. These thermometers list for $8.80 in their catalog. The Taylor superior grade bimetallic coil thermometers are calibrated at 3 points: 0F, 100F, and 200F. They list for $17.50 in the catalog.

This prompted me to call the head of engineering at Taylor to ask what happens if the standard grade instruments are calibrated at 32F in slush ice. To calibrate at 100F (mid-scale on the thermometer) requires a high-precision water bath and high-precision thermometer. I was told that it would not be accurate at any temperature except 32F. The bimetallic coil thermometer can be trusted about +/-20F from a set point. So, at 150F, the bimetallic coil thermometer that had been recalibrated in slush ice would have an unknown accuracy, but would not be any better than +/-2%, or approximately 4.4F.

The same is true for the superior grade thermometer with factory 3-point calibration. As soon as one would calibrate it in the field at 32F in slush ice, one would have no idea of the accuracy at 150F.

The chief engineer continuing by saying that one could guess at it by calibrating at 32F in slush ice (with the ice crushed in small pieces, and the water slightly below the top level of the ice). Water with ice cubes or larger chunks of ice will not be at 32F. It will be at 34 to 35F, probably. He believed that there are many problems allowing workers to calibrate the bimetallic coil thermometers.

At the high end of the scale, one could use the boiling point of water. This led me to examine the problem of accurate calibration at the boiling point. A lot of people talk about calibrating with boiling water.

There are two factors that must be considered for accurate calibration at the boiling point. First is altitude at which the thermometer is to be calibrated. For example, at sea level, water boils at 212F. However, for every 500 feet above sea level, water boils about at 0.9F less. At 1,000 feet, then, water boils at about 210.2; at 2,000 feet, about 208.4; at 3,000 feet, about 206.6, etc.

In addition to this correction factor, one must correct for barometric pressure. At a 0-feet altitude, if the barometric pressure is 29.921 inches of mercury, water boils at 212F. If the barometer is at 29.0, the water boils at 1.53F less than the 212F boiling point, with the altitude factor already considered. If the pressure is at 30.8 inches of mercury, one must allow for an increase in boiling of 1.43F.

Below are some calculation tables for these factors. These tables provide correction for altitude and barometric pressure if one wishes to use the boiling point method of calibration.

To be sure that this is not a unique problem with Taylor thermometers only, I spoke with Cooper Instruments. The head of engineering, Gary Sawicki, said that they do exactly the same type of calibration with their bimetallic coil thermometers--calibrate them about mid-scale (100F). This way, they can get their stated accuracy over the 0-220F range. The same problem exists, then, with the Cooper bimetallic coil thermometers. If one calibrates a bimetallic coil thermometer at 32F, one could be 2% off, easily, at 150F, which would mean 4.4F.

While one may say that these are trivial differences, there is also the problem that the coil measures temperature over an approximate 3-inch distance up the stem of the thermometer. In a steam table pan, this can be 100F. Also, the thermometers are quite easily put out of adjustment because of rough handling.

It is also a scientific fact that if one is off the desired pasteurization temperature by 3F, the time will change by a factor of 100%. That is, at 155F, pasteurization time is 15 seconds, but at 152F, the time is 30 seconds for the same 5D destruction of Salmonella in hamburger.

None of this correction information is in the FDA Food Code, and never has been. As far as the FDA and USDA are concerned, the bimetallic coil thermometer is a highly accurate device and considered to be more than sufficient to measure the pasteurization temperatures of thin foods such as hamburgers and chicken breasts. The USDA shows this thermometer on the package labels for raw meat and poultry.

When our government cannot even provide correct information about what thermometers to use to assure that we do not overcook or undercook our food--and when local inspectors are not given the money by their administrators to buy correct thermometers--we have no chance of serving safe food in the U.S. If we do not get correct information from the government, cooks should not held responsible if they prepare unsafe food. That would be the government's fault for telling us that we can use the bimetallic coil thermometer.

To calculate the boiling point of water at a location on any specific day use the following equation:
Boiling point of water = Boiling point at specified altitude (Table 1) ± boiling point barometric correction (Table 2).

In the tables, the following equations have been used:

Pressure (in. Hg) = 29.921* (1-6.8753*0.000001 * altitude, ft.)^5.2559
Boiling point = 49.161 * Ln (in. Hg) + 44.932

TABLE 1	**Changes in Standard Temperature and Pressure (in Hg) as a Function of Altitude**	**(Ref. 1)**		**TABLE 2**	**Boiling Point as a Function of Barometric Pressure**	**(Ref. 2)**
Altitude (ft.)	Pressure (in. Hg)	Boiling pt. (° F)		Pressure (in. Hg)	Boiling pt. (° F)	Boiling pt. [added or reduced] (° F)
-500	30.466	212.9		27.6	208.04	-3.96
0	29.921	212.0		27.8	208.39	-3.61
500	29.384	211.1		28.0	208.75	-3.25
1000	28.855	210.2		28.2	209.10	-2.90
2000	27.821	208.4		28.4	209.44	-2.56
2500	27.315	207.5		28.6	209.79	-2.21
3000	26.817	206.6		28.8	210.13	-1.87
3500	26.326	205.7		29.0	210.47	-1.53

4000	25.842	204.8		29.2	210.81	-1.19
4500	25.365	203.9		29.4	211.15	-0.85
5000	24.896	203.0		29.6	211.48	-0.52
5500	24.434	202.0		29.8	211.81	-0.19
6000	23.978	201.1		29.921	212.00	0.00
6500	23.530	200.2		30.0	212.14	0.14
7000	23.088	199.3		30.2	212.46	0.46
7500	22.653	198.3		30.4	212.79	0.79
8000	22.225	197.4		30.6	213.11	1.11
8500	21.803	196.4		30.8	213.43	1.43
9000	21.388	195.5		31.0	213.75	1.75
9500	20.979	194.6		31.2	214.07	2.07
10000	20.577	193.6		31.4	214.38	2.38

References

1. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. 1997. ASHRAE Handbook - Fundamentals, Inch-Pound Edition. ASHRAE. Atlanta, GA.

2. Perry, R.H., Green, D.W., and Maloney, J.O. 1984. Chapter 6. Psychrometrics. Perry's Chemical Engineers' Handbook. McGraw Hill. New York, NY.

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