Testing for Correctness of Thermometers and Pyrometers.

Instruments for measureing the caloric condition of bodies are subject to a number of influences that tend to render their reading incorrect. Such as the irregular expansion of thermometer and pyrometer tubes and their containing fluid. The shrinking of the bulb after long use. The change of the molecular state under high tempertures. And the graduation of instruments too soon after they are made, not allowing them sufficient time to assume their final position.

Mercury is generally employed as a means of estimating tempertures, as its coeficient of expansion remains constant for ordinary tempertures; but for very high tempertures it becomes unstable and boils at a point far too low to be employed in estimating the melting or boiling point of most metals. In such high tempertures it becomes necessary to employ a combination of metals

generally steel and brass so arranged that they indicate temperture by a dial face and hand.
Thus as caloric measures are constantly changing, frequent testings and correctings are necessary. There are several methods for doing this. The principle of the one I shall follow is simple, accurate, and comprehensive, and can be found in almost any book on physical manmpulations. First of all it is necessary to find at least two definite places on the instrument to be tested. One of these may be zero, or the melting point of ice and the other the temperture of boiling water in an open vessel. These phenomina are always constant under simillar circumstances. To find zero, or the melting point of ice place the bulb and several inches of the tube of the instrument to be tested in finely powdered ice, that is just melting, and give the water free chance to escape as the ice melts. This last may be accomplished by having the ice in a funnel shaped retort with a small tube at the bottom. Suppose the instrument to be tested is a mercury

thermometer. Leave it in the ice until the column of mercury remains stationary in the tube, note this point and how much it varies from the zero as tube is graduated; and we have one fixed point from which to compute our corrections. To determine the boiling point, which is somewhat more dificult, have a beaker of some kind two thirds full of clear water, place over this a tight cover and through the cover pass a tube large enough to allow of a free escape of steam, so it will not be under presure, and to contain the instrument to be tested so that it will not touch the sides or extend above the tube. This causes the steam to pass up around the instrument heating all parts uniformly, and yet it is not subject to any other influence. The water in the beaker should be heated until it boils freely and the thermometer bulb placed so it is near the surface yet not in the water, as the water is not of a constant temperture, while free by escaping steam is always at 212° Fr. or 100° Centi. at sea level. In computing the boiling point it is also necessary to take into consideration the hight of the barometer and its current tempertuire if a mercurial barometer. The greater the altitude of a place the lower will the boiling point be. So it becomes necessary in finding the true boiling point, to take the barometer reading for that time and place and correct accordingly. Higher temperatures than that of boiling water may be obtained if necessory by placing the instrument for instance in melting tin which will give us 440° Fr. its melting point. Other metals may be used for higher temperatures, care being taken that they are chemically pure and not alloys. After securing as many points on the instruments as are necessary or desirable it becomes necessary to see if the bore of the instrument is the same throughout its length. This is called calibration and is effected by separating a small portion of the mercury in the tube, if it is a mercury thermometer or pyrometer, and sliding it along the tube applying it at various places and noting if it is the same length in all parts of the tube judging from the number of graduation marks over which the thread extends. In a general way calibration can be determined by feeling of the exterior of the tube to see that there are no flaws in the glass, and that it is perfectly cylindrical and smooth; as the bore pretty closely conforms to the exterior. But for very accurate work it is necessary to calibrate with a short column. To secure a short column often requires much time and patience. Cool the bulb by placing it in ice or snow until the column in the tube is just the distance in length above the bulb of the required thread; for example say twenty degrees. Then apply this thread by sliding it along the tube first from 0 to 20°, then from 20° to 40°, and so on up to boiling point or the highest point tested. This will give the correction for every twenty degrees and a proof of the correctness of the work.

I give below the results of some experiments with high grade thermometers and pyrometers, tested in the manner indicated above and showing how similar instruments vary, how far this variation may extend, and the actual amount of the variation. The first was a centigrade thermometer about twenty inches long with a fine capilary tube; and a large sensitive bulb about one and a half inches long, and a quarter of an inch in diameter. This one was compared with another similar in every respect and graduated to tenths of a degree. Two of the pyrometers were modified mercurial thermometers one graduated to read as high 338° Fr. and the other to 600° Fr. Both had their bulbs inclosed in a brass tube to protect them from injury, the tube of the first was twelve inches long and the second twenty three inches long. The third was a true pyrometer twenty four and a half inches long and suited to measure temperatures up to 1500° Fr. It was composed of two metals so arrainged that their expansion and contraction under the influence of heat caused a hand to move over a dial face and thus indicate temperature. Only one of the pyrometers was graduated as low as zero so they were compared at 53.6° Fr. above zero, at boiling point, and at 440° Fr. the temperature of melting tin, this last was not entirely satisfactory yet it showed a great deal which is of interest. In the small vessel that was used, which was a long iron tube, it was dificult to keep the tin at just melting, and when removed from the fire the tin rapidly solidified as it had not sufficient body to retain high temperture for any length of time.

The comparison and correction of the tested instruments gives the following results

	1st "	2nd "
Zero	.4° Centi	.1° Centi.
Boiling Point	99.6°	99.5°
Barometer reading	731.8 mm	732.85 mm
" corrected for current temperture and reduced to inches	28.706	28.741
True B.P.	98.8°	99.°
Dif. between true and Apparent B.P.	.8°	.5°
Calibration	0 — 20 column reached	19.7°
	20 — 40	20.°
	40 — 60	18.8
	60 — 80	20.
	80 — 100	20.1

Let P_0 = Dif. between 0 of grad. and freezing point
" P_1 = " " B.P. " " " true B.P.
" d_1 = -.3° 1st variation of calibration.
" $d_2 = 0$
" $d_3 = -.2$
" $d_4 = 0$
" $d_5 = .1$
" a = interval we wish to calibrate
" n = no. of times column of calibration is applied

Applying formula from Loomiss.

$$a = \frac{P_0 - P_1 + d_1 + d_2 - - - - d_n}{n} = \frac{.4 - .8 - .3 - 0 - .2 - 0 + 1}{} = \frac{-.8}{5} =$$
$-.16$

Using correction table.

0	$-P_0$
a	$a - P_0 - d_1$
2a	$2a - P_0 - d_1 - d_2$
3a	$3a - P_0 - d_1 - d_2 - d_3$
— —	— — — — — — —
na	$na - P_0 - d_1 - d_2 - d_n$

0	$-.4$	$= -.4$
20	$-.16 - .4 + .3$	$= -.26$
40	$-.32 - .4 + .3 + 0$	$= -.42$
60	$-.48 - .4 + .3 + 0 + .2$	$= -.38$
80	$-.64 - .4 + .3 + 0 + .2 + 0$	$= -.54$
100	$-.80 - .4 + .3 + 0 + .2 + 0 - .1$	$= -.8$

Pyrometers	1st.	2nd.	3rd.
B. P.	209.5 Fr.	195.	195.
Barometer pressure	28.737 in	28.737 in	28.737 in
True B.P.	209.9	209.9	209.9.
At 53.6° Fr.	54° Fr	30°	30°

Calibration 54 – 84 --- 30

84 – 114 --- 30

114 – 144 --- 30.25

144 – 174 --- 30.25

174 – 204 --- 30.25

$\frac{+.4 + .4 + .25 + .25 + .25}{5} = .31$

54	−.4	= −.4
84	.31 − .4 + 0	= −.07
114	.62 − .4 + 0 + 0	= +.22
144	.93 − .4 + 0 + 0 − .25	= +.28
174	1.24 − .4 + 0 + 0 − .25 − .25	= +.34
204	1.55 − .4 + 0 + 0 − .25 − .25 − .25	= +.4

R. L. Wallis.