XIX.—EXPERIMENTS UPON THE TIME OF EXPOSURE REQUIRED FOR ACCURATE OBSERVATIONS WITH THE CASELLA-MILLER DEEP-SEA THERMOMETER.

By Commander L. A. Beardslee, U. S. N.

United States Steamer Blue-light,
Noank, Conn., September 1, 1874.

Sir: In compliance with your request that I should examine and compare the thermometers, standards and others, belonging to the United States Fish Commission, I have carried on a series of experiments with them, the results of which I herewith submit to you as one of the results of the summer's work of the Commission.

The instruments delivered by you to me to examine were the following, arranged and numbered according to their sensitiveness as developed during experiments:

No. 1. A mercurial standard, made by L. Casella, of London, No. 7,432, reading from zero up to 120°, on a scale marked on the glass, and twelve inches long, giving ten degrees to the inch; bulb cylindrical, .75 of an inch in length. No mounting; sensitive to the slightest change, and rapid in action.

No. 2. A mercurial standard, No. 16,578, made by James Greene, New York, reading from zero up to 120°, on a scale marked on the glass, and four and four-tenths inches long, giving twenty-seven and two-tenths degrees to an inch; bulb cylindrical, seven-tenths of an inch in length. No mounting; as sensitive as No. 1, and agreeing closely with it.

No. 3. A mercurial standard, no number, made by James Greene, New York, reading from 50° up to 105°, on a scale of six inches, marked upon a metal-back mounting. Very sensitive, but not convenient, on account of limited range.

No. 4. A mercurial standard, no number, made by Tagliabue, of New York, reading from 5° below zero up to 125°, on a scale 7.8 inches long, equal to nearly 16° to an inch; scale marked on a metal-back mounting; bulb spherical, with a brass guard. Moderately sensitive, but slow in action.

No. 5. A United States Navy mercurial thermometer, mounted with metal back and cup guard; spherical bulb; scale marked on back. Moderately sensitive, and fair in action.

No. 6. A Casella-Miller self-registering deep-sea thermometer, No. 15,720.

No. 7. The same, No. 17,017.

No. 8. The same, no number. Bought from James Greene, New York, and marked J. G.

Nos. 1, 2, 3, and 4 agreed closely when in equilibrium. No. 1, as the most easily read, on account of its larger scale, was selected as the standard by which to record the actual temperature. Its action was so rapid that no attempt was made to record it during its rise or fall.

No. 6 was defective in that it had an index error averaging 2½° to be added. It was, however, sensitive, and had fair action.

No. 7 recorded correctly, or nearly so, when in equilibrium.

No. 8 recorded more slowly, and had an index error of about .5 of a degree subtractive.

Our first experiments were made in a tub, containing about ten inches of water, on the surface of which about three inches of broken ice floated; the instruments were laid flat and read through the water. The necessity of constantly agitating the water caused the broken ice to frequently interfere with the range, and produced delay and inaccuracy, and if the water was not thoroughly mixed by stirring, no accurate results could be obtained, the difference in temperature between a point one-half inch below the ice and at the bottom, six inches deep, amounting to six degrees, when the water was tranquil, and so great was this cause of error that between No. 1 lying flat and No. 4 mounted on a metal back, which raised it over one-half inch above No. 1, there was a difference, due to position, of nearly 1°. A bath-tub was therefore devised, which enabled us to record correctly. This consisted of an ordinary aquarium, twenty inches by twelve and fourteen inches deep. This was divided longitudinally by a screen of wire gauze into two compartments, in one of which, nine inches wide, a bath of sea-water, well filled with broken ice, was put from a frame bar lengthwise, and six inches above the narrow section the thermometers were hung, with their bulbs on the same level in the iced water, but free from all contact with the ice.

The apparatus being placed so that the surface of the mercury was in line with the eye (an important precaution where extreme accuracy is desired), the record was read through the glass side and half-inch of water, which, slight enough to present no obstacle to a clear view, was all-sufficient to protect the delicate instruments from external influences.

METHOD OF EXPERIMENTS.

The standard No. 1 was suspended in the water, which was drawn from over the side of the vessel, and cooled down by ice to the desired temperature. An assistant, with a bucket of hot water, a bucket of finely-broken ice, and a table-spoon, stood ready, after the water had settled to the required temperature, to add at each reading a little hot or cold, as the standard's record, read aloud, indicated two or three tenths below or above the bath we wished, while at the same time, with

a spatula, the water was kept thoroughly stirred up. When we had steadied the temperature, the Casella was taken from its bath of sea-water, plunged quickly in, and read at the end of every twenty seconds, and at the same time the standard, which was so delicate that a breath would affect it, was noted.

Tests Nos. 1 and 3, in water and air, were for the purpose of comparing all the thermometers.

In Nos. 1 and 2 from want of practice, we did not succeed in maintaining a uniform temperature throughout, but, as the effect of the gradual cooling of the water was probably analogous to that experienced in lowering the instrument to a great depth, through a constantly lowering temperature, they may possess a value peculiar to themselves, and are therefore given. As they were taken by the first method, they are not strictly accurate, as the ice frequently prevented recording at the instant, and as large pieces were stirred sometimes nearer and sometimes farther from the bulbs, the bath itself was irregular.

This was particularly manifest when, at the end of ten minutes, more ice was added, and the temperature suddenly lowered over 5°; the sensitive instruments marked it at once, the Casellas more slowly, but at the end of five minutes had experienced a great fall. The inaccuracies in reading are probably in no case over one degree.

Test No. 1.—*Bath* 53°, *lowering to* 36° 5′.

The thermometers having been hung side by side in the open air and shade for one hour and recording as per column were placed in bath.

No.	Start.	End of 5m.	Fall.	End of 8m.	Fall.	End of 10m.	Fall.	End of 15m.	Fall.	End of 20m.	Fall.	End of 25m.	Fall.
	°	°	°	°	°	°	°	°	°	°	°	°	°
1	64.5	53	11.5	44.5	8.5	44	0.5	38.5	5.5	37.3	1.2	36.5	0.8
2	64.6	52	12.6	44	8	43.5	0.5	39	4.5	37.2	1.8	36.8	0.4
3													
4	65	53 5	11.5	46.5	7	43.5	3	38	5.5	37.3	0.7	36.7	0.6
5	64.3	54	10.3	49.5	4.5	44	5.5	38.8	5.2	38	0.8	37	1.
6	61.5	56.5	5	52	4.5	48	4	37.5	10.5	35	2.5	33.5	1.5
7	64.3	60	4.3	56	4	51.3	4.7	40	11.3	37.5	2.5	36.4	1.1
8	63.8	60.8	3	56.6	4.2	52.5	4.1	40.5	12	37.8	2.5	36.3	1.5

In the above table, as in all others, the correct temperature as shown by No. 1 and the point at which each instrument came to it are printed in Egyptian type. To the record of each instrument is applied its index error, in estimating this point, viz: No. 6, 2°.5 added, and from No. 8, ½° subtracted, and the point within .5 of correct assumed to be so.

Test No. 2.—*Bath* 40°, *lowering to* 33°.5.

The standard and three Casellas having been exposed in open air and shade one hour, and recording as per column, were placed in bath.

No.	Start.	End 1m.	Fall.	2m.	Fall.	3m.	Fall.	4m.	Fall.	5m.	Fall.
	°	°	°	°	°	°	°	°	°	°	°
1	67	40	27	39.5	0.5	38.5	1.0	37.5	1.0	36.2	1.3
6	67	54	13	49	5.0	45.5	3.5	41	4.5	39	2
7	68.5	53.5	15	50.5	3.0	46.6	3.9	43	3.6	41	2
8	68	56.5	11.5	52.5	4.0	48	4.5	44	4	42	2

No.	6m.	Fall.	7m.	Fall.	8m.	Fall.	9m.	Fall.	10m.	Fall.	11m.	12m.
	°	°	°	°	°	°	°	°	°	°	°	°
1	35	1.2	34.5	0.5	34.5	0.0	34	0.5	33.6	0.4	33.5	33.5
6	36.5	2.5	35	1.5	34	1	33	1	32	1	31.5	31
7	38.5	2.5	37.2	1.3	36	1.2	36	1	34	1	32.8	33
8	39.6	2.4	38	1.6	36.8	1.2	36	0.8	35	1	33.5	34

Test No. 3, in rising temperature of air.

After test No. 1, the instruments were thoroughly wiped and transferred to the cabin and hung side by side, bulbs on same line; doors and windows were closed and steam turned on to the heater. No. 3, which had been hanging in cabin was included in the test. About 3 minutes were occupied in the transfer, during which they were in air. Temperature 64°.

No.	Start.	End 5m.	10m.	15m.	20m.	25m.	30m.	35m.	40m.	45m.	50m.	55m.	60m.	65m.	70m.	75m.	80m.	85m.	90m.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	36.5	72	73	73.5	74	74.5	74.3	75	75.4	76.3	76.5	74.5	75.2	75	76	76	77	77	77
2	36.8	72.5	73.5	73.8	74.8	75	74.6	75.5	75.8	77	76	74.8	75.5	75.8	76.8	76.8	77.3	77.4	77.4
3	....	....	73.5	73.5	74.2	74.8	74.5	75	75.5	77	76.3	74.6	75.5	75.5	76.5	76.8	77.2	77.2	77.4
4	36.7	64	68	70.3	71.5	72.8	73.6	74.5	75.3	76.5	77	76.6	76.8	76.8	77.8	78	79	79	79
5	37	61	64.5	67	68.5	70.5	70.5	71.3	72	72.8	74	72.8	73	72	73	73.8	74.5	74.4	74.4
6	33.5	37	40	45	49.5	53.5	56.5	59	61	63	64	65	66	66.5	67	68	68.5	69	69.5
7	36.4	39	42	47	52	57	60	63.5	65	67	68	69.5	70	70.5	71	72	72.5	73	73.3
8	36.3	42	44.8	49	53	56	59	62	64	66	67	69	69.5	70	70	71.2	72	72.5	73.2

At ninety minutes the atmosphere of the cabin was so close that it affected my accuracy in reading, and the experiment was therefore ended. The No. 4 stood with the other standards in forty minutes at 75½°, but then, as the temperature rose, passed them and showed about 2° difference in the balance of the readings. I can assign no cause for this discrepancy, nor say which was the correct record, except that the weight of evidence is in favor of No. 1, with which Nos. 2 and 3 closely agreed. Nos. 5, 6, 7, and 8 at the end were still below the true temperature. This I attribute to the fact that, probably, we had not perfectly dried all crevices in the metal cases, and that we got the *evaporating* point in lieu of the true temperature. At the end of fifty minutes the cabin door was opened for a moment; this produced an instant change, which Nos. 1, 2, 3, and 5 recorded fully. No. 4 fell a little, but the three Casellas seemed to make no change on account of it.

Two hours later, the doors and windows having been opened, and steam turned off, the instruments hanging from the same peg, bulbs on a level, recorded: No. 1, 69°; No. 2, 69°.5; No. 3, 69°.5; No. 4, 70°; No. 5, 69°; No. 6, 63°.5; No. 7, 68°; No. 8, 67°.

Test No. 4.—Bath of sea-water, 65°.

The instruments were transferred from a cold bath, recording as per column, to a bath of sea-water and recorded.

No.	Start.	End 1m.	Rise.	2m.	Rise.	3m.	Rise.	4m.	Rise.	5m.	Rise.	6m.	Rise.	8m.	Rise.	9m.	Rise.	10m.	Rise.	11m.	12m.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	51.5	66	14.5	65	1	65	....	65	....	65	....	65	....	65	....	65	....	65	....	65	65
6	49	56	7	58.5	2.5	60	1.5	61	1	61.3	0.3	61.5	0.2	61.6	0.1	61.7	0.1	62	0.3	62.2	62.8
7	51	59.5	8.5	61.5	2	63	1.5	63.5	0.5	63.8	0.3	64	0.2	64.2	0.2	64.5	0.3	64.6	0.1	64.8	64.8
8	51.1	56.5	5.4	58	1.5	59.5	1.5	60	0.5	60.8	0.8	61.5	0.7	62	0.5	62.5	0.5	62.8	0.3	63.	63.4

Nos. 6 and 7 occupied full eleven minutes to get a correct record, although each was within one degree; No. 6 in nine minutes, No. 7 in eight. No. 8 was continued four minutes longer in the bath with no change.

A regular series of baths, each 5° lower than the other, was now begun—the instruments being started from as near to a uniform point as possible. No. 6, having been broken, not included in all.

Test No. 5.—Bath of 65°, starting from 69°.

No.	Start.	20s.	40s.	1m.	Fall.	80s.	100s.	2m.	Fall.	140s.	160s.	3m.	Fall.
	°	°	°	°	°	°	°	°	°	°	°	°	°
1	65	.....	.....	65	.....	.....	.....	65	.....	.....	.....	65	.....
7	69	68	67.5	67	2	66.5	66	65.8	1.2	65.6	65.6	65.5	0.3
8	69	68.5	68	67.8	1.2	67	66.5	66.3	1.5	66	66	66	0.3

Test No. 6.—Bath of 60°.

No.	Start.	20s.	40s.	1m.	Fall.	80s.	100s.	2m.	Fall.	140s.	160s.	3m.	Fall.	200s.	220s.	4m.	Fall.	5m.	6m.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	60	.....	.....	59.5	.....	.....	.....	59.5	.....	.....	.....	59.5	.....	.....	.....	59.5	.....	59.8	59.8
7	70.5	68.5	66.5	65	5.5	64	62.8	62	3.0	61.5	61	60.6	1.4	60.2	.....	60.1	0.5	59.8	59.8
8	70.5	68.8	67	66	4.5	64.8	64	63.5	2.5	62.8	62.2	61.8	1.7	61.5	61.2	61	0.8	60.5	60

Test No. 7.—Bath of 55°.

No.	Start.	20s.	40s.	1m.	Fall.	80s.	100s.	2m.	Fall.	140s.	160s	3m.	Fall.	200s.	220s.	4m.	Fall.	5m.	6m.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	55	.....	.....	54.6	.....	.....	.....	54.6	.....	.....	.....	54.5	.....	.....	.....	55	.....	55.2	55.2
7	71	69.5	66.8	64.5	6.5	62.8	61.3	60.2	4.3	59.2	58.5	58	2.2	57.2	56.8	56.5	1.5	55.5	55
8	71	69.8	67	65	6	63.2	62	60.8	4.2	59.8	59	58.5	2.3	57.8	57.2	56.8	1.7	56	55.5

Test No. 8.—*Bath of* 56° *in tub.*

No.	Start.	20s.	40s.	1m.	Fall.	80s.	100s.	2m.	Fall.	140s.	160s.	3m.	Fall.	200s.	220s.	4m.	Fall.	5m.	6m.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	56	.....	.....	56	.....	.....	.....	56	.....	.....	.....	56	.....	.....	.....	56	.....	56	56
6	63	60.5	59	58	5	56.5	56	55.5	2.5	54.8	54.5	54	1.5	54	53.8	53.8	.....	.....	.....
7	65	63.5	62	60.5	4.5	59.5	59	58	1.5	57.6	57	56.8	1.2	56.8	56.5	56.2	.....	.....	.....
8	66	64	63	62	4	60	59.5	59	3.0	58.5	58	57.5	1.5	57	56.8	56.5	.....	.....	.....

Test No. 9.—*Bath of* 55°, *in tub.*

No.	Start.	20s.	40s.	1m.	Fall.	60s.	100s.	2m.	Fall.	140s.	160s.	3m.	Fall.	200s.	220s.	4m.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	65	.....	.....	55	.....	.....	.....	55	.....	.....	.....	55	.....	.....	.....	55.4
6	62.3	60	58	57	5.3	56	55	58.8	2.2	54	53.8	53.5	1.3	53.2	53	53
7	64.8	62.5	60	59.5	5.3	58.6	57.8	57.5	2.0	56.8	56.5	56	1.5	55.8	55.5	55.2
8	63.4	62.5	61	60	3.4	59.4	58.8	58	2.0	57.2	57	56.5	1.5	56	55.8	55.8

Test No. 10.—*Bath of* 51°, *in tub.*

No.	Start.	20s.	40s.	1m.	Fall.	80s.	100s.	2m.	Fall.	3m.	Fall.	4m.	Fall.	5m.	Fall.	6m.	Fall.	7m.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	65.5	53	51	50.5	15	50.5	.....	50.5	.....	50.5	.....	51	.....	51.2	.....	.....	.....	51.5
6	64	62	58	57	7	56	55	54	3	52	2	51	1	49.8	1.2	49.5	0.3	49
7	66.5	64	61.5	59.5	7	58	57	56	3.5	54	2	53	1	51.8	1.2	51	0.8	.....
8	66	64.4	62	60.8	5.2	59.2	58.5	57.2	3.6	55	2.2	53.5	1.5	52.2	1.3	51.5	0.7	.....

Test No. 11.—*Bath of* 50°.5, *in tub.*

No.	Start.	20s.	40s.	1m.	Fall.	80s.	100s.	2m.	Fall.	140s.	160s.	3m.	Fall.	4m.	Fall.	5m.	6m.	7m.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	66	54	50.5	50.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	51	50.2	50.2
6	63	60.5	58	56.5	6.5	54	53	52.5	4	52	51.5	51	1.5	50	1	49.8	49	48.2
7	65	63	60.5	58	7	56.5	55.5	54.5	3.5	54	53.5	53.2	1.3	52.5	0.7	52	51.5	51
8	66	63	61	59	7	57.5	57	56	3	55.2	55	54	2	53.8	0.2	52.4	51.2	50.8

Test No. 12.—*Bath of* 50°, *in aquarium.*

No.	Start.	20s.	40s.	1m.	Fall.	60s.	100s.	2m.	Fall.	140s.	160s.	3m.	Fall.	4m.	Fall.	5m.	6m.	7m.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	70	55	50.3	49	.....	49	.....	49.5	.....	50	.....	.....	.....	50.4	.....	50	50.4	50.4
7	70	67.5	64	61	9	59	57.5	56.5	4.5	55.5	54.8	54	2.5	52.6	1.4	51.6	51	50.5
8	70	68.5	66.5	62	8	61.5	59.8	58.5	3.5	57.5	56.2	55	3.5	53.4	1.6	52.2	51.5	51

Test No. 13.—*Bath, average,* 45°, *in aquarium.*

No.	Start.	20s.	40s.	1m.	Fall.	60s.	100s.	2m.	Fall.	3m.	Fall.	4m.	Fall.	5m.	Fall.	6m.	7m.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	44	.....	.....	.....	.....	44.5	.....	.....	.....	45	.....	45	.....	44.8	.....	45.2	45
7	70	65.5	62.5	59	11	56.5	54.5	52.5	6.5	49	3.5	47.2	1.8	46.5	0.7	45.8	45.2
9	70	67	64.2	61.5	8.5	58.5	56.5	54	7.5	50.5	3.5	48.5	2	47	1.5	46.2	45.6

Test No. 14.—*Bath, average,* 44°.3, *in tub.*

No.	Start.	20s.	40s.	1m.	Fall.	2m.	Fall.	3m.	Fall.	4m.	Fall.	5m.	Fall.	6m.	7m.	8m.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	66.5	48	45	45	21.5	44	.....	43.6	.....	44	.....	44	.....	44.4	44.5	44.5
6	63.5	60	57	54.5	9.0	49	5.5	47	2.0	44.8	2.2	43.5	1.3	43	42.5	42.5
7	66.5	62	59	56.5	10.0	51.5	5.0	49	2.5	47	2	46.5	0.5	45.8	45	44.8
8	66	64	61	58.3	7.7	53	5.3	50.5	2.5	48.2	2.3	46.8	1.4	45.8	45	44.8

Test No. 15.—*Bath* 43°, *in tub, noted by* 10-*second intervals for* 5 *minutes.*

No.	Start.	10s.	20s.	30s.	40s.	50s.	60s.	Fall.	20s.	40s.	2m.	Fall.	3m.	Fall.	4m.	Fall.	5m.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	43.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	43
6	63.5	60	58	55.5	54	53	51.5	12.0	49	47.5	46	5.5	42.6	3.4	41.2	1.4	41
7	65	63.5	61.5	60	58.5	57	55.6	9.4	53.5	51.8	50.5	5.1	47.5	3	45.8	1.7	45
8	65.5	64	63	61	60	58.6	57.8	7.7	55	53	51.5	6.3	47.8	3.7	46	1.8	45

Test No. 16.—*Bath of* 40°, *in aquarium.*

No.	Start.	20s.	40s.	1m.	Fall.	80s.	100s.	2m.	Fall.	3m.	Fall.	4m.	Fall.	5m.	Fall.	6m.	7m.	9m.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	40	.....	.....	.....	.....	.....	.....	40.5	.....	40	.....	40.5	.....	40	.....	40	40	40
7	70	65	60	56	14	53	51	49	7	45.8	2.2	43.5	2.3	42.6	0.9	41.8	41.2	41
8	70	67	.....	59.5	10.5	56.5	54	52	7.5	47.6	4.4	44.2	3.4	42.8	1.4	42	41.2	40.8

Test No. 17.

(Canceled.)

Test No. 18.—*Bath of* 35°, *in aquarium.*

No.	Start.	20s.	40s.	1m.	Fall.	2m.	Fall.	3m.	Fall.	4m.	5m.	6m.	7m.	8m.	9m.	10m.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	36	.....	.....	35.5	.....	35	.....	35	.....	35	34.8	35.2	34.8	35	34.8	35
7	70	65.5	59.5	55	15	46	9	51.5	4.5	39	37.5	36.5	35.8	35.5	35.2	35
8	70	67.5	63	59.5	10.5	49	10.5	43.5	5.5	40.5	38.5	37.5	36.6	36	35.8	35.5

Test No. 19.—*Bath of* 35°, *in tub, recorded every* 10 *seconds for* 4 *minutes.*

No.	Start.	10s.	20s.	30s.	40s.	50s.	1m.	70s.	80s.	90s.	100s.	110s.	2m.	130s.	140s.	150s.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
6	63	62	58	55	54	52	50.5	49	48	46.8	45.5	44.8	43.8	42.8	42.2	41.8
7	65.5	62.5	60	58	56	54.2	53	51.6	50.5	49.1	48.5	47.5	46.8	46	45.2	44.8
8	64	63	61	59	57.5	56.5	54.5	53.5	51.5	50.1	49.5	48.6	48	46.8	46.3	45.8

No.	160s.	170s.	3m.	190s.	200s.	210s.	220s.	230s.	4m.	Remarks.
	°	°	°	°	°	°	°	°	°	
1	35	35	35	35	35	35	35	35	35	
6	41.3	40.6	40	39.5	39	38.7	38.3	38	37.7	Fall in 4 minutes, 25°.3.
7	44.1	43.8	43.1	42.7	42.1	41.7	41.1	41	40.8	Fall in 4 minutes, 24°.5.
8	45.1	44.7	44.3	43.8	43.1	42.8	42.2	41.8	41.3	Fall in 4 minutes, 22°.7.

Test No. 20.—Bath 31°.

In ice broken to the size of a walnut, with sufficient sea-water to fill interstices; depth enough to cover bulbs.

No.	Start.	1m.	Fall.	2m.	Fall.	3m.	Fall.	4m.	Fall.	5m.	Fall.	6m.	Fall.	6½m.	7m.	7½m.	8m.	8½m.	9m.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	31	31.2	.....	31	.....	31	.....	31.2	.....	31	.....	31	.....	31	31	31	31.1	31	31
7	57	48.5	8.5	42	6.5	38.5	3.5	36.5	2.0	35.2	1.3	34.3	0.9	33.8	33	32.5	32	32	32
8	57	52	5	45.5	6.5	40.8	4.7	38	2.8	36.2	1.8	35	1.2	34.5	33.8	33.3	33	32.8	32

Test No. 21.

In a large cake of ice auger-holes were bored and the bulbs of the standard and successively the two Casellas, Nos. 7 and 8, were placed in the holes, and then packed firmly with finely scraped ice. No. 1 fell to 32°.5 very quickly, and then, although looked at every 20 seconds, never varied a particle. The ice was in the shade, and the temperature 67°.

No.	Start.	20s.	40s.	1m.	Fall.	80s.	100s.	2m.	Fall.	140s.	160s.	3m.	Fall.	200s.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5
7	70	65	59	55	15	52	50	48.5	6.5	46.5	45	43.8	4.7	42.8
8	70	68	63	58	12	54	51	49	9	47.2	46	44.8	4.2	43.8

No.	220s.	4m.	Fall.	260s.	280s.	5m.	Fall.	320s.	340s.	6m.	Fall.	7m.	Fall.	9m.
	°	°	°	°	°	°	°	°	°	c	°	°	°	°
1	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5
7	42	41.2	2.6	40.6	40	39.4	1.8	39	38.4	37.8	1.6	36.8	1.0	35.8
8	42.8	42	2.8	41.3	40.8	40.2	1.8	39.8	39.5	39	1.2	38	1.0	37.2

No.	Fall.	9m.	Fall.	10m.	Fall.	11m.	Fall.	12m.	Fall.	13m.	Fall.	14m.	Fall.
	°	°	°	°	°	°	°	°	°	°	°	°	°
1	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5
7	1	35	0.8	34.6	0.4	34.2	0.4	34	0.2	34	.....	34	.....
8	0.8	36.4	0.8	35.8	0.6	34.8	1.0	34.4	0.4	34.2	0.2	34	.....

Test No. 22.

No. 7, from a low temperature, was brought up with warm water, and when at 70°, and rising moderately fast, placed in the ice as before. No. 1 maintaining 32°.5 throughout.

Start.	20s.	40s.	1m.	Fall.	80s.	100s.	2m.	Fall.	140s.	160s.	3m.	Fall.	200s.	220s.	4m.
°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
70	69	67.4	65.4	4.6	63.5	62	59.5	5.9	57	55.5	54	5.5	53	52	51.5

Test No. 22—Continued.

Fall.	260s.	280s.	5m.	Fall.	6m.	Fall.	7m.	Fall.	8m.	Fall.	9m.	Fall.	10m.	Fall.
°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
2.5	50.8	49.2	48.5	3.0	47	1.5	45.5	1.5	41	1.5	42.5	1.5	41	1.5

11m.	Fall.	12m.	Fall.	13m.	Fall.	14m.	Fall.	15m.	Fall.	16m.	17m.	18m.	33m.
°	°	°	°	°	°	°	°	°	°	°	°	°	°
39.5	1.5	38.4	1.1	37.5	0.9	36.5	1.0	35.8	0.7	34.6	33.8	33.5	33.5

This test shows the necessity of care that the mercury is neither rising nor falling when the instrument is sent down for temperature.

Test No. 24.

In a mixture of fine ice, salt, and a little sea-water.

No.	Start.	1m.	Fall.	2m.	Fall.	3m.	Fall.	4m.	Fall.	5m.	Fall.	6m.	Fall.	7m.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	22.5	24	.....	18.5	.....	18.5	.....	17.5	.....	16.5	.....	16.5	.....	17.5
7	69	47	22	33	14	26	7	22.8	3.2	21	1.8	19.8	1.2	19

No.	Start.	1m.	Fall.	2m.	Fall.	3m.	Fall.	4m.	Fall.	5m.	Fall.	6m.	Fall.	7m.	Fall.	8m.	Fall.	9m.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	21	20.5	....	19.5	.....	18	.....	17	....	16	....	15.5	....	16	....	16.5	....	14
8	69	55	14	48	7	40	8	33	7	27.5	5.5	23	4.5	21.5	1.5	19	2.5	18

Test No. 24 is not accurate, as it was impossible to keep the temperature at all regular, the standard going up and down four or five degrees at a jump as we stirred the mixture in the slightest degree.

From the experiments recorded I drew the following results: First, and most important, that there are but few cases where "five minutes are sufficient for the thermometer to take up the temperature of its position," as described in the manual accompanying the instruments, and that the length of time necessary to procure a correct record depends upon the difference between the temperature as recorded by the instruments when being lowered, and that of the temperature which is to be measured.

The following abstract from tables shows the truth of this:

Number of table.	Number of instrument.	Temperature at start.	Temperature of bath.	Difference.	Time by correct record.	Average.	Remarks.
		°	°	°	m. s.	m. s.	
5	7	69	65	4	2 20	2 20	Aquarium.
5	8	69	65	4	2 20		
8	6	65.5	56	9.5	3 40	3 50	Tub.
8	7	65	56	9	3 50		
8	8	65.5	56	9.5	4 00		
9	6	64.8	55	9.8	4 00	3 53	Do.
9	7	64.8	55	9.8	3 50		
9	8	63	55	8	3 50		
6	7	70.5	60	10.5	6 00	6 00	Aquarium.
6	8	70.5	60	10.5	6 00		
10	6	66.5	51	15.5	7 00	6 20	Tub.
10	7	66.5	51	15.5	6 60		
10	8	66	51	15	6 00		
11	6	65.5	50.5	15	7m to 8m	7m to 8m	Tub out 5m at 7m.
11	7	65	50.5	14.5	7m to 8m		Out 8m at 7 m.
11	8	66	50.5	15.5	7 60		
7	7	71	55	16	7 00	7 00	Aquarium.
7	8	71	55	16	7 00		
12	7	70	50	20	7 00	7 00	Do.
12	8	69.5	50	19.5	7 00		
20	7	57	31	26	Over 9m	Over 9m	At 9m 1° out.
20	8	57	31	26	9m to 10m	9m to 10m	At 9m ½° out.
15	6	66	43	23	5m to 6m	.....	Tub.
15	7	65	43	22	5 00	.....	At 5m lacked 2°.
15	8	65.5	43	22.5	5 00	.....	At 5m lacked 1½°.
16	7	70	40	30	9 00	.....	Aquarium; at 9m lacked 1°.
16	8	70	40	30	9 00	.....	Aquarium.
19	6	65.5	35	30.5	.....	.....	At 4m lacked 5°.2
19	7	65.5	35	30.5	.....	.....	At 4m lacked 5°.8 } 5m to 6m.
19	8	64	35	29	.....	.....	At 4m lacked 5°.8
18	7	70	35	35	10 00	10 00	Aquarium.
18	8	70	35	35	10 00		
2	6	69.5	33.5	36.5	12 00		
2	7	68.5	33.5	35	10m to 11m	11m to 12m	
2	8	67.5	33.5	34	12 00		
21	7	70	32.5	37.5	12 60	12 05	Still lacking 1°.
21	8	70	32.5	37.5	13 00		Still lacking 1°.
21	7	70	32.5	37.5	18 00	.....	1° lacking and remained steady 15m longer.
23	7	69	17.5	51.5	7 00	.....	Lacking 2° } Not very ac-
23	8	69	14	55	9 00	.....	Lacking 4° } curate.

Thus, when the difference in temperature is less than 10°, "five minutes are sufficient"; but as the differences increase, so does the time necessary to produce an equilibrium increase. The third experiment in Table 21 points to the necessity of having the mercury perfectly at rest when about to use the instrument.

An experiment was tried to ascertain the effect, if any, of the sun shining on the stems of the thermometers, the temperature in the sun being 71°; four thermometers with bulbs level in a bath were recorded, and the instruments were entirely immersed, with following results:

No. 1, 9 inches exposed, stood 36°.

No. 2, 4 inches exposed, stood 36°.5.

No. 4, 6 inches exposed, stood 36°.

No. 5, 6 inches exposed, stood 36°.5.

Entirely immersed and read in two minutes they stood: No. 1, 36°.2; No. 2, 36°; No. 4, 36°; No. 5, 36°.5. So that no appreciable error arises from this cause.

Experiments on difference of temperature, in a bath of ice-water not agitated.

No. 1.

No. 1, bulb immersed in contact with ice stood 33°, lowered to 100° stood 39°.

No. 2, bulb immersed in contact with ice stood 33°.2, lowered to 100° stood 36°.

No. 4, bulb immersed in contact with ice stood 33°, lowered to 100° stood 37°.

No. 5, bulb immersed in contact with ice stood 33°.4, lowered to 100° stood 36°.

The differences arising from differences in length of stem causing the bulbs to reach different strata.

Experiment No. 2.

No. 1 and No. 2, lying flat on bottom of tub, with 6 inches of water, 3 inches of broken ice, recorded 42°.5. No. 2 was raised with pincers 2 inches, and fell to 40°.

In addition to printed instructions I would respectfully suggest the following:

1. Keep thermometer at uniform temperature before and between lowerings.

2. Have two snaps on the line above the lead, to prevent delay in bending on.

3. Set and note indexes.

4. Note time of reaching lowest depth, and be sure and keep the instrument at its depth over *ten* minutes, unless previous lowerings have taught that the difference between surface and bottom temperatures is less than requires this time.

5. Do not count *as down* the time wasted if the ship be dragging or drifting and the line trailing out at an angle.

6. In reading hold the instrument *perpendicular*, with the bottom of the index on a level with the eye.

7. On registering, note time and tides.

If the mercury becomes badly disintegrated, and swinging and tapping are of no avail, I have succeeded in getting the thermometer to rights by this method:

No. 15,720 was found damaged; on the hot side the mercury was in four parts, one bit 5° in length, separated from the rest by a space of 10°, and nearly as bad on the cold side. Every other means failing, I placed it bulb up in the salinometer pot; having removed the ebonite guard and turned on steam, the mercury mounted on the hot side and formed a sphere at the lower part of the bulb, until nearly all coalesced, leaving still a columnar portion in the tube. I removed it from the sali-

nometer, and in a few moments the column dropped away from the sphere. This occurred twice, when I concluded that it must cool more slowly, so left it in the boiling water, to cool with it. This produced the desired result, and the hot side became perfectly restored. On the cold side I substituted a mixture of ice and salt, in which I placed the bulb, and with an ordinary cologne spray-bottle, substituting sulphuric ether, threw a spray on the bulb, which acted as did the steam. I was compelled to leave the instrument to warm gradually in a vessel of ice-water, and in an hour had it in good working order.

I send herewith a set of diagrams of the curves produced by the different baths tabulated, and am,

Very respectfully,

L. A. BEARDSLEE,
Commander, United States Navy.

Prof. S. F. BAIRD,
United States Fish Commissioner.

To ascertain the correctness of the standard used in the foregoing experiments, it was tested in the apparatus provided by the Signal Corps for testing thermometers—simply a tin can with a perforated tin false bottom about midway of its height to permit the leakage from the melted ice to escape.

A thermometer manufactured by Tagliabue for the Commission, with cylindrical bulb $1\frac{1}{4}$ inches long and $\frac{5}{16}$ in diameter, graduated from 30° to 140°, on a scale of $8\frac{5}{8}$ inches, was compared at the same time. The bulbs were immersed and packed snug in pounded ice. The Tagliabue recorded 31°.6, and the standard 32°.05. The experiment was repeated with the same result.

Respectfully,

L. A. BEARDSLEE,
Commander.

WOOD'S HOLL, *September* 23, 1875.

An additional set of tests were made with the Cassella-Miller thermometer in use this summer at Wood's Hole (No. 1,844). They were made with the utmost accuracy possible, with the same standard in use last summer, and the aquarium. They have developed the reason of the anomalous action of the thermometers in ice.

In test No. 1, in ice, the instrument was placed on its back in a trench cut in the ice, and the bulbs covered with pounded ice. The mercury corresponded in its action very closely to the action of a bath of 50° until it reached that point.

In test No. 2 the upper portion of the ebonite guard was removed, thus letting the crushed ice come into immediate contact with the upper

portion of bulbs. This induced quicker action, but still slower than a bath of 35°; and at last, as in former cases, the mercury apparently ceased to fall at 35°.

This experiment is put in simply for the purpose of guarding other experimenters against the mistake.

The standard, as in last year's tests, did not vary from 32°.05.

Respectfully,

L. A. BEARDSLEE,
Commander, United States Navy.

Experiments with Casella-Miller, No. 1844.

Time int.	Bath, 60°.		Bath, 55°.		Bath, 50°.		Bath, 45°.		Bath, 40°.		Bath, 35°.		Ice-bath, 32½°.		Ice-bath, 32½°.	
	Standard.	Casella-Miller.	Standard.	Casella-Miller.	Standard.	Casella-Miller.	Standard.	Casella-Miller.	Standard.	Casella-Miller.	Standard.	Casella-Miller.	Standard.	Casella-Miller.	Standard.	Casella-Miller.
m. s.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
0 00	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
0 20	60.0	66.2	55.0	67.5	50.0	68.0	45.0	67.5	40.0	66.5	35.0	64.5	38.0	67.5	32.5	66.0
0 40	60.0	67.5	55.0	64.5	50.0	65.0	45.0	64.5	40.1	63.1	34.6	58.5	32.5	65.0	32.5	61.2
1 00	60.0	66.5	55.0	62.5	50.2	63.0	45.0	62.0	40.2	59.8	34.6	54.5	32.5	63.5	32.5	57.5
1 20	60.0	66.0	55.0	60.5	50.2	61.0	45.0	59.5	40.2	56.9	34.6	50.0	32.5	61.8	32.5	54.0
1 40	60.0	65.0	55.0	59.2	50.5	59.5	45.0	57.8	40.2	54.5	34.6	48.0	32.5	60.2	32.5	52.0
2 00	60.0	64.5	55.0	58.2	50.2	58.2	45.0	56.0	40.2	52.4	34.6	46.0	32.5	59.0	32.5	50.0
2 20	60.0	64.0	55.0	57.5	50.5	57.0	45.0	55.0	40.0	50.1	35.0	44.5	32.5	58.0	32.5	48.0
2 40	60.0	63.5	55.0	57.0	50.5	56.6	45.5	54.0	40.0	49.4	35.0	43.5	32.5	57.0	32.5	46.8
3 00	60.0	63.0	55.0	56.6	50.5	55.0	45.0	53.0	40.1	48.1	35.0	42.0	32.5	56.2	32.5	46.6
4 00	60.5	62.0	55.2	56.0	50.0	53.2	45.0	50.2	40.2	46.3	35.0	40.5	32.5	54.0	32.5	44.8
5 00	60.5	61.8	55.2	55.6	50.2	52.6	45.0	48.8	40.2	44.0	34.6	37.0	32.5	52.0	32.5	40.0
6 00	60.5	61.5	55.0	55.2	50.4	52.2	45.0	47.5	40.2	42.2	34.6	35.5	32.5	50.5	32.5	38.8
7 00	60.5	61.2	55.0	55.0	50.0	51.8	45.0	47.0	40.0	41.8	34.8	35.0	32.5	49.0	32.5	37.5
8 00	60.5	61.0	55.0	55.0	50.0	51.2	45.0	46.0	39.8	41.2	34.5	35.0	32.5	47.5	32.5	37.2
9 00	60.5	61.0	55.0	55.0	50.2	51.2	44.8	46.0	39.0	40.6	34.5	34.5	32.5	46.2	32.5	36.8
10 00	60.5	61.0	55.0	55.0	50.4	51.0	45.0	45.8	39.5	40.2	34.5	34.5	32.5	45.0	32.5	36.5
11 00	.....	.....	.....	.....	50.4	51.0	45.0	45.8	40.0	40.0	34.5	34.5	32.5	43.0	32.5	36.2
12 00	.....	.....	.....	.....	.....	.....	45.0	45.8	40.0	40.0	.....	.....	32.5	42.2	32.5	36.0
13 00	.....	.....	.....	.....	.....	.....	45.0	45.8	40.0	40.0	.....	.....	32.5	40.5	32.5	35.4
14 00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	32.5	39.5	32.5	35.0
15 00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	32.5	38.5	32.5	35.0
20 00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	32.5	38.0	32.5	35.0
22 00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	32.5	35.6	32.5	35.0
25 00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	32.5	35.1	32.5	35.0
														35.2	.....	.....