ART. XLIII.—*Thermometer Exposure;* by H. A. HAZEN.

[Read before the Philosophical Society, Washington, D. C., October 13, 1883.]

THE subject of thermometer exposure may be discussed under two general divisions. The first of these relates to the locality in any large region where the thermometer shall be exposed, in order that it may give the true air temperature of the locality. The second relates to the immediate environment of the thermometer which shall fulfill the same requirement.

Under the first of these divisions: height above ground; proximity of trees or houses; freedom of access of air; absence of local heat effects; character of ground, etc., are all important. A great diversity of opinion relative to many of these points exists, but it may be said that a good height above ground and no interruption of the wind seem essential. If a thermometer is too near the earth's surface it will be affected unduly by dampness and fog which has a tendency to settle at a low level, and moreover, unless exposed on the summit of a hill, there will be danger of an interruption to the wind, so that in hot, nearly calm weather the air will become stagnant, thus vitiating the result we seek. For example, mean monthly temperatures from a maximum thermometer 4½ feet above ground in New Haven, Conn., were from four to five degrees higher during the summer months, than from a maximum thermometer, having free access of the wind, on a roof 111 feet above the ground, and about 500 feet from the first thermometer.

Careful experiments upon an open scaffolding at heights up to 80 feet have been made under the direction of Professor Wild, of St. Petersburg. Little difference was found in the warmer months in the air temperature of different heights. In general also the relative humidity was higher near the ground with a few notable exceptions, for example, the following table exhibits the mean relative humidity for four months' observations.

Relative humidity at various heights.

Month.	1·9 Meters.	15·9 Meters	26·3 Meters.
June, 1873,	63·3%	59·0%	70·1%
July,	62·2	62·0	60·7
June, 1874,	57·6	56·8	55·7
July,	72·1	71·4	76·2

It seems impossible to explain these peculiar results which do not follow any law with respect to height; on the whole, however, the humidity has a tendency to increase with approach to the earth's surface.

In order to show the importance of obtaining a proper locality for exposing a thermometer, table I is given which shows temperature and humidity at various places in Washington, D. C. (These and many other experiments have been tried and introduced in this paper since its original presentation to the Philosophical Society).

TABLE I.

Date.	Time.	Locality.	Dry.	Wet.	R. H.	Dist.fr'm Roof.
1883.						
Nov. 17,	6.45 P. M.	Roof.	36·1	29·5	41	
	6.50 "	Roof.	35·7	29·5	44	
	6.55 "	Roof.	35·6	29·2	42	
	7.41 "	Pa. av. and 17th st.	35·0	28·3	39	½ block.
		Pa. av. and 16½ st.	33·1	27·5	45	½ "
	7.55 "	I and 15th st.	34·0	27·6	40	3½ blocks..
		K and 15th st.	33·9	27·5	39	4½ "
		M and 15th st.	32·9	27·3	45	6½ "
		R. Island av. and 15th st.	30 3	25·9	53	7½ "
		P and 15th st.	30·5	26·1	53	9 "
	8.14 "	Q and 15th st.	29·9	25·6	54	10 "
		Corcoran and 15th st.	29·5	25·4	57	11 "
						=1⅛ mile..
Nov. 19,	6.45 P. M.	Roof.	48·2	41·0	48	
	7.00 "	Roof.	48·1	41·0	49	
	7.15 "	On ground.	44·5	38·5	53	
		Pa. av. and 16½ st.	42·6	37·3	56	
		H and 16th st.	42·3	37·3	58	
	7.30 "	L and 16th st.	39·9	35·9	64	
		O and 16th st.	38·8	35·1	66	
		Corcoran and 16th st.	38·3	34·9	68	
	8.00 "	R and 16th st.	36·9	34·0	71	
		Corcoran and 15th st.	37·8	34·7	71	
Nov. 20,	6.30 A. M.	Corcoran and 16th st.	31·4	30 3	88	
		P and 16th st.	31·9	30·4	84	
		M and 16th st.	32·0	30·4	83	
		H and 16th st.	31·9	30·3	83	
		Pa. av. and 17th st.	33·1	31·3	82	
	7.03 "	Roof.	35·9	32·8	70	
	7.08 "	Roof.	36·3	33·1	69	

On November 19 there is a remarkable difference of over 11° between the extreme stations with a corresponding difference of 23 per cent in the relative humidity. The results are not strictly comparable owing to the difference in time between the observations, yet as the temperature was changing but slowly this consideration can have little weight. Experiments are still under way relative to this matter.

Taking up now the second division of the subject, we find that the necessity of an uniform and satisfactory shelter or screen for thermometers has long been recognized. The international meteorological council, at the Berne meeting, while not recommending any particular form of shelter, yet urged the desirability of more extended experiment. Thermometers suspended in free air, in the shade of a dwelling or wall during the day, will give an approximate daily local temperature though generally too low both day and night. If, however, it be desired to critically study the past records, or what is more important to compare observations, whether mean or daily, at different stations it will manifestly be necessary to eliminate from them all effects of improper exposure.

It may be argued that the most important consideration is that of uniformity and that constant errors may be neglected, provided they are the same in all the exposures. If, however, varying atmospheric conditions diminish or intensify constant sources of error, it is wise to avoid these as much as possible. The essential point to be regarded is that a shelter shall at any and all times give an air temperature influenced as little as possible by harmful causes.

To accomplish this the following conditions must be realized if possible. 1st. There should be a perfect access of the air, whose temperature we wish to ascertain, to the thermometer. It will be seen that under all circumstances this is necessary for even if, as is frequently done, an artificial means of ventilation is employed, yet if the shelter affects in any way the air temperature or prevents the free circulation of air, it must to a certain extent vitiate the result obtained from the air propelled to or stirred about the thermometer.

2d. The shelter should shield, from all reflected heat, from direct radiation from the sun by day, to the sky by night, and from radiation from surrounding objects.

3d. No moisture should reach the thermometer.

The questions to be answered by experiment then, are, which if any of these conditions may be neglected, and what is the best form of shelter for accomplishing the desired result.

The forms of shelters adopted by different countries have been exceedingly diverse. That of the French, the "Renou" stand, consisting of a nearly horizontal platform under which the thermometers are exposed at 6¼ feet above sod, very nearly fulfills the first condition above. The east and west side pieces however, employed for screening from the morning and afternoon sun, would seem to check very light winds on those sides, and there does not seem to be sufficient provision against soil or sod radiation. A shelter similar in plan to this has been adopted as a standard in Melbourne, Australia. This shed has 144 square feet of horizontal surface, two roofs, of galvanized iron, nine inches apart, the ridge of the outer roof eight feet above ground, the thermometers suspended in a wire cage one foot below the inner roof. On the east and west are louvres to shield it from the rising and setting sun. In calm weather it would seem as though this shed would give too much shade.

In England, the Glaisher stand has been largely used. This consists of an upright frame which is rotated with the sun's motion so as to keep one side, on which the thermometers are placed at about four feet above sod, continuously in the shade of the frame. Professor Wild has shown that this stand may give four or five degrees too high temperature by day from sod radiation, and at night the same number of degrees too low by radiation to the sky and from surrounding objects. The Stevenson shelter is also in great favor in England, and consists of a cubical screen, of double louvres, 18″ long and high and 10″ wide. This is placed at a height of 4′ above sod. Professor Mohn, of Christiania, has shown that in the sun this shelter gives too high values. It is undoubtedly too small and close to give good results. A shelter similar to the above has been devised by Rev. F. W. Stow, of England. (Quart. Jour. Met. Soc., vol. viii, p. 234.) This is somewhat larger than Stevenson's and has metallic louvres instead of wooden. It has the advantage of great ease in construction and of good ventilation.

In Spain a double metallic shelter has been used. This has an inside louvre box 14×14×17 inches, between the inside and outside louvres there is a free air space and connected with this there is a common vane ventilator. In Russia, Professor Wild has constructed a novel form of shelter which has attracted much attention. This consists of a large cubical frame of wood, having the south side and roof double boarded (the free air space between these boards is connected throughout), the east and west sides of single louvres and the north side entirely open. There is no bottom but upon a cross-piece inside is placed a metallic screen of four quarter cylinders upon a central spindle, with the top and bottom cone-shaped. These cones have their elements parallel, thus causing more or less draft. The two opposite, outside quarter cylinders are rotated upon the spindle so as to expose to view the thermometers. The latter are at a height of 11 feet above sod. This form of shelter is open to the objection that it prevents a free access of air, the double boarded south side cutting off all south wind is especially unsatisfactory in this regard.

It is of the utmost importance that there should be a standard of comparison in all experiments, and this we have in the swung thermometer, called by the French thermometer fronde, which is a common thermometer attached to a string or wire, and rapidly swung through a circumferance whose radius is the length of the string. After experimenting some time a form of dry and wet bulb "fronde" was devised, which has been in constant use since and has given good satisfaction. The thermometers were lashed together, the stem of one two inches longer than the other, in such a manner as to bring the wet bulb about two inches below the dry. This permits of immersing the wet bulb without wetting the dry. A few swings only are needed in making an observation, it is swung perhaps forty or fifty times, then read, swung again and read, etc., it seldom requires more than three attempts except in very cold weather, 0° and below. This "fronde" is especially commended for experiments upon temperature and hygrometric conditions at any place where it is proposed to establish a meteorological station.

The theory of this thermometer is that since it is rapidly brought in contact with a large mass of air it must give its temperature unless the results are vitiated by other causes. It has been objected, for example, that friction with the air will tend to raise the temperature, and that the centrifugal force will on the contrary tend to depress the mercury column. Repeated experiments at low and high velocities (3 and 18 miles per hour), have invariably given the same results, showing that these causes do not produce harmful effects at any velocities possible by hand. This standard has been compared by Professor Wild with his shelter just described, and he concludes that during the day it shows about 0·7° too high a temperature, while at night it gives the same amount too low. It may be regarded as an open question whether this does not show that the difficulty was in the shelter rather than in the so-called standard. In order to make comparisons with any thermometer by day, it is essential to determine the effect of the sun or to shield from it. One of the difficulties met with in the use of "fronde" has been its extreme sensitiveness to the slightest air current, requiring several trials at each observation the mean of these giving the temperature sought. To determine the effect of direct sun heat, trials were made in the shadows of high isolated trees and in the shade of Washington monument, when the air was still or had very little motion, with the result that at midday with a clear sky, in the summer time, the temperature given by "fronde" may be ·7 to 1·0 degree higher in the sun than in the shade. It cannot be considered however, that such a shade temperature as was used represents the exact air temperature, but it was nearly correct, perhaps the true value of the air temperature was somewhat higher, and that the effect of the sun heat is a little less than 0·7°.

Since a thermometer exposed to the clear sky reads at times one degree lower than if sheltered, we might conclude that the "fronde" will be liable to the same effect unless entirely overcome by its rapid motion through a large body of air. Observations on clear nights in September and October have shown the "fronde" sometimes ·2 or ·3 degrees higher and sometimes the same amount lower than a thermometer from which all radiation was cut off. Experiments are still needed in summer and in different situations to fully settle the question, but it seems probable that the "fronde," if shielded from direct sun heat during the day, will give at all times the most accurate temperature that can be obtained.

The following brief description of some of the previous experiments in this field, will serve as an introduction to subsequent work. Possibly the most complete results hitherto published are those from observations taken, under the auspices of the English Royal Society, upon a large open field at Strathfield Turgiss. The observations were taken at 9 A. M., 3 P. M., and 9 P. M., from November, '68 to April, '70 inclusive, January, '70 only being omitted. The stands tested consisted of eight forms ranging between the open stand like Glaisher's and the closed like Stevenson's. As a result of these tests it was decided that the Stevenson was least faulty, though it was not claimed that even this was all that could be desired, and especially as regards hygrometric observations.

Another series of tests has been published in a Quarterly Report for 1880. These consisted in readings at Kew, at 9 A. M. and P. M., from June '79 till November '81, of thermometers in a Stevenson stand 4′ 4″ above sod and in a Wild's shelter near the former but 12′ above sod. The published cut of the photograph of the outside wooden structure of the latter, however, shows louvre work on the south side and indicates that Professor Wild's idea was not fully carried out. The result would have been somewhat different if the south side of the Wild shelter had been closed. The means showed nearly identical temperature in the two shelters, the Wild reading ·1° lower. The mean of the maximum was ·3° higher and of the minimum ·6° lower in the Wild. The monthly mean relative humidity ranged from one to two per cent lower in Wild's. Comparing individual differences between the two the highest that Wild's read above the other was 1·9° while the lowest was 3·5° (it would be a matter of much interest if the atmospheric conditions giving such large differences between two shelters so near each other could be studied). These comparisons would seem to show a lack of ventilation in the Wild shelter as that was so much higher than the other that the wind should have had freer access to it. Also a mere agreement between the two cannot be regarded as proving the accuracy of either, but since there are manifest defects in the Stevenson we may conclude that neither is satisfactory. Comparisons are also given between the Stevenson shelter and the Kew thermograph records which show the latter ·49° higher at 9 A. M. and ·82° lower at 9 P. M. Possibly these differences may be due in part to a freer exposure of the thermograph to the air.

In entering upon a series of experiments it was deemed best to construct a so-called Pattern shelter, whose main points should be good size and a free access of air to the interior. This shelter is 4×3×3 feet with single louvre work on all sides three inches wide and inclined at an angle of 30° to the horizontal. The roof is double and the bottom close. The north side is a door which can be removed. By the kindness of Mr. Clark, opportunity was granted for conducting the experiments upon the roof of one of his buildings in a thickly settled part of Washington. This roof is about 60 feet above ground, and is free to air currents save from the southeast. There were three shelters employed. A "Stow" about 12 feet above the roof and two "Patterns" at heights of 12 and 16 feet. At first the door of the lower "Pattern" was removed and a Wild metallic screen inserted, after several weeks' comparison this screen with its thermometers was placed in the upper "Pattern," its door having been removed.

The following plans and precautions were taken to determine the adaptability of these shelters, and to check the thermometers:

1st. The relative air circulation in the interiors has been obtained by comparison between dry and wet bulb thermometers and the effect of thorough ventilation has been learned by comparing the wet bulb in the shelter with the "fronde."

2d. The relative amount of reflective heat entering the shelter has been ascertained by using a black bulb thermometer, i. e. an ordinary thermometer with its bulb coated with lampblack.

3d. The readings of the three thermometers in each shelter were checked by using similar traveling thermometers which were placed in each shelter in succession, and numerous comparisons made.

4th. The thermometers used had cylindrical bulbs, with the exception of two in "Stow," and have been twice carefully compared with a standard, once at temperature 6° below zero. All readings have been corrected for instrumental error.

5th. All the observations have been made by one person, and it has been the practice to read forward and back, at nearly all times, in order to eliminate as much as possible effects of changes in temperature between the first and last observation.

6th. In making comparisons it has been deemed best usually to make a continuous series of readings for an hour or more, as a single reading a few times each day will hardly give what we wish except for the mean; while continuous observation, under known conditions which are slowly changing, will enable us to follow effects due to gradually rising or falling temperature, the increase or decrease of wind velocity, the shifting of the wind, slowly changing humidity, etc.

The following are a few of the results collected from the observations since September 1, 1883.

To determine the least size of a shelter necessary to overcome the effects of heat from the sides, there were arranged from east to west in the upper "Pattern," nine thermometers at equal distances. Observations were made in the early morning and in the afternoon. Under the most favorable conditions the inside of a shelter farther from the sun will undoubtedly give a slightly too low temperature in the morning owing to the fact that it is farther from the sun, but this effect will be exceedingly slight, and in fact will be entirely overcome if there is any breeze. Oftentimes with a still air and hot sun on one side of the shelter, if a slight breeze happened to spring up on that side the temperature would be brought even lower than on the opposite side; in fact so much difficulty was encountered from such gusts that it was found necessary after a while to fasten a test tube to each thermometer to shield it.

Table II shows the results of these observations.

Considering the difficulty of comparing thermometers hung side by side in free air, the accordance of these results is very satisfactory. In the morning there is a mean difference of 1·8° between the east and west sides; a fall of ·55° or nearly $\frac{1}{3}$ the whole amount, in the first 9 inches, and one of 1·2° or $\frac{2}{3}$ in the first 18 inches. In the afternoon there is a fall of 1·5° from west to east, in the first 9 inches it was about $\frac{1}{4}$ the whole fall and in the first 18 inches it was nearly $\frac{1}{2}$, i. e. in September a thermometer at 9 inches from the side of a shelter would indicate in calm sunny weather a temperature uniformly about 1·2° too high. Experiments are still needed in midsummer, with larger shelters, with double louvres, with metallic louvres and with traveling thermometers. We may conclude that a single louvred shelter exposed directly to the sun's rays should have the clear inside length not less than 36 inches.

Table III shows observations in the three shelters "Stow" (A), "Russian" (B) and "Pattern" (C); there are also added results from dry and black traveling thermometers and from a thermometer exposed on the *outside* of "Pattern."

Column 1 gives the mean time of each set or of five successive observations, the next five columns give, the dry and wet thermometers, the relative humidity from these, the black thermometer and the difference between this and the dry, in (A); the next five give the same values for (B); the next five for (C); the next three give the dry and black and their dif-

TABLE II.—*Comparisons of thermometers placed in a "pattern" shelter 4·5″ apart in an east and west direction, the outside ones being 4·5″ from the sides.*

Each figure represents the mean of five consecutive observations.

MORNING OBSERVATIONS.

Date.	Time.	Thermometers. I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	Wind.	Weather.
Sept. 6, 1883,	7.23 to 7.29 A. M.	57·74	56·96	56·60	56·40	56·42	56·02	56·04	55·88	55·98	Calm.	Sun bright.
" 7,	7.09 to 7.14 "	57·20	56·42	56·02	55·90	55·82	55·48	55·38	55·28	55·28	Lt. S.W.	"
" 7,	7.14 to 7.20 "	58·66	57·98	57·72	57·42	57·46	57·12	57·14	56·86	56·96	"	"
" 15,	7.07 to 7.12 "	69·34	69·08	68·72	68·26	68·10	67·94	67·78	67·54	67·70	Calm.	"
" 15,	7.12 to 7.18 "	70·30	70·00	69·60	69·14	68·98	68·82	68·56	68·24	68·40	"	"
" 26,*	6.51 to 6.55 "	51·80	51·20	[50·84]†	50·68	50·24	50·00	50·00	50·00	49·90	Lt. N.	"
" 26,*	7.10 to 7.15 "	52·76	52·36	[52·00]†	51·86	51·24	51·06	51·32	51·06	50·98	"	"
	Mean.........	59·69	59·14	58·79	58·52	58·32	58·06	58·03	57·84	57·89		

AFTERNOON OBSERVATIONS.

Date.	Time.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	Wind.	Weather.
Sept. 6, 1883,	4.31 to 4.43 P. M.	72·36	72·66	72·58	72.76	72·92	73·18	73·22	73·36	73 86	Lt. S.	Sun bright.
" 6,	4.45 to 4.50 "	72·50	72·60	72·56	72.98	73·12	73·26	73·32	73·42	73·94	"	"
" 26,*	4.27 to 4.32 "	63·24	63·38	[63·38]†	63·38	63·56	64·04	64·36	64·66	64·76	Calm.	"
	Mean.........	69·37	69·55	69·51	69·71	69·87	70·16	70·30	70·48	70·85		

* These observations were made after first inserting each thermometer in a test-tube in order to cut off fluctuations due to slight gusts of wind.

† Thermometer III was needed in another place; bracketed values have been interpolated.

TABLE III.—*Temperature observations in Stow, Russian and Pattern shelters, and in free air.*

Each reading represents the mean of five observations, October 10, 1883.

Time.	A–Stow.					B—Russian.					C—Pattern.					Traveling Thermometers in Pattern.			Ther. Free Air.
	Dry.	Wet.	Rel. Hum.	Black.	Black minus Dry.	Dry.	Wet.	Rel. Hum.	Black.	Black minus Dry.	Dry.	Wet.	Rel. Hum.	Black.	Black minus Dry.	Dry.	Black.	Black minus Dry.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
12.32 P.M.	72·7	62·8	54	73·1	·4	73·4	63·6	56	73·6	·2	71·9	62·4	56	72·7	·8	71·8	72·5	·7	73·3
12.38	72·8	62·9	55	73·2	·4	73·6	63·8	56	73·8	·2	71·8	62·4	56	72·6	·8	71·9	72·4	·5	73·9
12.48	72·6	62·9	55	73·0	·4	72·9	63·3	56	73·2	·3	71·2	62·0	57	72·1	·9	71·5	71·9	4	73·9
12.53	71·9	62·7	57	72·3	·4	72·9	63·2	56	73·2	·3	71·2	61·8	56	72·0	·8	71·4	71·8	·4	73·3
1.00	71·8	62·0	55	72·1	·3	73·1	63·2	55	73·5	·4	71·2	61·7	55	71·9	·7	71·2	71·8	·6	73·4
2.47	74·6	63·0	49	74·9	·3	75·6	64·3	51	76·0	·4	74·0	63·0	51	74·8	·8	74·0	74·8	·8	76·7
2.54	74·6	63·1	50	74·8	·2	75·6	64·4	51	75·8	·2	74·2	63·0	50	75·0	·8	74·3	74·8	·5	76·5
2.59	74·7	63·1	49	74·9	·2	75·3	63·9	50	75·4	·1	74·1	62·9	50	74·7	·6	74·1	74·7	·6	76·0
3.06	74·6	63·5	51	74·9	·3	75·6	64·4	51	75·8	·2	74·2	62·8	50	75·0	·8	74·4	74·8	·4	76·3
3.12	75·3	64·1	51	75·6	·3	75·8	64·7	52	76·0	·2	74·6	63·4	51	75·5	·9	74·8	75·2	·4	76·8
Mean....	73·6	62·0	52·6	73·9	·32	74·4	63·9	53·4	74·6	·25	72·8	62·5	53·2	73·6	·79	72·9	73·5	·53	75·0
																In Russian.			
3.31 P.M.	75·9	64·3	50	76·2	·3	76·3	65·0	51	76·6	·3	74·8	63·5	50	75·6	·8	76·4	76·4	·0	77·4
3.38	75·3	63·8	50	75·7	·4	75·8	64·6	52	76·0	·2	74·7	63·3	50	75.5	·8	75·8	75·9	·1	76·8
3.46	75·0	63·4	49	75·4	·4	76·0	64·7	51	76·2	·2	74·6	63·1	50	75·4	·8	76·0	76·1	·1	77·0
3.52	74·8	63·1	49	75·1	·3	75·6	64·2	51	75·8	·2	74·1	62·6	49	75·0	·9	75·6	75·6	·0	76·5
4.26	74·6	63·0	49	74·8	·2	75·3	64·0	51	75·4	·1	74·4	62·6	49	75·0	·6	75·2	75·1	·1	76·1
4.32	75·0	63·1	48	75·3	·3	75·4	63·9	50	75·5	·1	74·4	62·7	49	75·1	·7	75·4	75·3	·1	76·0
4.38	74·6	63·4	51	74·8	·2	74·8	64·2	53	75·0	·2	74·2	62·8	50	74·9	·7	74·8	74·8	·0	75·2
4.44	74·2	62·8	50	74·3	·1	74·6	63·9	53	74·8	·2	73·5	62·1	49	74·5	1·0	74·6	74·7	·1	75·1
4.49	73·8	63·3	53	73·9	·1	74·2	64·0	54	74·4	·2	73·4	62·7	52	73·8	·4	74·0	74·0	·0	74·3
4.56	73·6	63·4	54	73·6	·0	73·6	64·1	57	73·8	·2	73·0	62·8	54	73·5	·5	73·6	73·6	·0	73·3
Mean....	74·7	63·4	50·3	74·9	·23	75·2	64·3	52·3	75·4	·19	74·1	62·8	50·2	74·8	·72	75·1	75·1	·01	75·8

NOTE.—Weather calm and clear.

ference as determined from traveling thermometers placed successively in (B) and (C); the last column gives the temperature from a free thermometer.

Comparing these, we see from columns (7) (10), (12) (15), and (17) (18) that observations of dry and black in (B) and (C) are directly comparable. We find the black in (B) more than ·5° lower than in (C), though (C) shows the dry at the same time more than 1·0° lower than (B). This would seem to indicate that the free black bulb thermometer cannot aid in determining the true air temperature in a shelter, and also that, if a free circulation of air is provided for, the effect of reflected heat may be neglected. We also find that (C) gives a relative humidity ·2 per cent in one group and 2·1 per cent in the other *lower* than (C), while (A) agrees well with C.

Table IV gives a comparison of all observations of dry and wet thermometers from Sept. 20 to Oct. 11, and from Oct. 31 to Nov. 7; between these two sets the "Russian" screen was put in the upper "Pattern."

TABLE IV.—*Comparative observations in Stow A, Russian B and Pattern C shelters.*

Date.	No.	Wind.	Weath.	Stow.			Russian.			Pattern.		
				Dry.	Wet.	R. H.	Dry.	Wet.	R. H.	Dry.	Wet.	R. H.
Sept. 20,	25	Light.	Clo.	71·4	57·4	37·3	71·2	57·3	37·4	71·1	57·0	36·6
" 21,	95	Light	Fair.	73·4	59·1	37·9	73·0	58·9	38·3	72·9	58·7	37·8
" 26,	140	Brisk.	Clear.	59·0	48·4	40·1	58·3	48·7	44·6	58·3	48·5	43·6
" 27,	65	Brisk.	Fair.	71·3	61·8	55·5	71·3	62·1	56·9	70·9	61·7	56·6
" 28,	100	Light	Haze.	77·5	67·6	57·6	77·5	67·5	57·2	76·8	67·1	58·0
" 29,	75	Brisk.	Fair.	68·8	61·7	64·7	68·6	61·3	63·7	68·1	61·1	64·8
Oct. 3,	45	Light.	Clo.	63·5	56·2	60·7	63·6	56·5	61·6	63·3	56·3	62·1
" 5,	50	Light.	Fair.	55·0	45·5	41·6	54·9	46·1	45·5	54·4	45·4	43·8
" 10, A. M.	140	Light.	Clear.	69·2	60·7	58·5	69 1	61·3	61 7	67·8	60·0	60 9
" 10, P. M.	95	Light.	Clear.	74·0	63·1	51·5	74·5	63·9	53·1	73·5	62·7	51·6
" 11, A. M.	80	Brisk.	Clear.	69·8	59·5	51·1	70·0	59·9	52·0	69·8	59·2	49·7
" 11, "	75	Brisk.	Clear.	78·6	62·0	34·2	78·3	62·2	35·7	78·3	61·1	32·0
Total	985											
Mean	....	......	......	69·3	58·6	49·2	69·2	58·8	50·6	68·8	58·2	49.8
OBSERVATIONS WITH RUSSIAN AT 16 FEET AND PATTERN AT 12 FEET.												
Oct. 31,	15	High.	Clear.	67·1	52·8	31·7	67·0	53·0	32·7	67·2	52·8	31·1
Nov. 1,	25	Light.	Clear.	43·3	35·4	37·4	43·0	35·8	38·4	43·0	34·9	34·6
" 3,	65	Brisk.	Clear.	51·2	41·8	37·5	50·1	41.6	41·8	50·9	41·4	36·7
" 5, A. M.	40	Calm.	Clear.	55 4	48·7	59·6	55·5	49·0	60·1	56·2	49·1	57·2
" 5, P. M.	20	Calm.	Clear.	63·2	53·2	47·5	62·4	52·9	50·0	62·8	52·8	47·2
" 7,	20	High.	Clear.	50·1	42·2	46·5	49·7	42·2	48·5	50·1	42 2	46·5
Total	185											
Mean	....	......	......	55·0	45·7	43·4	54·6	45·8	45·2	55·0	45·5	42·2

In the first series we find "Pattern" giving a mean temperature ·4° lower than "Russian" with a mean relative humidity ·8 per cent lower. In the second series we find the "Pattern" which is now twelve feet above roof giving ·4° higher temperature and a relative humidity 3·0 per cent lower. Taking the mean of the two series we find no difference in the temperature, while the "Pattern" gives a relative humidity nearly 2·0 per cent lower.

The lack of ventilation in the Russian may be best shown by taking observations of the wet bulb when its temperature is below freezing. As shown in "Science," June 8th, 1883, it is under these conditions that ventilation is most needed.

Table V exhibits individual readings of dry and wet thermometers. 1st, "fronde;" 2d, "Russian;" and 3d, "Pattern."

TABLE V.—*Comparison of dry and wet "fronde" with Russian and Pattern.*

	"Fronde," 14 ft.			Russian, 16 ft.			Pattern, 12 ft.			Time.	Wind.	Weather.
	Dry.	Wet.	R. H.	Dry.	Wet.	R. H.	Dry.	Wet.	R. H.			
Nov. 13	31·7	26·3	45	31·5	31·5	--	31·6	26·9	52	7.23 A. M.	Calm.	Clear.
	32·0	26·7	47	31·9	31·4	95	32·3	26·8	44	7.31	"	"
	32·8	26·9	42	32·9	30·5	75	33·2	27·3	43	7.44	"	"
	34·4	28·7	47	34·7	30·6	62	35·1	29·7	50	8·09	"	"
Nov. 14	32·8	26·4	38	33·1	27·1	42	32·8	26·7	40	7.03 P. M.	Brisk N.W.	"
	33·1	26·3	34	33·2	28·0	49	32·9	27·1	43	7.16	"	"
	32·9	26·2	35	33·0	27·3	44	32·7	26·5	39	7.25	"	"
Nov. 15	22·8	20·4	68	23·0	31·2	--	23·0	22·7	96	7.05 A. M.	Calm.	"
	23·5	20·7	63	23·3	30·0	--	23·2	21·2	73	7.15	"	"
	23·8	21·4	68	23·5	24·2	--	23·7	21·7	74	7.25	Light S.	"
	35·4	27·9	32	35·3	30·4	55	36·2	31·8	58	11.03 A. M.	Light S.S.W.	"
	35·1	28·5	40	35·3	31·6	58	36·0	29·6	43	11.19	"	"
	35·1	28·1	36	35·4	30·6	56	36·6	30·5	46	11.30	"	"
	35·1	28·2	37	35·4	30·1	51	36·2	29·8	43	11.35	"	"
Nov. 17	41·1	31·7	23	40·5	33·3	38	42·7	33·2	24	3.00 P. M.	Calm.	"
	41·6	31·1	20	41·1	32·3	27	41·4	31·7	21	3.17	Light S.S.W.	"
	36·1	29·5	41	35·4	30·6	56	35·2	30·3	54	6.45	"	"
	35·7	29·5	44	35·4	30·4	54	35·3	30·1	52	6.50	"	"
	35·6	29·2	42	35·2	30·3	55	35·2	30·1	53	6.55	"	"
Nov. 20	35·9	32·8	70	35·0	34·4	94	34·9	33·9	86	7.03 A. M.	Calm.	"
	36·3	33·1	69	34·9	33·3	84	34·9	33·0	81	7.08	"	"
	35·2	32·7	75	35·1	33·4	83	34·8	33·2	84	7.18	"	"
	35·9	33·1	72	35·3	33·7	86	35·2	33·3	81	7.30	"	"
	36·1	33·4	73	35·6	33·8	82	35·4	33·6	81	7.35	"	"
Mean --	33·8	28·3	48·4	33·5	30·8	---	33·8	29·2	56·7			
Mean, omitting the four observations in which wet was higher than dry in Russian.	35·4	29·5	45·8	35·2	31·2	62·3	35·4	30·4	53·3			

The mean results in Table V show nearly identical air temperatures by the three methods, but a relative humidity more than 16 per cent too high for "Russian" and over 7 per cent for "Pattern."

The following conclusions are advanced:

1st, Thermometer shelters when exposed to direct sun heat should be at least 36″ long.

2d, With proper precautions the thermometer "fronde" both dry and wet will give the most correct air temperature and relative humidity.

3d, The interposition of a second louvre seems hardly necessary; it not only prevents the free access of air, but also if ventilation is used it must affect the air which is propelled to the thermometer.

4th, While the thermometers in a single louvred shelter may in heavy storms be wet, yet it takes but a moment to wipe the bulb dry, besides in rainy weather both dry and wet indicate nearly the same temperature.

5th, For obtaining even approximate relative humidity in calm weather single louvred shelters are necessary, and for the best result an induced air current is essential especially in the winter in northern countries.

At the same time that the above experiments were being carried on, another series of observations was made in window shelters. These have shown, as is well known, that in summer the temperature is slightly too low by day and too high by night, and that no satisfactory hygrometric observations can be made without artificial ventilation. As many are not in a situation to use any but a window shelter the following suggestions are added for places north of 35° lat. N.

1st, There should be a free air space of 6 to 12 inches between the shelter on the north side of the building and the wall.

2d, The simplest form of screen would be four pieces of board 10 to 12 inches square, nailed together box fashion, leaving the bottom and side toward the window open; the thermometers dry and wet should be placed five inches apart near the center of this screen, with their bulbs projecting below the plane of the lower edge. In the summer months, when the sun shines on the north side, the window blinds can very easily be brought at right angles to the wall of the house and fastened there, thus shielding from the sun. As to a more elaborate arrangement it may be said that nothing extensive is needed; probably a shelter made after the "Stow" pattern, as just described, thirty inches long, eighteen inches wide and twenty-four inches high with closed bottom would answer perfectly in latitudes north of 35°. A shield with half shut blinds can be easily arranged as mentioned above, the blinds being widened if necessary to cover the shelter with their shadow. Experiments are still being carried on upon this matter. The Chief Signal Officer has kindly permitted the publication of these results preparatory to a more exhaustive study.