(3) Optical determinations of images by means of photographs supplied by the Brothers Henry.—M. Struve.

(4) The study of three or four stars nearly in a straight line embracing the total angular distance of about 1°, and photographed necessarily at the centre and at the corner of a plate.—Paris, Algiers, Pulkowa, and Leyden.

(5) Study of the deformations of films.—Algiers, Meudon, and Potsdam.

(6) Study of curved plates from the triple point of view of construction, means of covering with a film, and measures.—Mr. Christie.

(7) Study of absolute orientation—that is to say, the mounting of the plates in the photographic telescope.—The Cape and Paris.

(8) Study of the measuring-instruments to be applied for the future utilization of negatives.—This was postponed.

(9) The study of formulæ for the preparation of plates in accordance with the general rules laid down by the Conference—Messrs. Abney and Eder.

(10) Opinions of colours of stars on their photographic magnitudes.—M. Dunér.

THE TEMPERATURE OF THE CLYDE SEA-AREA.[1]

II.

FROM the curves for each station, temperature sections were constructed for every cruise, showing the position of the isotherms with relation to a profile of the bottom along certain lines. It is not easy to give an intelligible description of the distribution of temperature without reference to those diagrams; but an attempt may be made. The most important section runs from the Channel, across the Plateau, up the Kilbrennan Sound branch of the Arran Basin, through Inchmarnoch Water, to the head of Loch Fyne. It is sufficient to recollect that the Plateau is covered by about 25 fathoms of water, that the depth increases on the inside up to 107 fathoms off Skate Island, then diminishes rapidly to 15 fathoms at Otter and Minard, and increases again to nearly 80 in Upper Loch Fyne. The section is a little more than 90 miles long.

In April the whole section was filled with water between 41°·3 and 44°. The water of the Channel, the Plateau, and the surface layers (to 10 or 20 fathoms) was above 42°. The average bottom temperature was 41°·3, except in the Channel (42°), and in Upper Loch Fyne (41°·9). The June section shows marked surface heating to a depth of about 5 fathoms. Water at 47°·5 filled the Channel, covered the Plateau, and extended in a layer of about 5 fathoms thick over the inner reaches. The great mass of water was between 44°·5 and 44°. In Upper Loch Fyne the remarkable distribution of temperature, referred to when discussing the curves for Strachur, was found to extend from Minard to the head of the Loch, in the form of a lenticular mass of water of temperature under 44°, with warmer water above and below. The minimum temperature, 42°, was found off Inveraray at a depth of 30 fathoms, and the gradient of temperature was much steeper in the upper layers of the cold mass than in the lower. No satisfactory explanation of the mode of formation of this intermediate minimum of temperature has yet been arrived at, and any suggestions as to its origin would be received with interest. In August the section shows that the cold mass remained in the same position but with a rather higher temperature, and of much smaller dimensions. As in previous months, the warmest water was that nearest the Atlantic, which had a temperature of over 53°. The great Arran Basin presented a considerable range; from 54° on the surface to 50° at 20 fathoms, 48° at 30, 46° at 60, and 45°·3 on the bottom. The September cruise showed a very similar state of matters, accompanied by a general rise of temperature and an increase in thickness of the warmer layers. As in each previous month, the Channel was warmest (54°·5 throughout), and the warm surface layer became thinner and thinner until at Otter the surface temperature was under 53°. The section clearly shows, what careful experiments have proved, that the abrupt rise of the sea-bottom, from off Skate Island at 107 fathoms to Otter at 15, is characterised by a rise of colder water from beneath to the surface. The gradient at this place is 550 feet in ten sea-miles, or 1 in 100; and perhaps vertical circulation is set up as much by the sudden narrowing of the Channel, as by its shoaling. A similar effect was observed at Row Point in the Gareloch, and at the narrowest part of the Kyles of Bute. In September the bottom temperature of the Arran Basin was 47°·5, that of Upper Loch Fyne 44°·2; the intermediate minimum had disappeared from the latter. November showed the influence of surface cooling in a marked degree. The Channel and Plateau had cooled down to 50°, and for the Arran Basin the average surface temperature was 49°·5, that at the bottom 51°·5. This shows a great equalisation of temperature, and a reversal of the summer conditions, the warmer water being now below, the cooler on the surface. In Upper Loch Fyne the temperature was 44° at surface and bottom, but a maximum of a little over 50° was found at 15 fathoms. Further cooling and greater equalisation of temperature characterised December; the Channel was warmest, at 48°·5; the whole Arran Basin varied from 46°·8 on the surface to 47°·5 on the bottom; and Loch Fyne maintained its independent position by a quite new arrangement of temperature-layers. On the days of our work there (December 29 to 31) the whole upper part of the Loch was covered with a sheet of frozen fresh water, the ice being nearly half an inch thick in places. Three inches beneath the ice the temperature was 36°, and a few feet under, it was 44°. The maximum temperature of 47°·5 was met at 20 fathoms; and the warm layer of water was giving out its heat to the superficial strata, being cooled by this winter's cold, and to the lower mass which still retained the cold of last winter, although the bottom temperature had risen about half a degree since November. In February it was impossible to observe in the Channel on account of bad weather, but the water on the Plateau was slightly colder (43°·4) than that in the Arran Basin (43°·7 to 44°). There was little range of temperature, the surface being in all cases, however, slightly colder. Throughout the Arran Basin the temperature of the mass of water was the same as in June: this may be held as pointing to the end of April as the period of minimum. Loch Fyne showed a steady rise of temperature as the depth increased down to 45 fathoms, where the thermometer registered 46°·5; from that point to the bottom there was a fall to 45°·8.

Dividing the Clyde sea-area into three parts, each comprising regions of like physical configuration, the direction of the annual march of temperature may be summed up thus.

Starting from the simple case of a minimum uniform distribution, the Channel heats uniformly up to September. and then cools uniformly; the strong tidal currents, or some other cause, keeping the water thoroughly mixed, and equalising all heat transactions.

The deep open basins, to which the tide has free access, heat up most rapidly on the surface, and more uniformly lower down; the mass which heats uniformly decreases until at the period of maximum there is an unbroken fall of temperature from surface to bottom, and a considerable range. Then, at the autumnal equinox, the surface water begins to cool, while summer heat is still travelling downwards: this leads to the typical winter state—exactly complementary to the summer condition—of a uniform gradient of temperature rising from surface to bottom, but with a slight range. As winter goes

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[1] Continued from p. 39.

on, the rate of cooling becomes more nearly equalised, and on approaching the spring minimum the whole mass of water is at one temperature, and cooling steadily throughout.

The deep inclosed basins differ from the deep open basins only in degree; but in the same direction as the deep open basins differ from the Channel. On this matter I do not care to speak with so much certainty; as, the conditions in the inclosed basins being much more complicated, there is more probability there than elsewhere of local and temporary disturbances being mistaken for the normal progress of events. It appears, however, that summer heating takes place more slowly throughout the mass, although the surface maximum is earlier; and that in the deep, comparatively still water there may be at one time the conjoint effects of more than one summer and winter.

One step further in the direction of conditioning the phenomena of temperature in water is to entirely cut off even superficial tidal communication with the ocean; to form, in fact, a deep inland lake. Observations made by Mr. Buchanan, Mr. Morrison, and myself, on Loch Lomond and Loch Katrine, show that there the annual march of temperature is very much what might be expected from the Clyde observations; but there is the great difference of the water being fresh, and having a maximum density-point varying with the depth, which prevents a rigid comparison being made.

From the temperature sections, which have been described, the average temperature of the whole mass of water for each trip was deduced, by measuring the areas occupied by each range of 2°, multiplying these by their respective mean temperatures, adding the results together, and dividing by the number representing the whole area of the section. In order to ascertain the temperature of the surface water, that of the superficial 2 fathoms was calculated in the same way. By the kindness of Mr. Buchan, of the Scottish Meteorological Society, I was supplied with the mean monthly air temperature (average of twenty-four years) of the Clyde sea-area, and the deviations from the average for each month from January 1886 to February 1887. The figures are given in the accompanying table, and are expressed graphically by curves in Fig. 4.

MEAN MONTHLY TEMPERATURES 1886–87.

	January	February	March	April	May	June	July	August	September	October	November	December	January	February
	°	°	°	°	°	°	°	°	°	°	°	°	°	°
Mean air temperature	39·5	40·0	41·5	46·0	50·5	56·0	58·0	58·0	54·5	48·5	42·5	40·0	39·5	40·0
Deviation for 1886–87	−3·5	−4·0	−2·5	−1·5	−2·5	−2·5	−1·0	−1·0	−0·5	+2·5	+2·5	−4·0	−2·5	—
Temperature of 2 surface fathoms	—	—	—	43·8	—	49·6	—	53·4	53·0	—	49·5	45·6	—	42·5
Average temperature of water	—	—	—	41·7	—	44·8	—	48·7	52·0	—	50·6	46·7	—	44·0

The temperature of water is not the monthly mean, as in the case of air, but that at the time when observations were made.

This shows that the year in which our observations have been made is rather an unfortunate one; because the low temperature of spring and summer, and the high temperature of autumn tended to retard the heating and the cooling of the water so as to produce a curve much flatter than the normal one may be expected to be. The maximum of air temperature occurred between July and August, that of the surface water between August and September, and of the whole mass of water apparently in October. The air and the whole mass of water from surface to bottom had the same mean temperature about the beginning of October; after that date the water remained warmer than the air, and the whole mass of water than the 2 superficial fathoms. It is specially noticeable that, while during heating the surface water is far above the main mass in temperature, it is only a very little below it during cooling.

Knowing the mass of water in the sea-area under consideration, it is easy to convert the temperature data into terms of heat; and, using for convenience the unit of one ton of sea-water raised 1° Fahrenheit in temperature, the following table expresses the actual changes taking place:—

QUANTITY OF HEAT.

Trip.	Commenced	Ended	Interval from last	Change of mean-temp.	Average change per day	Total change of heat	Average change of heat per day
			days	°	°	millions	millions
April	13th	21st	—	—	—	—	—
June	16th	22nd	63	+3·1	+0·05	+465,000	+ 7,000
August	4th	12th	50	+3·9	+0·08	+585,000	+11,600
September	22nd	29th	49	+3·3	+0·07	+495,000	+10,000
November	11th	19th	50	−1·4	−0·03	−210,000	− 4,000
December. ...	23rd	31st	42	−3·9	−0·09	−585,000	−14,000
February	3rd	12th	42	−2·7	−0·07	−405,000	− 9,600

To summarise the above and give an account of heat transactions, it is sufficient to say that from April to September there was a gain of 1,545,000 million ton-degrees, corresponding to a rise in average temperature of 10°·3; while from September to February there was a loss of 1,200,000 million ton-degrees, corresponding to a fall in average temperature of 8°·0, thus leaving 343,000 million ton degrees of heat to be expended by April next, supposing the water to return to the state in which it was in April last. These numbers for heat are of course based to a considerable extent on assumptions, and must only be taken as part of the preliminary discussion of the exact observations already recorded.

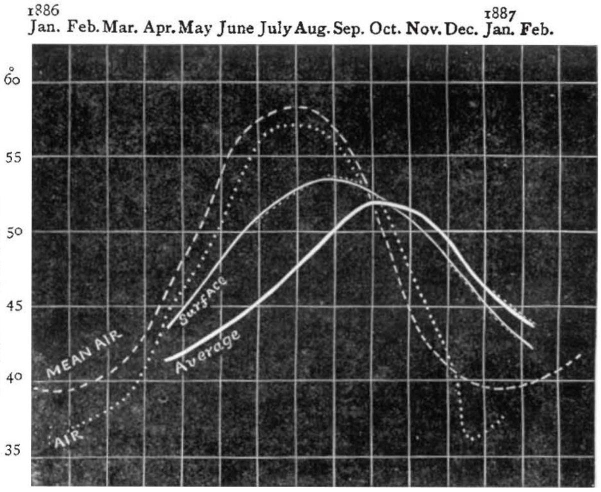

FIG. 4.—Clyde Sea-Area. Annual march of temperature.

Observations made from March 25 to April 3, since the greater part of this paper was in type, show a general temperature of about 43°·5 over the whole area, and confirm all the provisional conclusions stated above. The figures observed in the three typical positions are as follow :—

Place ...	Channel.	Off Skate Island.	Strachur.
Date ...	March 30.	March 28.	March 29.
Temp. surface ...	44°·7 ...	43°·8 ...	44°·9
,, bottom ...	44·2 ...	43·9 ...	45·5

From the forms of the curves the spring minimum appears to be past, and over all the temperature is about 2°·5 higher than at the same period last year. The water in Upper Loch Fyne is now cooling at the bottom and heating again on the surface, the range for the year at great depths having been only 4°. The actual change of temperature in the sea-area between the beginning of February and the end of March is very slight, but it is significant in showing by its direction that the period of minimum lay between the two.

One interesting application of the observations may be made to climatology. A great proportion of the heat gained is derived not from solar radiation, or the contact of heated air with the surface, but from the warm Atlantic water entering by the tides. Since the water on the Plateau appears to remain warmer than that inside all the year round, no heat is lost to the Atlantic in winter; but all must be radiated off from the surface or employed in evaporating water or heating air by contact, and in this way more heat is returned to the air of the Clyde sea-area in winter than was received from it in summer. Another observation may be mentioned which serves to show how important a bearing temperature observations may have on biology. On February 4, four tow-nets were used off Strachur at different depths: one at 70 fathoms, one at 50, one at 30 fathoms deep, and the fourth at the surface. There was nothing in the surface-net, and the surface temperature was 43°. The contents of the other three nets were examined by Mr. David Robertson, of Millport, who reports :—"In all three nets Copepoda were moderately abundant. The nets at 70 and 30 fathoms contained one and the same species; but the contents of the net at the middle depth were different, confined to an abundant species of copepod loaded with ova (*Euchæta norvegica*). With them there were two or three adult schizopods (*Nyctiphanes norvegica*)." At 70 fathoms the temperature was 45°·9, at 30 fathoms 45°·6, and at the position of the middle net 46°·3. Mr. Robertson concludes : "As the middle water of the loch at this time is shown to be warmer than either the layer above or below, we may reasonably assume that the species in ova sought the warmer layer." Similar observations repeated at many different places during the March trip showed the same result, the minute Crustacea being most abundant where the temperature was highest.

The work is being carried on meanwhile, purely as a piece of physical and meteorological research, and a considerable time must necessarily elapse before all the latent meaning of the great mass of figures now being accumulated can be brought to light. There is no doubt that when the problem of the interchanges of heat in comparatively deep water has been made out, important practical applications to other sciences, and to some arts and industries, will be discovered.

HUGH ROBERT MILL.

SCIENCE AND GUNNERY.[1]

II.

LAST week we pointed out the great advantages which accrue from retiring guns behind inconspicuous parapets, and mentioned that the energy of the discharge had been utilised to raise the guns again into the firing position without the aid of extraneous power.

The theory of the discharge of cannon involves many interesting considerations, not only with respect to the strength and structure of the guns but also with reference to the force required to control the recoil. A gun may be considered as a heat engine of the simplest construction, performing its work in one stroke. The fuel used is gunpowder, and the energy developed is, as in other engines of this class, in proportion to the weight of fuel used and to the heat it is capable of developing. The main difference between explosives and most other fuels is that explosives are complete in themselves; that is to say, they burn independently of the presence of extraneous bodies, and that consequently the chemical union which causes the explosion takes place simultaneously throughout the mass and in an exceedingly short time.

Fuel in large masses burns slowly because the air, which forms its complement, can come into contact with only limited surfaces, but if reduced to fine powder the combustion may be made to assume almost the intensity of an explosion, as for example in the dust-fuel used in Crampton's furnace, and the dusty atmosphere of coal-mines and flour-mills.

The materials in gunpowder, intimately mixed throughout, are in a state of unstable equilibrium with respect to each other; a very moderate increase to the thermal movement of the molecules causes them to clash together with sufficient energy to insure combination, and if such increase of motion be communicated to one portion of the explosive by the application of percussion or of a hot body, it is carried through the mass by the luminiferous ether with all the rapidity with which radiant energy travels, and the increase of motion, sufficient to cause combination, is communicated to every molecule nearly simultaneously, the consequence being a change of form and volume produced with the suddenness which marks an explosion. We believe that Mr. Anderson was the first, in his lectures on heat at the Society of Arts, to point out that it is unfair to compare the calorific value of fuels in their incomplete form; that is to say, that such fuels as require air for combustion should have the necessary weight of air added to them, and when that was done the singular fact appeared that the quantity of heat evolved by most combustibles per unit of weight was very nearly the same; thus in nine cases cited, which included coal, coke, wood, petroleum, illuminating gas, and gunpowder, the extreme variations from the mean calorific value did not exceed 9 per cent. In the same lectures it was shown that in guns, as in most heat-engines, a very large proportion of the thermal energy of the fuel was dissipated in a useless manner; in the case of cannon more than half was wasted in heating up the gun, and about one-third only in producing recoil, which was the reaction to the energy communicated to the shot, to that imparted to the powder gases, and to the work of displacing the atmosphere Of these three effects only the energy imparted to the shot was known with precision, for by means of sufficiently simple apparatus it was possible to determine with great accuracy the velocity with which the projectile left the gun, and the energy therefore was easily determined by multiplying half its mass by the square of that velocity.

The determination of the work done in expelling the powder gases was more difficult to estimate. In the first place, only about 43 per cent. of the products of the combustion of gunpowder are in the state of gas, the remaining 57 per cent. are in the form of very finely-divided solids; next, the combustion goes on nearly all the time that the shot is travelling out of the gun, the pebbles of powder igniting in succession, a fact which is proved by the circumstance that in short guns a good deal of powder is blown out without being consumed at all, and it is doubtful even whether in the modern long guns combustion is always complete. While the shot is travelling along the chase, the centre of gravity of the powder charge is moving also

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[1] Continued from p. 37.