XXII.—*Notice of the Completion of the New Rock Thermometers at the Royal Observatory, Edinburgh, and what they are for.* By Professor PIAZZI SMYTH, Astronomer Royal for Scotland.

(Read 5th July 1880.)

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PLATE, No. XV, representing the above numerical tables, graphically.

On the 26th of last month the full year appointed by Government Contract for the testing of the new Rock-Thermometers having expired, and they having approved themselves at all points, been accepted, and set fairly afloat on a new course of observation,—I hasten to announce the event to the Royal Society, Edinburgh, who have long had a lively interest both in these instruments and in the problems they have been employed upon.

Those new thermometers, viz., four more or less gigantic and deeply sunk in the rock, supplemented by two smaller ones for surface and air temperatures, are almost exact counterparts of the former magnificent set, which was so wilfully and calamitously destroyed by a Portuguese madman early one September morning in 1876, after having been continuously recorded at the Royal Observatory, Edinburgh, ever since 1837.

Now those earlier thermometers were constructed at that date by Messrs ADIE & SON of this city, at the expense of the British Association for the Advancement of Science, but according to the plans of Professor JAMES DAID

FORBES of the Edinburgh University ; and if there was any one thing in Nature or Art which that eminent Natural Philosopher understood more intimately than another, it was the making of observations upon heat. Every one therefore of that day was perfectly satisfied with his being the sole scientist to give the design, and in the then resident member of the ADIE firm, viz. Mr JOHN ADIE, being the mechanical artist to execute it.

But when, after the lapse of forty years, our calamity of 1876 occurred, and leave was after a while, or in 1877, granted by Government to get a new set of this species of thermometer made,—both JAMES DAVID FORBES and the humbler JOHN ADIE had long since passed away, and no one had applied meanwhile for any more of such colossal instruments. The still continuing firm however of ADIE & SON bravely undertook the new order ; Mr RICHARD ADIE occasionally came here from his establishment in Liverpool, and I am breaking no confidences, and doing that firm more good than harm in saying further,—that they have now in Edinburgh as foreman, one who, still young and rising, has been found equal to the occasion ; who entered into the work with a fine enthusiasm, and continued either to perform, or immediately superintend every part of it, up to its successful termination,—this person being Mr THOMAS WEDDERBURN.

Now it is said to be a general law of human nature, that the very same works or events are intuitively described by different men according to their own several parts and responsibilities therein. Wherefore, to obtain a good account of the real making of these long thermometers (the longest of them several feet longer in the stem than the hall of this Society is high), it was my duty, not to try to write the account myself, but to go to the practical artist in the matter, viz., Mr WEDDERBURN, and ask him for his account of his own doings.

Accordingly at the end of this paper I have to thank him for enabling me to give, after a copy of the contract, and then some comprehensive remarks by Mr RICHARD ADIE,—his own, Mr WEDDERBURN's, account of how every thing was done, from the first clearing out of the old bore-hole 3 to 5 inches in diameter and 26·5 feet deep in the solid porphyry rock of the Calton Hill, to the final placing of the new set of thermometers therein, after two winters of anxious, careful testing of the zero points and deciding on the scales.

All that, together with many *naïve* and very much to the purpose remarks on the several practical processes that had to be gone through, should be read, when printed, in Mr WEDDERBURN's own words, which are authoritative there. But now when his work is over, and the thermometers are in regular course of observation at the Royal Observatory, a new class of questioners may arise, demanding to be told what it is all for ? and why would not smaller and cheaper thermometers have answered as well ? In which case it is I who have to come to the front and try to explain.

And yet, in the first portion of my reply, it is not merely I that speak, but far more the spirit of that grand scientist of Scotland in the last generation,—JAMES DAVID FORBES. He, in his deep and earnest studies of nature, desired to obtain numerical expressions for certain Natural Philosophy constants; such as, given the summer heat, the winter cold, and the daily variations on the surface of the ground, together with the physical rock below,—at what rate do those temperatures and variations of the same travel downwards towards the centre; the results being required accurate to the hundredth of a degree Fahr., and a fraction of a day as to time.

The only mode of correctly ascertaining these data free from very large and possibly ruinous disturbances, was then well considered to be, the having thermometers large enough to allow of their bulbs being set in the heart of the rock, at every required depth, viz. 3, 6, 12, even 24 feet, while their scales were on the surface of the ground.

The necessary expense was therefore most willingly incurred, though in the economical days of forty and more years ago; together with the labour of observing for many seasons. Not only too the Observatory set of thermometers, but two other sets like it, one at the Craigleith Quarry, and the other at the then Experimental Gardens. And these measures proved successful; for the problem was at length solved by them; in a manner and with a completeness too, not only to satisfy Professor FORBES himself,—after whose passing over a scientific field, there was little enough left for any one else to glean—but to well content the Royal Society, Edinburgh, also. For the Society printed the Professor's noble Memoir on the subject in their Transactions for 1845–46 (Vol. XVI.), and crowned it with a prize.

Soon after the above clenching event, the other two sets of thermometers were reported broken; and the question then came before me, in my official capacity at the Royal Observatory,—what shall be done with the one remaining set of rock thermometers there?

After consulting with Mr ALEXANDER WALLACE, the Assistant-Astronomer, who had carried out, under my predecessor, THOMAS HENDERSON'S, supervision, all the previous observations for Professor FORBES from the first,—I decided that they should continue to be observed; largely because I believed them to be the best set of rock-thermometers in the world, and also because there is still an immense deal connected with the temperature of man's planetary abode, which he has not mastered yet. So the observations were continued without a break, and before long another practical use did appear for them;—thus,—

The Transit Instrument in the Royal Observatory, Edinburgh, had been known to my predecessor to be affected with an annual fluctuation of level from East to West, nearly in accordance with the readings of a small thermometer under the floor of the building; and there was a belief in the community

at large, that that level effect was produced by the afternoon Sun shining on, and expanding, the rocky western side of the Calton Hill. Wherefore also, said various wise men, "the rock foundation of the Edinburgh Observatory is just about the worst sort of foundation that could possibly have been selected for an accurate, meridian, Astronomical Observatory."

But on examining the dates and configurations of the curve representing each annual progress of the level fluctuations, and comparing them with the similar points of the annual temperature curves of the several rock Thermometers,—I was presently able to demonstrate, that what particular thing or matter the heat was acting on to disturb the instrument's level,—so far from being any rock-surface, more than 200, or even only 20, feet off, must be within less than 3 feet from the instrument itself. And it has been experimentally proved since then to depend on the abnormal expansion of the mountings of the instrument within its own chamber. While the grand porphyry rock of the Calton Hill has at the same time been shown to be fully worthy of supporting a much grander and more celebrated Observatory than has yet been erected upon it.

Again, in following years, these rock thermometer observations were discussed by Sir WILLIAM THOMSON, and by aid of his suggestive philosophy and powerful analysis made to indicate the beginnings of some vast and soul-elevating results; such as

First, the amount of the Earth's central heat which is still year by year escaping through the surface and radiating into space; and

Second, setting forth something as to the age of that heat; or the time which has elapsed since the whole earth was of a life-forbidding, because light-emitting, temperature. Of these high reasonings the Society has already heard at various times from that eminent philosopher, and it is hoped will further hear from him directly again and again.

More than thirty years had thus passed by. Our stock of observed temperature facts of the Calton Hill was always growing, simply because we were an Observatory, and not any other kind of institution, however estimable; and presently a third supplementary useful purpose appeared, quite different from any of the former, and fraught with practical applications for the future, of no ordinary kind.

What is so important to both the business and pleasures, the life and the glories of this country of ours, as the seasons of summer and winter; and who does not know their intimate dependence on the physical nature of the Sun, combined with the grandly ordered angle of the Obliquity of the Ecliptic, the rotation of the Earth on its axis, and the whole globe's envelopment in a most composite atmosphere, of permanent gases and watery vapour! But then again who does not also know, by even terrific personal experience, that there are

occasionally summers in this country *and* summers ; winters also *and* winters ; though why or wherefore, is still a scientific mystery.

Taking up then that particular subject, in 1869, by means of our accumulated years of observation of the rock-thermometers, I tried a simple method of eliminating the effects of the ordinary seasons ; and then examined closely the residual quantities. They might of course be expected to indicate *some* variations with time ; and the one all important question for the hopes of science was, would it be regular, or irregular ?

Great therefore was my joy when the result said immediately, for all the larger variations, REGULAR ! Regular even to a surprising degree, for this was the order that came out ;—Every eleven years nearly (and this three times over in succession during the limits of our observations, so that there could be no mistake about it), a wave of heat had struck the earth's surface from without (not from within, as proved by the dates being later and later according to the depth of each thermometer) ; and between those most signal eleven year heat epochs, there was no other hot wave of a supra-annual order, which could compare with what occurred then, for either size or intensity.* Their dates were 1846, 1857 and 1868.

That was the first law of occurrence deduced by the inquiry ; and the second, approaching to something like a cause, was—that each of those dates was found to mark the beginning, the well commenced beginning too, of precisely the most intense period of a well-known cyclical habitude of Solar activity ;—acting doubtless, both by its increased heat and other radiant emanations, though chiefly observable to man by an accompanying optical phenomenon, “the Sun-spots.”† And, after that was settled, then came the third law of occurrence, viz. that close on either side of the heat wave, or more exactly 1·7 year therefrom, came a specially cold trough. Sometimes the preceding, sometimes the following of these cold waves was the severer of the two ; but the curious rule of two was always kept up at every successive cycle ; and for reasons most probably of terrestrial physics which are exceedingly interesting, but too long, and far from our subject, to be entered on here.

Practically confident then that this new mode of treating the accumulated observations of our rock thermometers, had helped me to a most important

* These epochal waves of heat may apparently come to a head at any time in the course of a year ; but are never so powerful as to destroy altogether the ordinary summer or winter. If therefore one, of any cycle, occur just at mid-winter, it merely makes it an unusually mild winter ; not a season as hot as, or hotter than, an ordinary summer.

† These Sun-spots have been proved, by Professor LANGLEY and others, to have no power in themselves to produce any notable alteration in the quantity of the Sun's radiant heat practically felt by the earth and its atmosphere ; but bear about the same relation to it, that the cinders dropping into the ash-pit of a steam engine's fire-place, do to the amount of mechanical work being performed by the engine at the moment ; and if the engine itself is not observable by us, it is well to note and reason on the number and size of the red-hot cinders, and the rate at which they fall.

beginning of a higher Meteorology,—I sent up, in March 1870, a full account of the affair, with a copy of all the original observations for thirty-three years to the Royal Society, London. Unfortunately that learned Society had not then begun to perceive the bearing of Solar physics on variations of terrestrial climate, as, through a Committee, it is now professing to do, and is corresponding about with H.M. Government: so, in their then state of knowledge, they summarily extinguished my paper, and buried it out of sight.

But no matter! For was I not freed thereby to print some of the originals of the Manuscripts, which I had fortunately preserved, in the next issuing volume of the Edinburgh Astronomical Observations, the thirteenth of the series, early in 1872? Of course I was; and I also took that occasion to go further, and announce (see Appendix 4 to this paper), that the next very cold period would not take place until 1878·8,—*i.e.*, near the end of the year 1878—and that the next hot period would occur in 1880! Making thus two distinct statements for critical and opposite kinds of weather in this country, and to an unheard of distance of time beforehand, to have any ordinary chance of success.

But having been permitted to live and publish that most crucial, double-headed conclusion in 1872, alas! that I had not died thereupon, and simply left those numbers behind me, pure, untouched and in all their integrity. For then, when those two dates, predicted so many years beforehand by one who was no longer in the way of troubling, no longer in rivalry with any one, should have come round,—and been found by a new race of scientists to be so remarkably close to the subsequently observed leading features of meteorology which followed,—better men than I would have rushed into the subject in crowds, and a whole new science might have been born in a day.

But it was ordered that I should not die then and there; but should live on; and after five years, stumble, and spoil everything by one unhappy slip; for this is the dismal version of what ensued.

Our hopes of future confirmations had been growing continually more precise with every additional year,—when suddenly, in the autumn of 1876, befell us that ever regrettable calamity, of the mad-man climbing in the dawn of early morning over the dilapidated Observatory boundary wall, and smashing our staff of strength, the whole of our rock thermometers. After that loss, I knew no more of the march of earth-temperature, than any one else in the community; and in my ignorance was blown hither and thither by vague surmises. So that when in 1877, one continental scientist announced that the then, and still the last, Sun-spot minimum occurred in 1876·8, and another said 1877·5,—I was wise enough to recoil from the former, but stupid enough to believe the latter, and act accordingly. For that latter date being a year earlier than what, in 1872, I had hypothetically taken for the next Solar-spot minimum,

—I felt obliged, when republishing on the matter in our volume XIV. in 1877, to say,—that both the coming cold, and the coming hot, seasons before alluded to, would each of them arrive a year earlier than previously stated.

Fatal mistake ! For when the thus erroneously amended date for the then approaching cold season, or the winter of 1877 and 1878 arrived, and was not a cold one ; and the similarly amended date 1879 for the following warm season, and was not warm ;—how instant every one was then to cry out against the error, to be scandalized at it, and to point the finger of scorn, not only at me, which would have been excusable enough, but at the whole subject of Solar physics, and at the Royal Observatory on the Calton Hill too !

One prominent patron of Science had even gone so far as to say :—“ There is no evidence to show, that there is any more connection between Sun-spots and famines, than there is between comets and wars, or planets and the death of kings.”

That was darkness indeed,* and looked then as if it was going on to

* In Mr GEORGE F. CHAMBERS' “ Handbook of Astronomy,” 3d edition (Clarendon Press, Oxford), there is an immense amount of well-collected, useful information, in the course of the first chapter, on the Sun-spots and their influence, first on the magnetism, and then on the Auroras of the weather of the earth, as determined by a positive crowd of first-rate and honourable observers, mathematicians, astronomers, and physicists.

Closely following on M. SCHWABE's announcing the periodicity of Sun-spots, there were published in 1850 to 1852 a series of almost simultaneous but independent discoveries and demonstrations by Professors LAMONT of Munich, GAUTIER of Geneva, WOLF of Zurich, and General SABINE of London, of the close connection between Sun-spots and the earth's changes of magnetism, so that, not only were the periods the same in the whole, but the maxima and minima were conformable also. While still more pointedly, when in 1859, a terrestrial magnetic storm of unprecedented magnitude occurred from August 28 to September 7, it was shown by Professor BALFOUR STEWART (“ Philosophical Transactions,” 1861, p. 423), that this was synonymous with the period of maximum activity of one of the largest Sun-spots ever observed. (See a Physical Treatise on Electricity and Magnetism, by J. E. H. GORDON, B.A., 1880, vol. i. p. 197.)

Whereupon Mr CHAMBERS quotes the shrewd and far-seeing Manchester scientist, Mr BAXENDELL, as considering,—“ That diversities of solar activity are to be regarded as causing changes in the magnetic condition of the Earth, and so producing changes in the directions and velocities of the great currents of the atmosphere, and in the distribution of barometric pressure, temperature, and rainfall.” And he expressly lays down further on, that “ the future progress of meteorology must depend, to a much greater extent than has generally been supposed, upon the knowledge we may obtain of the nature and extent of the changes which are constantly taking place on the surface of the Sun.”

Mr CHAMBERS quotes also Professor BALFOUR STEWART for proving that a bond of connection exists between Sun-spots and these three terrestrial features—magnetic declination, “ earth currents,” and Aurora ; also Professor LOOMIS of America, as having well remarked through long periods, the connection between Sun-spots, magnetic declination and Aurora, and given an effective map of them.

Also M. PÖEY, for the connection of tropical storms with the maxima of Sun-spots through more than a century.

Also Mr ELVIRS of Canada, for connection between Cycles of Sun-spots and rainfall frequency.

Also the Oxford Observatory, for connection between Sun-spots and the mean direction of the wind ; the westerly element increasing with the amount of spots.

Also Mr STONE, at the time Astronomer Royal at the Cape of Good Hope, and equally M. ABBÉ of Cincinnati, but then discussing Munich observations ; for they were each led to a connection between Sun-spots and terrestrial temperature.

Again, since the date of 1872, Mr NORMAN LOCKYER, F.R.S., Dr W. W. HUNTER (Statistician

dominate every one and every thing. But meanwhile a most unexpected ray of light had beamed upon us here in Edinburgh. Urged to it, as I am happy now to confess by my Wife, and having had all along some suspicion of those foreign accelerated dates for the Sun-spot minimum, I took to observing Sun-spots myself. Only in a rough way and at home; but it was enough! For I soon found that the minimum had by no means taken place in 1877·5; but was delayed until 1879 was begun. And not indeed until 1879·8 was there any very decided manifestation of the Solar forces of a new Cycle in strenuous action. But at that date one morning, something so signal was witnessed in the Sun, that I wrote of it the same day to "Nature," under the title of "Sun-spots in earnest;" and five months after that, on the strength of a certain night observation, wrote of "The Aurora at last." Since the publication too, I have been doubly confirmed as to the Sun-spots from the Royal Observatory, Greenwich; first by the chief Assistant Mr CHRISTIE, writing to "Nature" after seeing my Sun-spot letter there, and detailing similar observations at Greenwich; and second, by the Astronomer Royal, Sir G. B. AIRY, in his late annual Report, expressly giving the same dates, viz., the beginning of 1879 for the epoch of the minimum of Sun-spots, and October 1879 as a later date from which period onwards and ever since, the display of spots has been large and generally increasing. The return of the Aurora was also confirmed, first by a disturbance of the magnets at Greenwich on the same night,* and then after a while by a Canadian observer (Colonel BULGER) announcing that after a long barren interval an Aurora had at last appeared there, on the same evening that I had observed it in Edinburgh, and so like it in character that my description in "Nature," of the Edinburgh phenomenon would have served for the Canadian one as well. And now a Scandinavian Professor,† at Bergen in Norway, is advertising in "Nature" (No. 567, vol. xxii. for July 1, 1880) for Auroral observers; because in the next few years he expects Auroras to be so much more numerous and intense than they have been for years past.‡

General for India), Mr MELDRUM of Mauritius Observatory, Professor STANLEY JEVONS of London University, and Professor DOUGLAS ARCHIBALD have written so much both separately and combinedly on Sun-spots, Indian rainfalls, and Indian famines, ship assurances in the Tropics, and commercial panics, and become so widely approved therein, that I need only allude to them here by name. Though it has not been sufficiently brought out yet that Dr W. W. HUNTER received, apparently, his earliest ideas on the subject somewhere in 1875, from Mr N. POGSON, Government Astronomer at Madras, who was then in rather low spirits *because* he was expecting a famine in the next year; and expressly, as he particularly explained, on account of the approach of the period of a minimum of Sun-spots; which famine did take place, and with all the disastrous consequences to life in India, and purse in Great Britain, which the daily papers have chronicled since, but Mr POGSON saw feelingly so long beforehand.

* The disturbance of the Earth's Magnetism appears to have been noticed the same night at Vienna and also at Lisbon; see "Nature," p. 220, No. 558, vol. xxii. or for July 8, 1880.

† SOPHUS TROMHOLT, Professor of Mathematics.

‡ Some of these were closer than he was aware of, for on August 11 and 12, summer season though it was, the most magnificent of coloured Auroras were witnessed over a large part of England

So with 1879·0, now sur-abundantly proved to be the real date of that typical solar phenomenon, the last minimum of Sun-spots—which serves so usefully on this inquiry as a finger-post, or mile-stone of Solar physical energy,—I applied on to that, as an absolute date, our thermometrical differences as before; and behold, the result was almost perfect! For the very acme of the cold season came out just as it was experienced by every one in the end of 1878 and beginning of 1879. And the following warm season is now upon us, increasing from day to day, exactly as the whole series of rock-thermometer observations long ago taught us, it ought to do at this time.

Hence we may most certainly accept,—that if that admirable book of scientific predictions, the Government's Nautical Almanac (which publishes four years beforehand several thousand minute particulars of the coming places of Sun, Moon and Stars), had only been enabled, by high learning and physical knowledge, to add thereto in 1876, the true date of the then impending minimum of Solar-spots,—the cold season of 1878 and 9,—which the country had already been preliminarily and approximately warned about by me in 1872,—would have been most exactly spotted in 1877, or a full year and a half before it began. In which case Agricultural Science would doubtless have bent itself to a new task; and, elaborating some variation of farming for 1879, suitable to a cold and wet year, might have saved no small portion of the hundred and fifty millions of pounds sterling which are said to have been lost in that year throughout Great Britain; and largely because the character of the season was generally unexpected, and therefore totally unprepared for.

This then is the last of several insights into Nature, which the first set of rock-thermometers, by their forty years of observation, have just brought us in view,—not put us altogether into possession, of. For there remain many smaller variations of the cyclical quantities to be explained. And in order to give a clearer idea of both what has already been accomplished, and what remains to be done, I have, with obliging assistance from Mr BUCHAN, who is Scottish Meteorology personified, and with help from the two assistant Astronomers on the Calton Hill, prepared a collection of various observations from 1821 to 1880, in Appendix 5; inclusive of course of our own rock thermometer results in a condensed shape; and also such Sun-spot dates as I have been able to gather; those of the immortal discoverer of their periodicity, M. SCHWABE, being always preferred wherever they exist, viz., 1826 to 1863.

A large Plate, No. XV., further represents these quantities graphically; and the whole, should it be approved and advocated by this Royal Society, may perhaps strengthen the hands of Government in doing for Sun-spots and Solar and Scotland, accompanied by the most violent magnetic storm that had been felt for many years (see "Nature," p. 361, No. 564, vol. 12; Aug. 19, 1880); while the Mean Temperature of that month turned out higher than for any August (that of 1857 excepted) chronicled by the Meteorological Society of Scotland, September too followed, with the same temperature characteristic.—*P. S.*, Oct. 1880.

physics generally, what they have done with universal commendation, for the Moon during two centuries ; viz., kept a Royal Observatory continually observing it, until at last the said Observatory is able, now very nearly, to predict the Lunar places for future years from its own observations, and with all the extreme accuracy demanded by the advanced national requirements of the present time.

APPENDIX

No. I.

(Contract for the New Rock Thermometers.)

Estimate by ALEX. ADIE & SON, 50 Princes Street, Edinburgh, for Underground and Standard Thermometers to be placed at the Royal Observatory, Edinburgh.

6th February 1877.

Six thermometers of the following lengths, including the scales above ground:—One 23 feet, one 13 feet, one 6 feet, one 4 feet, one 2 feet, one 1 foot, to hang in air-box. These thermometers to have gun-metal scales, with a strip of platina half-an-inch wide inlaid in the gun metal to receive the graduations and resist oxidation. The bulbs of four of the above thermometers to be cased in copper cylinders, and packed therein with fine clay. Iodine to be used for colouring the alcohol. The thermometers to be carefully compared weekly and daily, with three mercury standards to be, as below, from the time of being made until insertion, that is while the temperature permits this being done, . £140 0 0

The three necessary mercurial standard thermometers above alluded to, to be prepared with all necessary attention to high scientific accuracy, finished with scales like the first six, to be 16 inches long, and to range from 30° to 220°. 18 0 0

A pine wood box with luffer-boards, made for free ventilation, fastened to the rock with copper fastenings, the door to have a brass lock and hinges; also one pine wood box to fit outside the above, to be 7 inches free all round, and to be fastened to the rock with copper bolts, the door locked with a brass lock. The doors of these two boxes to open outwards only, 17 0 0

Preparing well of rock in Royal Observatory grounds to receive thermometers, and filling same after insertion of the thermometers with fine clay, 21 10 0

£196 10 0

Total amount, One hundred and ninety-six pounds ten shillings. The whole of the work to be performed to the satisfaction and approval of the Astronomer Royal for Scotland, who is to have the power to vary the specified length of the long thermometers to the extent of 30 inches each. All the above work to be maintained in good condition by our firm for the space of twelve months.

(Signed) ALEX. ADIE & SON.

* The lengths for the five principal thermometers as eventually constructed were, from the surface of the ground down to the centre of each bulb, $t^1=250$ British inches ; $t^2=125$; $t^3=50$; $t^4=25$; $t^5=1$; while above the surface of the ground every thermometer had 30 inches additional of scale length.

No. II.

Supplied by R. ADIE, Esq.

The Earth Thermometers in the Observatory Grounds, Calton Hill.

In the XIth volume of the Astronomical Observations made at the Royal Observatory 1849-54, there is, pp. 225-279, an account of the earth thermometers, with observations from 1837-54. This paper contains all the information in detail in regard to structure, and correction for surface temperatures on the stems of the long tubes. What is there stated applies to the thermometers inserted by us on 18th June 1879, in the bore of the rock occupied by the first set.

An accident destroyed the thermometers of 1837; to replace them it was necessary to clear the broken stems of the old tubes out of the bore. In doing so, we found the clay placed on the surface to have changed, through 42 years' exposure to rain, into a piece of hard rock, which held the glass tubes of the thermometer stems very firmly. After removing the stone containing the stems of the tubes, the sand and clay for a depth of six inches was partially indurated, when we reached the sand in the state that it had been inserted.

When the bore had been cleared of the old sand, we found that when empty it acted as a perpendicular drain, receiving water from the fissures in the rock which quickly passed away with dry weather.

In the new set of the thermometers, clay on the top of the sand has not been used, as we consider it unsafe to bind the tubes therewith; one of the 1837 set having been broken in a frosty morning when so bound. The scales of the new set of thermometers are platina, and fastened to their respective tubes with platina wire.

(Signed)

ALEX. ADIE & SON, 37 Hanover Street,
8th January 1880.

No. III.

Account of the Making and Placing of the New (1877-79) Rock Thermometers at the Royal Observatory, Edinburgh, by THOMAS WEDDERBURN, Foreman of the Firm of ADIE & SONS, Opticians, Edinburgh.

On our receiving the order from Professor PIAZZI SMYTH for the reconstruction of the destroyed earth or rock thermometers, it was considered that, in the first place, the hole that they were sunk in should be cleared out, and on our clearing off the surface mould we found a hard compact substance instead of a "puddle clay" as mentioned in the Observatory Transactions. The sections of the tubes now being seen, we then found the substance to be about 6 inches thick in the hard state, and then gradually softening for other 3 inches until it came in contact with the sand that filled the hole. As it was wanted to be ascertained if the portions of the thermometers underground were the same in construction as what the new thermometers were to be, we proceeded to remove the hard mass, with the sections of the tubes, and then the sand, until we got down to the 3 feet thermometer bulb, which we removed; then to the 6 feet bulb, which was also removed; but on reaching down to the 12 feet bulb it was found to be firmly fastened to the side of the hole by the rust of its tin case, so that we had to give up hopes of bringing it to the surface. We then proceeded in a rough and ready way, by means of a 30 feet pole with 3 feet of 2 inch brass tube attached to it, to remove the rest of the contents of the hole, which was found to be $26\frac{1}{2}$ feet deep, the opening at surface, $5\frac{1}{2}$ to 5 inches.

in diameter; the first 12 feet of it was much the same, after which it closes to a hole of about 3 inches diameter for the remainder of the depth. We may state here that we found some obstruction in removing the sand from a copper wire about the 20th of an inch in diameter. There having been no evidence of it when opening out the hole, we could only bring it up in small portions. On showing these to Professor ALEX. S. HERSCHEL of Newcastle-on-Tyne, he thought them to have been portions of a thermal pile (though no written note of such a thing has been found), and from the length of wire brought up it must have reached the bottom of the hole.

In proceeding with the construction of the new thermometers, we had carefully retained portions of each tube for the size of bore, and having applied to Mr FORD, of the South Back of Canongate, for these extra long tubes, we had them drawn on the 14th of August 1877. The first five tubes of 40 feet did not come up to what was expected of them, though for the shorter thermometers there were pieces of them that answered. It was then proposed to draw tubes of a 100 feet, instead of carrying on the drawing of the 40 feet lengths. On a 100 feet tube being drawn, it was found on careful examination to answer the purpose, 30 feet of it being cut from the centre. For the scale tubes we had eighteen drawn of 3 feet each, and after carefully callipering them, we found them sufficient to answer the purpose. After the tubes were drawn they were laid in their "gutters," which were made of 26-inch deals, set at right angles, with pieces of cork 3 feet apart for the tubes to rest on, where they remained until their insertion in the Royal Observatory grounds. In the drawing of the bulbs of the thermometers, we had carefully prepared sketches of each size, so that there was no trouble in working them, and we may mention that they were annealed, the glass of them being as near as possible the 20th of an inch in thickness.

In the making of the thermometers our first care was to find if we had got the bulbs of the right *size*, which we did by fixing a piece of the scale tube to each bulb, and then filling them with spirit, and testing them in the usual way with the standard, when they were all found to be correct for each range of bulb. We then attached each bulb to its own tube, and in the shorter thermometers filled them with the spirit in the usual way. With the 12 and 24 feet tubes we turned the bulb ends uppermost, and poured the spirit in through a small filler made of inch glass tube drawn to a fine point, until the bulb was nearly filled. The points of the bulbs were then sealed, and the thermometer reversed, and a small portion of spirit placed in the expansion bulb at top. Then warm water was applied to the bulb to expand the spirit and expel the remaining air; the air passing through the spirit in the expansion bulb, and allowing it to descend; when after a few applications of heat and cold, we had the satisfaction of seeing them filled.

Our next care was to regulate them, which was done in a tub of cold water, with the three standard thermometers made for the purpose, and having fixed the points as near as possible, we then had temporary scales of boxwood made and attached to each. They were then removed to Professor PIAZZI SMYTH's house, at 15 Royal Terrace, for comparison with the three standards. In the work of comparing the thermometers, the bulbs were placed in a tub of water, so that they were always covered; the temperature of the water being carefully noted, as well as of the atmosphere, each time a reading was taken with the three standards. The readings through the winter of 1877 and 1878 were but few, from the mildness of the season and the thermometers being inside the house. Wherefore, to make more certain of the following winter season, the thermometers were removed to the outside of the house, where the final readings were got in the spring of 1879.

The three standard thermometers with which the comparisons of the long thermometers

were made are a set that were made in 1867, of very fine tubes, the callipering being almost perfect. The points were taken in 1877, when these thermometers were finished; the scales of them being of gun metal inlaid with a strip of platina, on which the dividing is done. There is also a strong bar of gun metal on the sides of the scales to prevent their bending, owing to the unequal expansion of the two metals.

The final work of placing the thermometers in the hole was done on the 26th of June 1879. They were removed that morning from the Royal Terrace house to the Royal Observatory, where the copper cases were placed on the bulbs, and filled with plaster of Paris. In the bottom of each copper case there is a layer of cork, varying in thickness from 3 inches downward, cupped to receive the bottom of each bulb; the points of the bulbs being about an inch from the bottom of each case.

The placing of the 250 inch thermometer in the hole was done by having a cross spar at the top, having four pulleys, two of the pulleys being close to the tube, and the other two being 12 inches apart, over which was carried on each side a cord, the one cord being attached to the top of the tube, and the other to the copper case. The cord was then passed one on each side of the two outside pulleys, and made of sufficient length to reach the ground, when the case with the thermometer was placed erect. There was then placed a 3 lb. weight on each side, the effect being that when the case with the thermometer was placed against the triangle, and the thermometer freed of its tyings, it passed down of its own weight. Fine fresh water sand, specially procured for this purpose from an excavation in the Easter Road, was filled in for the 125 inch, which was passed down by hand, the others being done in the same way. On the following day the scales of platina were wired on, and the two wooden cases, or little houses for protection from the weather, fastened down with gun-metal bolts.

THOMAS WEDDERBURN,
Foreman of Adie & Son.

P.S. (1).—The following articles were taken from the hole:—

The hard block with the sections of the tubes, the 3-feet bulb with its tin case, the 6-feet bulb with its tin case, the remains of the 12-feet bulb tin case, the portions of copper wire, a sample of the sand used in filling up the hole, a piece of the supposed thermal-pile wire perfect, taken from the transit-house pipe that was supposed to have been once in connection with the hole, and is within 3 feet of its mouth. Of this arrangement no records are known to exist; and from 1845, downwards, the piece of lead pipe with a short length of the copper wire wrapped in cere-cloth, to insulate them, and struck through the east wall of old-transit house, had been considered the relics of some experiments once carried on by Professor J. D. FORBES, but not described, or subsequently cared for, by him.

T. W.

P.S. (2).—The attachment of the big bulb to its long tube was done in the usual way by sealing up the tube at one end, and blowing a small oval bulb, and cutting away the half of it, the same being done with the stem of the big bulb, and then the two half bulbs on the tubes and stem being melted together by a Bunsen flame.

T. W.

No. IV.

The Cyclical Seasons predicted in 1872.

Extracts from pp. R 105, R 106 of the XIIIth Vol. of the Edinburgh Astronomical Observations, published in the beginning of 1872. (Subsequent additions in parenthesis, thus).

“How intimately the well-being of the poor generally, as well as of the agricultural classes

depends on those characteristics of weather (viz., cyclical returns at several, or many years' interval), which no scientific Society can at present foretell, and no Ministry prevent in their destructive effects to the national revenue when they do come" (has been proved in the famine history of the past, and may be repeated in the future, for we find as follows in the Edinburgh rock thermometers)—

" 1. The most striking and positive feature of the whole series of observations" (viz. of the Rock Thermometers at the Royal Observatory, Edinburgh) "is the great heat wave, which occurs every eleven years and a fraction, and nearly coincidently with the beginning of the increase of each sun-spot cycle of the same eleven year duration. The last observed occurrences of such heat wave, which is very short lived and of a totally different *shape* from the sun-spot curve, were in 1834·8, 1846·4, 1857·8 and 1868·8; whence, allowing for the greater uncertainty in the earlier observation, we may expect the next occurrence of the phenomenon in or about 1880·0.

" 2. The next largest feature is the extreme cold close on either side of the great heat-wave. We may perhaps be justified in concluding that the minimum temperature of the present cold wave was reached in 1871·1; and that the next similar cold wave (*i.e.* similar in being one or other of the two satellites attending on the heat wave, though that of 1871·1 was the *follower* of the 1868·8 heat wave, and that now spoken of as to come in 1878·8, is the *predecessor* of the expected heat wave of 1880) will occur in 1878·8.

" 3. Between the dates of these two cold waves (1871·1 and 1878·8), there are located, according to all the cycles observed,—3 moderate and nearly equi-distant heat waves, with their two intervening and very moderate cold troughs, but their characters are quite unimportant as compared with what is alluded to under heads 1 and 2."

(To the above it may now, or in 1880·9, be added—that the following satellitary cold wave after the heat of 1880, should occur in 1882, subject to some uncertainties dependent not only on the still inexactly ascertained epochs of several past minima, as well as maxima of sun-spots,—but on the total inability of all modern science up to its latest advanced position, to *predict* whether the date of the next maximum of sun-spots will be at a long, a short, or an average interval after the last minimum. The variations of those intervals in past cycles having amounted to anything within three years; an amount of uncertainty far too great to allow of useful agricultural warnings.)

No. V.

Scottish Meteorological Data of various kinds, arranged either in simple Annual, or more generally in Quadruple Annual Means for Cyclical inquiries.

TABLE I. Simple annual Means chiefly for SCHWABE'S Sun-spot curves, and WOLF'S dates of max. and min. of Sun-spots.

TABLE II. Quadruple annual Means of the Rock Thermometers, at Royal Observatory, Edinburgh, from 1837 to 1876. Pages 1 and 2.

TABLE III. Quadruple annual Means of Air Temperature, by Scottish Meteorological Society, 1856–1880.

TABLE IV. Quadruple annual Sums of Scottish Rainfall, by Scottish Meteorological Society, 1856–1880.

TABLE V. Edinburgh Air Temperature by A. ADIE, from 1821 to 1850, in Quadruple Ann. Means.

TABLE VI. Edinburgh Rainfall, by A. ADIE, from 1822 to 1850, in Quadruple Ann. Sums.

TABLE VII. Quadruple Annual Sums of Rainfall, at Culloden, from 1841 to 1862, to fill the gap between the last Rainfalls of A. ADIE and the first of the Scottish Meteorological Society.

TABLE I.—Single Annual Means of the Edinburgh Earth-Thermometers, and others; begin with the first observations of M. SCHWABE, the discoverer of the Periodicity of the Sun-spots.

(See Plate XV.)

Date.	t_1 or 25·6 British feet deep Therm.	t_2 or 12·8 British feet deep Therm.	t_3 or 6·4 British feet deep Therm.	t_4 or 3·2 British feet deep Therm.	Air Mean Temp. in Edin. by Alex. Adie.	Air Mean Temp. over Scotl. by Sc. Met. Soc.	Schwabe's New Groups of Sun-spots. Kew Obs. Wolf's Nos. $\times 2$.	Wolf's Sun Spots, Dates of.		Rainfall in Edinburgh, by Alex. Adie.	Rainfall over Scotl., by Sc. Met. Soc.
	° F.	° F.	° F.	° F.	° F.	° F.		Max.	Min.	Inches.	Inches.
1826·50	...	...	...	...	48·7	...	118	...	...	15·27	...
1827·50	...	...	...	...	47·1	...	161	...	...	32·59	...
1828·50	...	...	...	...	48·5	...	225	...	...	25·23	...
1829·50	...	...	...	...	45·2	...	199	1829·5	...	29·96	...
1830·50	...	...	...	...	46·0	...	190	...	...	33·25	...
1831·50	...	...	...	...	47·5	...	149	...	...	24·53	...
1832·50	...	...	...	...	47·7	...	84	...	...	23·23	...
1833·50	...	...	...	...	47·2	...	33	...	1833·8	20·88	...
1834·50	...	...	...	...	48·7	...	51	...	...	21·04	...
1835·50	...	...	...	...	46·8	...	173	...	...	25·22	...
1836·50	...	...	...	...	45·7	...	272	...	...	33·03	...
1837·50	47·26	46·65	46·26	46·08	45·7	...	333	1837·2	...	26·77	...
1838·50	46·94	46·16	45·89	44·81	44·7	...	282	...	...	31·04	...
1839·50	46·69	46·15	45·67	45·33	46·4	...	162	...	...	23·45	...
1840·50	46·77	46·44	46·02	45·68	46·7	...	152	...	...	25·50	...
1841·50	46·78	46·48	46·06	45·70	46·6	...	102	...	...	26·22	...
1842·50	46·88	46·81	46·78	46·85	48·0	...	68	...	...	16·87	...
1843·50	47·14	46·92	46·49	46·18	47·6	...	34	...	...	23·80	...
1844·50	47·21	47·11	46·83	46·44	46·7	...	52	...	1844·0	20·94	...
1845·50	47·06	46·56	45·97	45·57	46·3	...	114	...	...	26·62	...
1846·50	47·29	47·60	47·76	47·78	49·6	...	157	...	...	31·54	...
1847·50	47·59	47·33	46·88	46·60	47·4	...	257	...	...	22·77	...
1848·50	47·38	46·97	46·42	46·02	47·0	...	330	1848·6	...	30·60	...
1849·50	47·25	46·86	46·61	46·52	46·5	...	238	...	...	22·21	...
1850·50	47·24	47·00	46·69	46·49	47·0	...	186	...	...	...	...
1851·50	47·40	47·26	47·02	46·80	...	...	151	...	...	...	...
1852·50	47·55	47·48	47·28	47·05	...	...	125	...	...	...	...
1853·50	47·48	47·03	46·50	46·10	...	...	91	...	...	...	...
1854·50	47·41	47·18	46·92	46·75	...	...	67	...	...	...	...
1855·50	47·30	46·79	46·22	45·78	...	...	79	...	...	...	...
1856·50	47·14	46·67	46·34	46·11	...	45·7	34	...	1856·2	...	33·00
1857·50	47·30	47·34	47·42	47·54	...	48·0	98	...	...	...	30·56
1858·50	47·86	47·98	47·71	47·34	...	46·6	188	...	...	...	33·91
1859·50	47·85	47·64	47·26	46·90	...	46·8	205	...	...	...	37·17
1860·50	47·36	46·43	45·62	45·14	...	44·5	211	1860·5	...	...	37·88
1861·50	47·12	...	46·50	46·34	...	46·9	204	...	...	...	45·07
1862·50	47·20	...	46·30	45·96	...	46·1	160	...	...	...	45·29
1863·50	47·20	...	46·74	46·67	...	46·8	124	...	...	...	42·11
1864·50	47·16	...	46·25	45·84	...	45·5	115	...	...	...	38·58
1865·50	47·08	...	46·50	46·41	...	46·9	93	...	...	...	33·91
1866·50	47·30	...	46·65	46·22	...	46·3	45	...	...	...	41·41
1867·50	47·14	...	46·18	45·82	...	45·7	15	...	1867·0	...	38·52
1868·50	47·34	...	47·31	47·37	...	47·6	75	...	...	...	43·03
1869·50	47·55	...	47·11	46·92	...	46·4	148	...	...	...	36·54
1870·50	47·37	...	46·54	46·16	...	46·1	278	1870·9	...	...	31·81
1871·50	47·32	...	46·52	46·24	...	46·4	222	...	...	...	37·19
1872·50	47·36	...	46·73	46·50	...	46·9	203	...	...	...	54·15
1873·50	47·28	...	46·38	46·08	...	46·4	133	...	...	...	39·33
1874·50	47·38	...	47·09	46·80	...	46·5	89	...	...	...	40·17
1875·50	47·36	...	46·59	46·41	...	46·9	34	...	...	...	39·08
1876·50	47·24	...	46·30	45·96	...	46·6	23	...	1876·8 (1877·5)	...	44·88
1877·50	...	...	...	...	...	45·7	...	...	Since proved by British Obs. to be 1879·0.	...	51·83
1878·50	...	...	...	...	...	46·8	...	...	...	...	36·28
1879·50	...	...	...	...	...	43·9	...	...	...	...	36·43

TABLE II.—*Quadruple Annual Mean Temperatures for Four several Sub-Annual Epochs.*

(See Plate XV.)

Date.	t_1 or 25'6" ft. deep Therm.	t_2 or 12'8" ft. deep Therm.	t_3 or 6'4" ft. deep Therm.	t_4 or 3'2" ft. deep Therm.	Date.	t_1 or 25'6" ft. deep Therm.	t_2 or 12'8" ft. deep Therm.	t_3 or 6'4" ft. deep Therm.	t_4 or 3'2" ft. deep Therm.	Date.	t_1 or 25'6" ft. deep Therm.	t_2 or 12'8" ft. deep Therm.	t_3 or 6'4" ft. deep Therm.	t_4 or 3'2" ft. deep Therm.
	° F.	° F.	° F.	° F.		° F.	° F.	° F.	° F.		° F.	° F.	° F.	° F.
1837-0	...	...	...	...	1850-0	47.23	46.83	46.52	46.33	1863-0	47.14	...	46.60	46.26
25	...	...	...	...	25	47.22	46.91	46.66	46.49	25	47.17	...	46.79	46.45
50	47.26	46.65	46.26	46.08	50	47.24	47.00	46.69	46.49	50	47.20	...	46.85	46.67
75	47.18	46.62	45.94	45.40	75	47.28	47.15	46.99	46.82	75	47.23	...	46.69	46.17
1838-0	47.12	46.55	45.94	45.40	1851-0	47.34	47.22	46.97	46.75	1864-0	47.22	...	46.44	46.12
25	47.04	46.36	45.58	44.99	25	47.38	47.21	46.91	46.66	25	47.19	...	46.31	46.00
50	46.94	46.16	45.39	44.82	50	47.40	47.26	47.02	46.80	50	47.16	...	46.25	45.84
75	46.82	46.07	45.43	45.02	75	47.44	47.28	46.98	46.69	75	47.13	...	46.06	45.69
1839-0	46.75	46.08	45.52	45.16	1852-0	47.46	47.32	47.09	46.82	1865-0	47.09	...	45.96	45.67
25	46.72	46.13	45.60	45.21	25	47.49	47.42	47.32	47.20	25	47.06	...	46.27	46.19
50	46.69	46.16	45.67	45.34	50	47.55	47.48	47.28	47.05	50	47.08	...	46.50	46.41
75	46.68	46.21	45.81	45.58	75	47.59	47.43	47.02	46.60	75	47.15	...	46.89	46.82
1840-0	46.70	46.39	46.14	45.94	1853-0	47.59	47.25	46.79	46.47	1866-0	47.23	...	46.93	46.70
25	46.75	46.44	46.09	45.82	25	47.54	47.14	46.56	46.10	25	47.30	...	46.76	46.33
50	46.77	46.44	46.02	45.68	50	47.48	47.03	46.50	46.10	50	47.30	...	46.65	46.22
75	46.77	46.38	45.88	45.54	75	47.41	46.92	46.47	46.28	75	47.28	...	46.44	46.01
1841-0	46.76	46.41	46.00	45.66	1854-0	47.38	47.06	46.74	46.56	1867-0	47.24	...	46.33	45.88
25	46.76	46.44	46.03	45.73	25	47.39	47.10	46.84	46.74	25	47.13	...	46.24	45.87
50	46.78	46.48	46.08	45.70	50	47.41	47.18	46.92	46.75	50	47.14	...	46.18	45.82
75	46.79	46.48	46.12	45.79	75	47.45	47.25	46.85	46.42	75	47.10	...	46.34	46.30
1842-0	46.80	46.48	46.16	45.99	1855-0	47.44	47.01	46.88	45.85	1868-0	47.11	...	46.81	46.89
25	46.82	46.62	46.52	46.49	25	47.37	46.89	46.35	45.95	25	47.21	...	47.25	47.40
50	46.88	46.81	46.78	46.84	50	47.30	46.79	46.22	45.78	50	47.34	...	47.31	47.37
75	46.99	47.08	47.06	46.98	75	47.23	46.68	46.25	46.07	75	47.45	...	47.48	47.39
1843-0	47.10	47.12	46.79	46.41	1856-0	47.19	46.78	46.44	46.22	1869-0	47.54	...	47.26	47.06
25	47.15	46.99	46.58	46.27	25	47.18	46.72	46.26	45.79	25	47.56	...	47.03	46.88
50	47.14	46.92	46.48	46.18	50	47.14	46.67	46.34	46.11	50	47.55	...	47.11	46.92
75	47.13	46.92	46.52	46.20	75	47.13	46.79	46.55	46.30	75	47.53	...	46.66	46.28
1844-0	47.13	46.97	46.82	46.74	1857-0	47.15	46.85	46.64	46.48	1870-0	47.46	...	46.63	46.34
25	47.17	47.10	46.85	46.54	25	47.20	47.05	46.96	46.98	25	47.40	...	46.66	46.29
50	47.21	47.11	46.82	46.44	50	47.30	47.34	47.42	47.54	50	47.37	...	46.54	46.16
75	47.23	46.97	46.52	46.13	75	47.43	47.67	47.74	47.73	75	47.34	...	46.59	46.40
1845-0	47.20	46.83	46.25	45.74	1858-0	47.59	47.88	48.05	48.14	1871-0	47.33	...	46.62	46.34
25	47.13	46.68	46.04	45.52	25	47.75	48.05	48.10	48.06	25	47.33	...	46.58	46.30
50	47.06	46.56	45.98	45.57	50	47.86	47.98	47.71	47.34	50	47.32	...	46.52	46.24
75	47.01	46.64	46.39	46.32	75	47.88	47.77	47.56	47.44	75	47.31	...	46.82	46.68
1846-0	47.03	46.85	46.71	46.69	1859-0	47.87	47.76	47.49	47.21	1872-0	47.33	...	46.80	46.54
25	47.12	47.19	47.32	47.49	25	47.86	47.70	47.42	47.19	25	47.34	...	46.78	46.49
50	47.29	47.60	47.76	47.78	50	47.85	47.64	47.26	46.90	50	47.36	...	46.73	46.50
75	47.48	47.74	47.54	47.24	75	47.82	47.38	46.64	46.00	75	47.36	...	46.56	46.10
1847-0	47.60	47.70	47.37	46.92	1860-0	47.71	47.02	46.18	45.58	1873-0	47.35	...	46.48	46.17
25	47.64	47.56	47.08	46.57	25	47.54	46.71	45.81	45.20	25	47.32	...	46.42	46.00
50	47.59	47.33	46.88	46.60	50	47.36	46.43	45.62	45.14	50	47.28	...	46.38	46.08
75	47.52	47.21	46.82	46.58	75	47.20	...	45.80	45.52	75	47.24	...	46.60	46.15
1848-0	47.46	47.16	46.84	46.68	1861-0	47.10	...	46.05	45.85	1874-0	47.25	...	46.85	46.70
25	47.42	47.09	46.66	46.40	25	47.09	...	46.23	46.03	25	47.31	...	46.96	46.85
50	47.38	46.97	46.42	46.02	50	47.12	...	46.50	46.34	50	47.33	...	47.09	46.80
75	47.31	46.93	46.59	46.47	75	47.17	...	46.68	46.48	75	47.44	...	46.76	46.33
1849-0	47.28	46.95	46.56	46.33	1862-0	47.22	...	46.68	46.41	1875-0	47.32	...	46.41	46.10
25	47.27	46.88	46.53	46.34	25	47.23	...	46.43	46.09	25	47.27	...	46.39	46.06
50	47.25	46.86	46.61	46.52	50	47.20	...	46.30	45.96	50	47.24	...	46.30	45.96
75	47.24	46.82	46.47	46.26	75	47.16	...	46.38	46.17	75	...	...	...	...

TABLE III.—*Mean Temperature of Air of Scottish Country and Town Stations, by the Meteorological Society of Scotland.*

QUADRUPLE ANNUAL MEANS FOR QUARTERLY PERIODS.

Date.	Q. Ann. Mean Temp. of Air.	Date.	Q. Ann. Mean Temp. of Air.	Date.	Q. Ann. Mean Temp. of Air.	Date.	Q. Ann. Mean Temp. of Air.
	° F.		° F.		° F.		° F.
1856-50	45.7	...	...	...	...	...	...
1856-75	45.8	...	...	...	...	...	...
1857-0	46.2	1863-0	46.6	1869-0	46.8	1875-0	46.2
1857-25	47.0	1863-25	46.5	1869-25	46.6	1875-25	46.4
1857-50	48.0	1863-50	46.9	1869-50	46.4	1875-50	46.9
1857-75	48.1	1863-75	45.6	1869-75	45.6	1875-75	46.7
1858-0	48.2	1864-0	45.8	1870-0	46.3	1876-0	46.3
1858-25	47.8	1864-25	45.9	1870-25	46.5	1876-25	46.2
1858-50	46.6	1864-50	45.5	1870-50	46.2	1876-50	46.6
1858-75	47.3	1864-75	45.4	1870-75	46.7	1876-75	46.8
1859-0	47.2	1865-0	45.8	1871-0	46.1	1877-0	46.4
1859-25	47.2	1865-25	46.6	1871-25	45.9	1877-25	45.9
1859-50	46.8	1865-50	46.9	1871-50	46.4	1877-50	45.7
1859-75	45.6	1865-75	47.6	1871-75	46.8	1877-75	46.0
1860-0	45.1	1866-0	47.0	1872-0	46.9	1878-0	46.3
1860-25	44.5	1866-25	46.3	1872-25	46.8	1878-25	47.6
1860-50	44.5	1866-50	46.3	1872-50	46.9	1878-50	46.8
1860-75	45.2	1866-75	45.9	1872-75	46.2	1878-75	45.3
1861-0	45.8	1867-0	45.8	1873-0	46.2	1879-0	44.4
1861-25	46.3	1867-25	46.0	1873-25	46.1	1879-25	43.6
1861-50	46.9	1867-50	45.8	1873-50	46.4	1879-50	43.9
1861-75	46.8	1867-75	46.8	1873-75	47.0	1879-75	45.3
1862-0	46.6	1868-0	47.3	1874-0	47.1	1880-0	46.5
1862-25	46.2	1868-25	47.8	1874-25	47.3	1880-25	46.7
1862-50	46.2	1868-50	47.6	1874-50	46.5	...	...
1862-75	46.7	1868-75	47.5	1874-75	45.9	...	...

TABLE IV.—*Rainfall in Inches, of Scottish Country and Town Stations, per the Meteorological Society of Scotland.*

QUADRUPLE ANNUAL SUMS FOR QUARTERLY PERIODS.

Date.	Q. Ann. Sum of Rainfall.	Date.	Q. Ann. Sum of Rainfall.	Date.	Q. Ann. Sum of Rainfall.	Date.	Q. Ann. Sum of Rainfall.
	Inches.		Inches.		Inches.		Inches.
1856-50	33.00	...	...	...	...	...	...
1856-75	34.32	...	...	...	...	...	...
1857-0	32.40	1863-0	43.08	1869-0	37.32	1875-0	41.76
1857-25	29.64	1863-25	43.44	1869-25	36.96	1875-25	39.12
1857-50	30.60	1863-50	42.12	1869-50	36.48	1875-50	39.12
1857-75	29.40	1863-75	42.00	1869-75	34.56	1875-75	42.24
1858-0	29.52	1864-0	39.24	1870-0	35.04	1876-0	42.84
1858-25	31.44	1864-25	37.92	1870-25	33.00	1876-25	42.24
1858-50	33.84	1864-50	38.64	1870-50	31.80	1876-50	44.88
1858-75	39.60	1864-75	36.72	1870-75	33.24	1876-75	46.32
1859-0	38.16	1865-0	35.64	1871-0	34.32	1877-0	48.48
1859-25	36.60	1865-25	35.16	1871-25	37.32	1877-25	51.84
1859-50	37.20	1865-50	33.96	1871-50	37.20	1877-50	51.84
1859-75	36.24	1865-75	38.16	1871-75	41.52	1877-75	46.20
1860-0	38.40	1866-0	38.04	1872-0	44.88	1878-0	44.64
1860-25	37.68	1866-25	41.40	1872-25	48.72	1878-25	41.52
1860-50	37.92	1866-50	41.40	1872-50	54.12	1878-50	36.24
1860-75	38.64	1866-75	38.52	1872-75	49.20	1878-75	35.76
1861-0	35.88	1867-0	42.96	1873-0	43.80	1879-0	36.36
1861-25	44.04	1867-25	41.88	1873-25	43.44	1879-25	40.20
1861-50	45.12	1867-50	38.52	1873-50	39.36	1879-50	36.48
1861-75	44.40	1867-75	42.96	1873-75	38.76	1879-75	37.20
1862-0	50.28	1868-0	40.56	1874-0	39.12	...	...
1862-25	44.28	1868-25	39.36	1874-25	38.88	...	...
1862-50	45.24	1868-50	42.96	1874-50	40.20	...	...
1862-75	45.12	1868-75	38.76	1874-75	40.68	...	...

TABLE V.—*Edinburgh Air Temperatures, observed by Alex. Adie, discussed by Prof. J. D. Forbes, in the Transactions of Royal Society, Edinburgh, Vol. xxii., 1860.*

QUARTERLY MEANS, AND ALSO ANNUAL MEANS, SPECIALLY TAKEN AT EVERY QUARTER.

Date.	Quarterly.	Annual.	Date.	Quarterly.	Annual.	Date.	Quarterly.	Annual.	Date.	Quarterly.	Annual.
1821-00			1829-00			1837-00			1844-00		
.125	39.6		.125	36.9	47.2	.125	36.2	44.6	.125	39.5	48.6
.25			.25		46.5	.25		45.2	.25		47.9
.375	48.8		.375	50.0		.375	47.6		.375	51.2	
.50		47.4	.50		45.2	.50		45.7	.50		46.8
.625	57.0		.625	53.6		.625	55.6		.625	55.2	
.75		47.8	.75		45.6	.75		45.0	.75		45.9
.875	44.4		.875	40.5		.875	43.4		.875	41.1	
1822-00		48.7	1830-00		45.4	1838-00		44.8	1845-00		45.6
.125	41.1		.125	38.2		.125	33.2		.125	36.2	
.25		48.2	.25		45.6	.25		45.1	.25		45.6
.375	52.4		.375	49.4		.375	47.2		.375	50.0	
.50		47.8	.50		46.0	.50		44.7	.50		46.3
.625	55.1		.625	54.2		.625	56.5		.625	55.0	
.75		46.4	.75		46.1	.75		45.7	.75		48.0
.875	42.6		.875	42.1		.875	41.9		.875	43.9	
1823-00		45.5	1831-00		45.7	1839-00		46.3	1846-00		48.8
.125	35.3		.125	38.6		.125	37.2		.125	43.2	
.25		45.4	.25		46.8	.25		46.2	.25		49.9
.375	49.0		.375	48.0		.375	49.5		.375	53.2	
.50		45.3	.50		47.5	.50		46.3	.50		49.6
.625	54.6		.625	58.3		.625	56.2		.625	59.5	
.75		46.3	.75		48.0	.75		46.9	.75		48.3
.875	42.2		.875	45.1		.875	42.6		.875	42.5	
1824-00		46.7	1832-00		48.5	1840-00		47.2	1847-00		47.5
.125	39.5		.125	40.5		.125	39.3		.125	37.9	
.25		47.4	.25		48.0	.25		47.0	.25		46.8
.375	50.6		.375	50.1		.375	50.6		.375	50.0	
.50		47.2	.50		47.7	.50		46.7	.50		47.4
.625	57.2		.625	56.4		.625	55.5		.625	57.0	
.75		47.3	.75		47.0	.75		46.7	.75		47.6
.875	41.6		.875	43.9		.875	41.5		.875	44.8	
1825-00		47.5	1833-00		47.5	1841-00		46.7	1848-00		47.9
.125	39.8		.125	37.7		.125	39.3		.125	38.4	
.25		48.0	.25		47.2	.25		46.8	.25		47.6
.375	51.3		.375	51.9		.375	50.4		.375	51.5	
.50		48.2	.50		47.2	.50		46.6	.50		47.0
.625	59.5		.625	55.5		.625	56.0		.625	55.7	
.75		48.0	.75		48.2	.75		46.6	.75		47.6
.875	42.2		.875	43.7		.875	40.8		.875	42.4	
1826-00		48.5	1834-00		48.0	1842-00		46.9	1849-00		46.9
.125	39.0		.125	41.6		.125	39.2		.125	40.7	
.25		48.4	.25		48.5	.25		47.2	.25		46.8
.375	53.3		.375	51.4		.375	51.6		.375	48.9	
.50		48.7	.50		48.7	.50		48.0	.50		46.5
.625	59.2		.625	57.2		.625	57.1		.625	55.4	
.75		48.1	.75		48.2	.75		47.8	.75		46.0
.875	43.3		.875	44.7		.875	44.0		.875	41.1	
1827-00		47.4	1835-00		47.6	1843-00		47.0	1850-00		46.5
.125	36.5		.125	39.4		.125	38.7		.125	38.6	
.25		46.7	.25		47.4	.25		47.2	.25		46.7
.375	50.7		.375	49.3		.375	48.3		.375	51.0	
.50		47.1	.50		46.8	.50		47.6	.50		47.0
.625	56.2		.625	56.3		.625	57.9		.625	56.1	
.75		48.2	.75		46.6	.75		47.8	.75		
.875	45.0		.875	42.3		.875	45.6		.875	42.4	
1828-00		48.3	1836-00		46.7	1844-00		44.6	1850-00		46.5
.125	40.8		.125	38.3		.125	38.7		.125	38.6	
.25		48.3	.25		46.0	.25		47.2	.25		46.7
.375	51.1		.375	49.9		.375	48.3		.375	51.0	
.50		48.5	.50		45.8	.50		47.6	.50		47.0
.625	56.4		.625	53.5		.625	57.9		.625	56.1	
.75		47.5	.75		45.2	.75		47.8	.75		
.875	45.6		.875	41.3		.875	45.6		.875	42.4	

TABLE VI.—*Edinburgh Rainfalls, observed by Alexander Adie, discussed by Professor J. D. Forbes, in the Transactions of Royal Society, Edinburgh, Vol. xxii., 1860.*

QUARTERLY MONTHLY MEANS, AND ALSO ANNUAL MONTHLY MEANS AND ANNUAL SUMS, SPECIALLY TAKEN AT EVERY QUARTER.

Date.	Quarterly.	Annual		Date.	Quarterly.	Annual		Date.	Quarterly.	Annual		Date.	Quarterly.	Annual	
1822-00				1829-00				1836-00				1843-00			
.125	2.43			.125	1.47	2.32	27.84	.125	3.16	2.47	29.64	.125	1.35	1.66	19.92
.25				.25	2.55	30.60		.25		2.72	32.64	.25		1.79	21.48
.375	1.52			.375	2.05			.375	1.53			.375	2.37		
.50		2.18	26.16	.50	2.49	29.88		.50		2.75	33.00	.50		1.98	23.76
.625	2.72			.625	4.35			.625	3.93			.625	1.96		
.75		2.13	25.56	.75	2.46	29.52		.75		2.35	28.20	.75		2.09	25.08
.875	2.04			.875	2.11			.875	2.39			.875	2.25		
1823-00				1830-00				1837-00				1844-00			
.125	2.25	2.17	26.04	.125	1.31	2.51	30.12	.125	1.55	2.47	29.64	.125	1.79	1.77	21.24
.25		2.32	27.84	.25	2.83	33.96		.25		2.35	28.20	.25		1.88	22.56
.375	1.68			.375	2.26			.375	2.00			.375	1.09		
.50		2.52	30.24	.50	2.77	33.24		.50		2.23	26.76	.50		1.74	20.88
.625	3.31			.625	5.63			.625	3.47			.625	2.40		
.75		2.28	27.36	.75	2.98	35.76		.75		2.38	28.56	.75		1.64	19.68
.875	2.85			.875	1.88			.875	1.91			.875	1.70		
1824-00				1831-00				1838-00				1845-00			
.125	1.30	2.13	25.56	.125	2.17	2.72	32.64	.125	2.15	2.70	32.40	.125	1.35	1.84	22.08
.25		1.70	20.40	.25	1.98	23.76		.25		2.62	31.44	.25		1.82	21.84
.375	1.07			.375	1.21			.375	3.23			.375	1.91		
.50		2.07	24.84	.50	2.04	24.48		.50		2.59	31.08	.50		2.22	26.64
.625	1.57			.625	2.67			.625	3.14			.625	2.32		
.75		1.94	23.28	.75	1.78	21.36		.75		2.44	29.28	.75		2.32	27.84
.875	4.33			.875	2.12			.875	1.78			.875	3.29		
1825-00				1832-00				1839-00				1846-00			
.125	0.81	2.24	26.88	.125	1.11	1.93	23.16	.125	1.56	2.01	24.12	.125	1.74	2.48	29.76
.25		2.25	27.00	.25	1.74	20.88		.25		1.92	23.04	.25		2.95	35.40
.375	2.24			.375	1.82			.375	1.57			.375	2.58		
.50		1.84	22.08	.50	1.94	23.28		.50		1.96	23.52	.50		2.63	31.56
.625	1.63			.625	1.90			.625	2.79			.625	4.18		
.75		1.95	23.40	.75	2.04	24.48		.75		2.04	24.48	.75		2.32	27.84
.875	2.70			.875	2.92			.875	1.90			.875	2.02		
1826-00				1833-00				1840-00				1847-00			
.125	1.22	1.64	19.68	.125	1.51	2.05	24.60	.125	1.91	2.22	26.64	.125	0.48	2.32	27.84
.25		1.66	19.92	.25	2.00	24.00		.25		2.13	26.16	.25		1.57	18.84
.375	1.02			.375	1.87			.375	2.30			.375	2.60		
.50		1.27	15.24	.50	1.74	20.88		.50		2.12	25.44	.50		1.90	22.80
.625	1.72			.625	1.69			.625	2.61			.625	1.18		
.75		1.78	21.36	.75	1.84	22.08		.75		1.94	23.28	.75		2.55	30.60
.875	1.13			.875	1.89			.875	1.67			.875	3.33		
1827-00				1834-00				1841-00				1848-00			
.125	3.25	2.00	23.88	.125	1.93	1.58	18.96	.125	1.16	1.68	20.16	.125	3.09	2.54	30.48
.25		2.26	27.12	.25	1.90	22.80		.25		1.87	22.44	.25		2.65	31.80
.375	1.88			.375	0.80			.375	1.28			.375	2.57		
.50		2.72	32.64	.50	1.75	21.00		.50		2.18	26.16	.50		2.55	30.60
.625	2.77			.625	2.96			.625	3.38			.625	1.60		
.75		2.22	26.64	.75	1.76	21.12		.75		2.36	28.32	.75		2.18	26.16
.875	2.96			.875	1.32			.875	2.92			.875	2.94		
1828-00				1835-00				1842-00				1849-00			
.125	1.29	2.09	25.08	.125	1.95	1.88	22.56	.125	1.85	2.25	27.00	.125	1.62	2.02	24.24
.25		2.26	26.88	.25	1.87	22.44		.25		1.77	21.24	.25		2.20	26.40
.375	1.36			.375	1.28			.375	0.86			.375	1.92		
.50		2.10	25.20	.50	2.10	25.20		.50		1.41	16.92	.50		1.85	22.20
.625	3.44			.625	2.93			.625	1.45			.625	2.30		
.75		2.15	25.80	.75	2.40	28.80		.75		1.28	15.36	.75		1.83	21.96
.875	2.33			.875	2.25			.875	1.47			.875	1.56		
1829-00				1836-00				1843-00				1850-00			
.125				.125				.125				.125	1.53	1.78	21.36
.25				.25				.25				.25	1.73	1.68	20.16
.375				.375				.375				.375	1.89		
.50				.50				.50				.50			
.625				.625				.625				.625			
.75				.75				.75				.75			
.875				.875				.875				.875			

TABLE VII.—*Rainfall at Culloden, from Scottish Meteorological Society's Journal, July 1873.*

QUADRUPLE ANNUAL SUMS, CHIEFLY TO FILL THE GAP BETWEEN THE LAST OF A. ADIE'S OBSERVATIONS, AND THE FIRST OF THE METEOROLOGICAL SOCIETY.

Date.	Quar- terly.	Annual.	Annual Sums.	Date.	Quar- terly.	Annual.	Annual Sums.	Date.	Quar- terly.	Annual.	Annual Sums.
1841-00				1848-00		2-14	25-68	1855-00		2-07	24-84
.125	1-19			.125	2-26			.125	1-72		
.25				.25	2-02	24-24		.25		2-16	25-92
.375	1-64			.375	2-08			.375	1-26		
.50		2-44	29-28	.50	2-06	24-72		.50		1-75	21-00
.625	3-21			.625	1-51			.625	2-61		
.75		2-59	31-08	.75	2-06	24-72		.75		1-70	20-40
.875	3-70			.875	2-40			.875	1-39		
								1856-00		2-09	25-08
1842-00		2-46	29-52	1849-00		1-85	22-20	.125	1-53		
.125	1-78			.125	2-27			.25		2-20	26-40
.25		2-26	27-12	.25	2-21	26-52		.375	2-82		
.375	1-13			.375	1-22			.50		2-18	26-16
.50		1-97	23-64	.50	1-93	23-16		.625	3-05		
.625	2-43			.625	2-96			.75		2-14	25-68
.75		1-83	21-96	.75	1-74	20-88		.875	1-30		
.875	2-55			.875	1-26			1857-00		1-80	21-60
								.125	1-37		
1843-00		1-95	23-40	1850-00		1-76	21-12	.25		1-66	19-92
.125	1-22			.125	1-54			.375	1-47		
.25		1-90	22-30	.25	1-53	18-36		.50		1-82	21-84
.375	1-60			.375	1-28			.625	2-48		
.50		1-90	22-80	.50	1-91	22-92		.75	1-96		
.625	2-23			.625	2-05			.875		1-99	23-88
.75		2-16	25-92	.75	1-89	22-68		1858-00		2-06	24-72
.875	2-56			.875	2-77			.125	1-61		
								.25		2-07	24-84
1844-00		2-00	24-00	1851-00		1-82	21-84	.375	1-91		
.125	2-23			.125	1-48			.50		2-30	27-60
.25		2-17	26-04	.25	0-96	19-44		.625	2-75		
.375	1-00			.375	1-24	14-88		.75	2-00		
.50		1-98	23-76	.50	1-29			.875		2-12	25-44
.625	2-88			.625	1-23	17-40		1859-00		1-91	22-92
.75		1-81	21-72	.75				.125	1-19		
.875	1-82			.875				.25		2-17	26-04
								.375	1-90		
1845-00		1-95	23-40	1852-00		1-46	17-52	.50		2-00	24-00
.125	1-55			.125	2-32			.625	3-04		
.25		1-92	23-04	.25	1-72	20-64		.75		2-10	25-20
.375	1-54			.375	1-01			.875		2-12	25-44
.50		2-30	27-60	.50	2-20	26-40		1860-00		1-79	21-48
.625	2-75			.625	2-34			.125	1-99		
.75		2-28	27-36	.75	1-97	23-44		.25		1-72	20-64
.875	3-37			.875	3-14			.375	1-73		
								.50		1-74	20-88
1846-00		2-53	30-36	1853-00		2-08	24-96	.625	1-58		
.125	1-45			.125	1-38			.75		2-35	28-20
.25		2-51	30-12	.25	2-02	24-24		.865	1-68		
.375	2-54			.375	1-47			1861-00		2-62	31-44
.50		2-36	28-32	.50	2-09	19-92		.125	4-41		
.625	2-68			.625	1-72	18-72		.25		2-60	31-20
.75		2-15	25-80	.75				.375		2-73	32-76
.875	2-77			.875				.50		2-15	25-80
								.625		2-06	24-72
1847-00		2-17	26-04	1854-00		1-55	18-60	.75	2-09		
.125	0-62			.125	0-97			.875	2-43		
.25		2-00	24-00	.25	1-41	18-96					
.375	2-62			.375	1-92	23-04					
.50		1-86	22-32	.50	2-24						
.625	1-99			.625	3-07	25-32					
.75		2-27	27-24	.75							
.875	2-21			.875							