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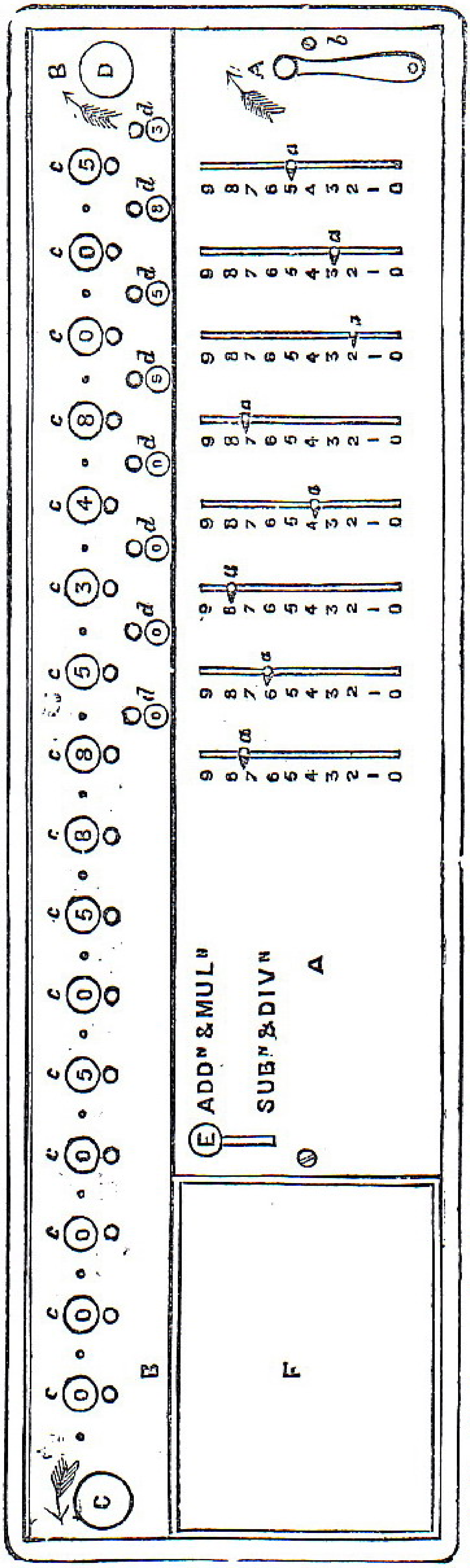
The Fourth Ordinary General Meeting, was held on Wednesday, April 10th, 1872, C. W. SIEMENS, Esq., F.R.S., President, in the Chair.

The Paper read was "ON THE APPLICATION OF THE CALCULATING MACHINE OF M. THOMAS DE COLMAR TO ELECTRICAL COMPUTATIONS," by Thomas T. P. Bruce Warren, Electrician to Hooper's Telegraph Works (Limited) Member of the Society of Telegraph Engineers.

The following diagram represents a top view of a sixteen figure machine drawn to one-fourth full size. The same illustration and arrangement, of its parts apply to the smaller and larger machines, except the smallest sizes which do not contain the Quotient holes and Effacers. The description here given is taken from an interesting paper by Major-General Hannyngton, of the India Office, which was read before the Society of Actuaries Feb. 27th, 1871. The convenience in retaining the same terms for the parts of the machine concerned in its working, and the completeness of the directions, have tempted me to reproduce his description verbatim.

"The fixed brass plate AA may be called the Face Register or Face, on which numbers expressed by nine or fewer figures may be indicated by the moveable markers *a*. When we desire that any given number should be so indicated, the direction will be to set on that number.

The moveable plate BB we shall call the Sliding Register or Slide, and when we desire that a number be transferred from the face to the slide the direction will be to put up that number. In the diagram the number 76847235 is 'set on,' and the number 505885348005 is 'put up,' while the numbers 6583 appear in the 'quotient holes.' The figures in the upper holes shew the product of the first and last of these numbers.



Sometimes it will be convenient to put up numbers by hand—which may be done by turning the studs which are under the figure holes *c* (sixteen in number in the diagram). These studs are fixed on the axes of the figure disks, which disks turn in either direction, and have the numerals 0 to 9 so arranged on them as to appear, one at a time, in the figure holes. A smaller set of holes *d*, studs and disks (in the diagram nine in number) are placed below the others on the right hand half of the slide, these may be called the '*quotient*' holes, *studs* and *disks*, being as will appear, serviceable chiefly in the operation of division. The smaller holes between the figure holes *c* serve to hold an ivory pin to mark, when requisite, the decimal point, and also to point off the figures in extracting square roots. By turning the milled head C towards the left hand, and the head D towards the right hand, the figures in the holes *c* and *d* respectively will become zeros; these heads may therefore be called *Effacers*. Before commencing any operation, it is necessary to see that all significant figures have been effaced. The button E which slides along the slit shown in diagram, may be called the *Regulator*, because as marked on the face its position determines the action of the instrument. The *winch b*, turned by hand, always in one direction, to the right, gives motion to the mechanism. One turn 'puts up' the number that has been 'set on' the face, and if this number be not changed, another turn will put it up again, and so on continuously. Under the winch lies a pin, not shewn in the diagram. This may be called the *Stopping pin*, at which the winch should always be stopped. When the winch is not at the stopping pin, the regulator cannot be moved. Attached to the markers, under the face, is a spring to keep them when in use in their proper place. F is a small plate of ground glass to serve as a writing tablet.

The arrows indicate the directions in which the milled heads and the winch respectively are to be turned.

When using the machine, if the winch *b* be found not to move freely, the plate B B should be lifted up and the winch turned three or four times, after all the markers have been placed to zero. The winch should turn freely and smoothly. A very small quantity of clock oil or refined neat's-foot oil, applied from time to time, is all that is required to keep it in order. The accumulation of dust in the machine may be avoided by keeping it shut up when not in use.

Before turning the handle, care should be taken that the sliding plate is accurately dropped into its proper position; sometimes the regulator, by being pushed too far towards the top, may prevent the teeth of the wheels from catching each other properly when the machine is in action. Inattention to this will frequently lead to incorrect results.

A description of its mechanism appeared in the *Engineer*, May 20, 1870. The only addition I have to make to this is, that the figure disks in the holes *d* (the "quotient holes") are each marked with the numbers 0 to 9 ascending and from 8 to 1 descending, and arranged around the same circle. It is by this that successive additions and subtractions of numbers "set up" are indicated without confusion. The quotient holes shew the number of turns given to the handle, which gives the operator an opportunity of checking his results. When effacing the figures, either in the quotient holes or in the larger holes, the sliding plate should be lifted up, and when we desire to put up a number by turning the figure disks, the same precaution must be taken.

As it is generally convenient to be able to refer to the constants which are noted for any calculations, I replace the glass tablet with pieces of paper cut to the same size.

The mechanism for carrying from one set of figures to another deserves special notice. The following description is given by Edward Sang, Esq., F.R.S.E., in a lecture before the Actuarial Society of Edinburgh, on "Mechanical Aids to Calculation":—*

"Under each of the slits is a cylinder, which makes a complete revolution for every turn of the handle. On the surface of each cylinder are placed nine parallel bars, or, as we may call them, elongated teeth, which are to work the teeth of the counting wheels. The lengths of these bars are equi-different, so that at one part of the cylinders the whole nine are ready to act, at the next place eight, and so on. The markers, when any number is set up, can thus only catch the number of teeth to which it is placed. The counting wheel is moved upon a square axis, and by means of the markers can be brought opposite to any desired part of the cylinder."

"If we bring the counting wheel so as to be acted on by four bars, one turn of the cylinder will cause an addition of four, and each succeeding turn will cause a new addition of four. Now, for each of the indices, that is for units, tens, hundreds, and so on, we have a special cylinder, and therefore if we set the counting wheels to specified digits, and turn each of the cylinders once round (for the present we shall suppose once in succession) we shall have added the specified number to the previous indication."

"If we do this for one cylinder after another, some considerable time will be required. The contrivance for economising that time is exceedingly ingenious in Thomas's machines. He causes all the cylinders to be actuated at once by the working handle, so that all the additions go on *nearly at once.* If the additions were made all at once, a confusion would of necessity arise in the carrying. He therefore makes the index wheels entirely independent of each other, and arranges the carrying in another way. On each index wheel there is fixed a stud to come in contact with a lever whenever the indicator passes from 9 to 0, and so as to push this lever aside, and a detent is provided to keep this lever back after the stud has passed onwards. This lever brings into action the carrier fixed on the axis, and this carrier only acts after the addition by the bars has been

* *Journal of the Institute of Actuaries,* Vol. 16, part 4.

completed. Thus by arranging the cylinders one tooth in arrear at each step the carrying is completely effected, and the whole addition completed by one turn of the handle."

If we put up 1 in the 9th figure hole, and place the marker in the unit's place on the fixed plate at 1, and place the regulator at subtraction, we shall, on turning the handle slowly, observe the progressive action of this part of the mechanism. The operation is simply to subtract 1 from 100,000,000, when we get 99,999,999 in the dividend holes. This simple operation is given as a test of the completeness of a machine.

When we require to set up any number on the fixed plate, it will be best, in nearly all cases, to begin at the left hand or units' place. In transferring figures from the fixed plate to the moveable plate, if we require to put up more figures than can be indicated on the face, the slide may either be moved out so far as to enable us to put up the remaining figures to the left by hand, or if left in its ordinary position the front figures may be similarly supplied.

The calculations which are involved in the testing of Telegraph Cores and Cables although simple and easily systematized, become irksome and monotonous even to the most ardent admirer of figures, There are but few expedients available in reducing the number of these calculations, and these are, when testing the different sections of Core, to take the observations at one uniform temperature, and to have these sections of the same linear measures, but even then the reductions for Specific Conductivity, Capacity, and Dielectric Resistances offer the same labour to the computer, for although the sections may be uniform in their linear dimensions, their electrical values may be found to vary more or less. A table of Specific Conductivities could be calculated for all the possible or admissible variations in the resistances of a Specified Conductor, but the calculations for Capacity and Dielectric Resistance cannot be reduced to tables within reasonable dimensions, as the constants by which they are determined are liable to extensive variation. There are other preliminary calculations as constants, shunts, &c., which in a general way of testing are also numerous and varied. The rapidity with which ordinary Arithmetical operations are performed by this machine, is attended with results which are strictly and mechanically accurate.

Each of the tables accompanying this paper represents one hour's work on the Machine at full power, the result being recorded only with as many figures as in practice will be required.

The operations which in the usual way are performed by logarithms, are performed by the machine with the natural numbers or their reciprocals, so that the time in looking up logarithms is saved, and if required, a result can be obtained in nearly the same time, true either to 4 or 10 figures, or to the full extent of the powers of the machine.

I do not propose to deal separately with the methods of performing the operations of Addition and Subtraction, Multiplication and Division, but to give a few illustrations in working out electrical problems, and in which these operations are combined.

Let it be required to find the multiplying power of a shunt of 5 units, used with a Galvanometer of 5762 units.

We proceed thus:—5762 is first "set up" on the fixed plate A A, and turning the regulator to addition, by one turn of the handle we reproduce the number on the slide B B above it, at the same time the figure 1 appears on the same plate in the quotient holes under the figure 2. The figure 5 is next set up in the unit's place, and the other indices or markers are brought back to zero; another turn of the handle adds 5 to 5762, which is already put up, so that we have 5767 for dividend. The regulator is now turned to division, the figures in the quotient holes effaced, and the sliding plate moved outwards to the right, so that the figure 5 is immediately over and above the 5 in the fixed plate last set on, one turn of the handle divides the first figure of the dividend, and we find 1 in the quotient hole immediately over the handle, and 767 on the slide for remainder. The slide is now moved inwards one notch, so that the 7 is over the 5, and the handle turned once more, when the figure 1 will appear in the next quotient hole, and 267 will be left as remainder; the plate is again moved one notch further inwards, and the handle turned 5 times, when the figure 5 will appear in the next quotient holes, and 17 on the moveable plate as remainder. This plate is moved in another notch, and the handle turned three times, when the quotient holes will shew the figures 1153, and 2 will be left as remainder on the moveable plate.

If the slide had been moved out previously to commencing the operation, the division could have been carried one figure further, and so have exhausted the dividend, we should then have 5672, followed with as many 0s as there had been notches in the slide moved outwards; a decimal point should then be placed after the figure 2 before going further, the 5 should then be added, and the division carried on as before, the quotient holes will then shew the figures 1153·4, and the dividend plate will contain all 0s.

As multiplication is performed with much greater rapidity than division, it is preferable, in most cases, to multiply the dividend by the reciprocal of the divisor than to divide in the ordinary way; for instance, we should set up on the fixed plate 5767, and, turning the regulator to multiplication, give 2 turns of the handle, ·2 being the reciprocal of 5; when on the moveable plate will appear the product 11534. The rules for supplying decimal points will shew at once that this should read 1153·4.

Again, let a resistance of 25·7 units be used as a shunt to the same galvanometer; we move the plate either out to its full extent, or so far out as to obtain the number of quotient holes to the right of the fixed plate as may be required for the result; we set up 5762, and by one turn of the handle, the regulator being to addition, the figures will appear on the dividend plate, a decimal point is placed after the figure 2, and the slide moved inwards one notch; 257 is now set up on the fixed plate, when another turn of the handle adds it to 5762, so that 5787·7 will appear as dividend; the slide is now moved out, so that the first three figures of the dividend, 578, stand immediately over 257 on the fixed plate, the figures in the quotient holes are effaced, and the regulator being turned to division we grind out the result as before (225·2023). In pointing off the decimal figures we must not forget that the divisor is 25·7.

The decimal points need not be used, provided it is understood where they belong, which by a little practice is readily acquired.

When dividing, the conditions to which attention should be directed are,—that the figures on the dividend plate, *which are over the divisor*, must appear in value greater than the divisor, so that the slide must be moved inwards until the number on it will contain the divisor. Care should be taken when multiplying or dividing, but more especially when dividing, that the quotient holes are all at 0s.

Before commencing the operation of division, we must see that we have a sufficient number of quotient holes to the right of the handle as to give the desired number of figures in the quotient. In multiplying the quotient holes supply a check, inasmuch as they indicate the number of turns given to the handle, and consequently the number of times which the multiplicand has been multiplied.

In calculating the multiplying power of the 25·7 units shunt we may have set up 5787·7, and multiplied by the reciprocal of 25·7 (=·03891051). This is performed by placing the regulator to multiplication, and giving one turn of the handle, moving the slide out one notch and turning the handle five times, putting the slide out two more notches and giving one turn, and so on for the other figures; the result on the dividend plate will be 225·202358727, the decimal point being supplied according to the usual rules. When using the reciprocals of numbers in this or for similar operations, the first three or four significant figures will be sufficient for almost any practical purpose.

When the slide is moved outwards, we effect the multiplication of any number which is to appear on it by 10, 100, 1,000 and so on, and conversely in placing the slide backwards, we effect the division by 10, 100, 1,000, &c.

In performing multiplication it may be worth pointing out, that when the multiplier consists of high figures, the labour of multiplying may be considerably reduced by combining with it the operation of division, thus to multiply any number by 999, we move the dividend plate out to the fourth notch, when by one turn of the handle, with the regulator at multiplication, we multiply the number set up by 1,000, we have now to turn the regulator to division, and move the dividend plate backwards to its original position, when by one turn of the handle we subtract 1-1,000th part of the result, and obtain the same product on the slide as we should have obtained by multiplying in the ordinary way, hence by two turns of the handle we perform the same work as would be required by 27 turns:—

$$\text{Thus, } 5762 \times 1000 = 5762000$$
$$\text{Subtract 1-1000th} = 5762$$
$$5756238 = 5762 \times 999$$

In order to obtain a clear conception of the *modus operandi* of the machine, it is necessary to bear in mind that the four elementary rules of arithmetic, addition, subtraction, multiplication, and division are reducible to the fundamental principles of addition and subtraction.

It does not appear that the machine can help us very much, if indeed at all, in the calculations for the derived circuit, for we should have to transfer the several products from the slide to the face to be multiplied by the succeeding resistances. The following abbreviated method of adding together the reciprocals of the resistances, and then finding the number of which this sum is the reciprocal, does not appear to be capable of being presented to the machine with any important saving of time or trouble, unless perhaps, for the determination of the last result, in which case unity is to be set up on the slide, and the sum of the reciprocals on the face, when we have merely to perform the division. Considering that it is much easier to find from the tables the reciprocals corresponding to numbers, than it is to find a number corresponding to any given reciprocal, it is doubtful whether a slight advantage might not exist on the side of the machine. But an unquestionable advantage must be claimed for the machine in calculating reciprocals, and to which I shall refer presently.

Another method is open to us for calculating the resistance of a derived circuit, and which although it does not admit of machine assistance, may be worth noting here as it gives us a conception in forming tables of reciprocals.

Since any number and its reciprocal have the same logarithm, but with contrary signs; and the sum of the logarithm of any number and its complement, is equal to O., the co-logarithm of any sum of resistances will be the logarithm of the resulting resistance. Let 4 and 8 represent the resistances in parallel circuit:—

$$\text{Then } \frac{4 \times 8}{12} = 2{\cdot}666 \quad \text{or}$$

$$\begin{array}{lrl} \text{reciprocal of } 4 = & {\cdot}25 & \\ \text{,,} \qquad\quad 8 = & {\cdot}125 & \\ \hline \text{Log.} & {\cdot}375 & = \bar{1}{\cdot}57403 \\ \text{Colog.} & & = 0{\cdot}42597 = \text{log. of } 2{\cdot}666. \end{array}$$

Although the machine is not capable of shewing the product of more than two factors at once, it will give the sum of the products of several factors without shewing the products themselves separately, this should be of great utility in calculating areas which are generated by curves of the second or higher orders, as well as problems contained in the ordinary mensuration of solids and conic sections. Its more immediate application to Telegraphic Engineering will be in finding the contents of cable tanks, tonnage of ships, ascertaining the weight of materials composing a cable, the specific gravity of a cable from the known weights, and specific gravities of the materials respectively composing it, and so on. Tensile strength of iron wires, weights and diameters of iron, and copper wires, dielectric, &c. The constants in these latter cases must be determined from the law of variation indicated in each particular case.

As these calculations do not fairly come within the province of this paper, but are nevertheless of interest, I shall merely submit to you a few tables calculated by the machine for these latter cases, all that is necessary is to put on the constant in each particular case, and to multiply by the square of the diameters.

WEIGHTS OF COPPER WIRES PER NAUTICAL MILE.

In.	0	1	2	3	4	5	6	7	8	9
·10	183	186	190	194	197	201	205	209	213	217
·11	221	225	229	233	237	241	245	250	254	258
·12	263	267	271	276	280	285	289	294	299	303
·13	308	313	318	323	327	332	337	342	347	352
·14	358	363	368	373	378	383	389	394	399	405
.15	411	416	421	427	432	438	444	449	455	461
·16	467	473	478	484	490	496	502	508	514	521
·17	527	533	539	546	552	558	565	571	577	584
·18	591	597	604	610	617	624	630	637	644	651
·19	658	665	672	679	686	693	700	707	714	721
·20	730	736	743	751	758	766	773	781	788	796
·21	805	811	819	826	834	842	850	858	866	874
·22	883	890	898	906	914	922	931	939	947	956
·23	965	972	981	989	998	1,006	1,015	1,023	1,032	1,041
·24	1,051	1,058	1,067	1,076	1,085	1,094	1,103	1,112	1,121	1,130
·25	1,139	1,148	1,157	1,166	1,176	1,185	1,194	1,203	1,213	1,222

If the figures in the column (in.) be divided by 10 we have merely to deal with the two figures towards the left hand of the number opposite to it as decimals—thus a wire ·025 = 11·41 lbs. ·0255 = 11·85 lbs.

This remark applies also to the other tables in which the variation is as D^2. Tables involving the second power of a function, and in which the second differences are constant, can be computed by simply adding on these differences to the value already on the face. This method is more rapid than multiplying by D^2.

TABLE,

Shewing the Breaking Strain of Iron Wires of different sizes, from the data "that the Breaking Strain varies as the Squares of the Diameters and is equal to 1 ton per square inch, and uniform for all diameters."

In.	0	1	2	3	4	5	6	7	8	9
1.0	.7854	.8012	.8171	.8332	.8495	.8659	.8825	.8992	.9161	.9330
1.1	.9503	.9676	.9851	1.0028	1.0206	1.0386	1.0567	1.0750	1.0935	1.1121
1.2	1.1310	1.1498	1.1689	1.1881	1.2075	1.2271	1.2468	1.2667	1.2867	1.3069
1.3	1.3273	1.3477	1.3684	1.3892	1.4102	1.4313	1.4526	1.4740	1.4956	1.5174
1.4	1.5394	1.5615	1.5837	1.6061	1.6286	1.6502	1.6730	1.6961	1.7192	1.7425
1.5	1.7672	1.7908	1.8146	1.8385	1.8619	1.8869	1.9113	1.9359	1.9608	1.9856
1.6	2.0106	2.0358	2,0612	2.0867	2.1124	2.1383	2.1642	2.1904	2.2167	2.2432
1.7	2.2698	2.2966	2.3235	2.3506	2.3779	2.4053	2.4329	2.4606	2.4885	2.5165
1.8	2.5447	2.5730	2.6016	2.6302	2.6591	2.6880	2.7172	2.7465	2.7759	2.8055
1.9	2.8353	2.8652	2.8953	2.9255	2.9559	2.9865	3.0172	3.0481	3.0791	3.1103
2.0	3.1416	3.1731	3.2047	3.2366	3.2685	3.3006	3.3329	3.3654	3.3980	3.4307
2.1	3.4636	3.4967	3.5299	3.5633	3.5968	3.6305	3.6644	3.6984	3.7325	3.7668
2.2	3.8013	3.8359	3.8707	3.9056	3.9407	3.9760	4.0114	3.0470	4.0827	4.1186
2.3	4.1548	4.1909	4.2272	4.2638	4.3004	4.3373	4.3743	4.4114	4.4487	4.4862
2.4	4.5239	4.5616	4.5995	4.6376	4.6759	4.7143	4.7528	4.7915	4.8304	4.8695
2.5	4.9088	4.9481	4.9876	5.0273	5.0671	5.1071	5.1472	5.1875	5.2279	5.2685

If the figures in the column (in.) be divided by 10, we move the decimal point two places further to the left, thus a wire ·1″ would sustain ·007854 tons, ·105″ ·008659 &c.

The numbers in this table multiplied by any specified breaking strain in tons per square inch, will give the breaking strain to the required standard.

TABLE OF WEIGHTS (IN LBS.)

Per Nautical Mile of a material whose Sp. Gr. is 1. The number corresponding to a given diameter multiplied into the Sp. Gr. of any material will give the weight per Nautical Mile of that material.

	0	1	2	3	4	5	6	7	8	9
1.0	2,074	2,116	2,158	2,200	2,243	2,286	2,330	2,374	2,419	2,464
1.1	2,509	2,555	2,601	2,648	2,695	2,743	2,791	2,839	2,888	2,937
1.2	2,986	3,036	3,087	3,138	3,189	3,241	3,293	3,346	3,399	3,452
1.3	3,505	3.560	3,613	3,668	3,724	3,780	3,836	3,892	3,949	4,007
1.4	4.065	4,121	4,182	4,241	4,300	4,360	4,421	4,481	4,543	4,604
1.5	4,666	4,729	4,791	4,855	4,918	4,982	5,047	5,112	5,177	5,243
1.6	5.309	5,376	5,443	5,510	5,578	5,646	5,715	5,784	5,853	5,923
1.7	5,993	6,064	6,135	6,207	6,279	6,351	6.424	6,496	6,571	6,645
1.8	6,719	6,794	6,869	6,945	7,021	7,098	7,175	7,252	7,330	7,408
1.9	7,487	7,566	7,645	7,725	7,805	7,886	7,967	8,048	8,130	8,213
2.0	8,295	8,379	8,462	8.546	8,631	8,715	8,801	8,886	8,972	9,059
2.1	9,146	9,233	9,321	9,409	9,497	9,586	9,676	9,766	9,856	9946
2.2	10,037	10,129	10,221	10,313	10,406	10,499	10,592	10,686	10,781	10,876
2.3	10,971	11,066	11,162	11,259	11,356	11,452	11,551	11,649	11,747	11,846
2.4	11,945	12,945	12,145	12,246	12,346	12,448	12,550	12,652	12,755	12,858
2,5	12,962	13,066	13,170	13,275	13,380	13,485	13,591	13,700	13,804	13,912

TABLE OF WEIGHTS (IN LBS.)

Per Statute Mile of a Material whose Sp. Gr. is 1. The number corresponding to a given diameter multiplied into the Sp. Gr. of any material will give the weight per Statute Mile of that material.

	0	1	2	3	4	5	6	7	8	9
1·0	1,799	1,835	1,872	1,908	1,946	1,983	2,021	2,060	2,098	2,137
1·1	2,177	2,216	2,257	2,297	2,338	2,379	2,420	2,463	2,505	2,547
1·2	2,590	2,634	2,677	2,722	2,766	2,810	2,856	2,901	2,947	2,994
1·3	3,040	3,087	3,134	3,182	3,230	3,279	3,327	3,376	3.426	3,476
1·4	3,526	3,576	3,627	3,679	3,730	3,782	3,835	3,887	3,940	3994
1·5	4,048	4,102	4,156	4,211	4,266	4,322	4,378	4,434	4,491	4,548
1·6	4,605	4,663	4,721	4,780	4,838	4,898	4,957	5,017	5,077	5,138
1·7	5,199	5,260	5.322	5,384	5,446	5,509	5,572	5,636	5,700	5,764
1·8	5,828	5,893	5,959	6,024	6,090	6,157	6,224	6,291	6,358	6,426
1·9	6,494	6,563	6,632	6,701	6,770	6,840	6,911	6,981	7,052	7,124
2·0	7,196	7,268	7,340	7,413	7,486	7,560	7,634	7,708	7,783	7,858
2·1	7,933	8,009	8,085	8,161	8,238	8,315	8,393	8,471	8,549	8,628
2·2	8,707	8,786	8,866	8,946	9,026	9,107	9,188	9,270	9,351	9,434
2·3	9,516	9,599	9,682	9,766	9,850	9,934	10,019	10,105	10,190	10,276
2·4	10,362	10,448	10,535	10,622	10,710	10,798	10,886	10,975	11,064	11,153
2·5	11,243	11,333	11,424	11,514	51,606	11,697	11,789	11,882	11,974	12,067

Not only is the machine capable of shewing the sum of several factors, but I have found that it will also give us the difference between two factors at once on the slide, and in calculating the weights of conductor and dielectric per mile, when the diameters are given, the following simple method gives satisfactory results.

Set on the Face AA the specific gravity of the dielectric, and multiply by the number opposite the diameter corresponding to the core, the result on the slide will be the weight per mile of a solid core of the material, turn the regulator to division and multiply the number still left on the face by the number standing opposite to the diameter corresponding to the conductor, the result now on the slide will be the weight of a solid core of dielectric, less the weight of a solid core equal in bulk to the conductor. For the weight of the conductor we may either refer to the table or set on the number opposite its diameter and multiply by its specific gravity.

Similarly as General Hannyngton has observed, "a series of addends and subtrahends, arranged in any order of succession, may be summed by attending to the signs, and placing the regulator accordingly. In such the occurrence of an intermediate negative value will not embarrass the action of the machine, or interfere with the exhibition on the slide of a final positive result. But if the sum of the subtractive quantities exceed that of the additive quantities, the result will shew one or more superfluous figures, nines, on the left of the slide. These nines must be rejected, and the complements of the other figures taken, thus from 94765 take 181983, the result will be 9999912782, which represents 87218."

Now in dealing with subtractive products, the only difference is that when the subtractive quantities are greater than the products on the slide, we obtain a number of figures, nines, which we have to reject, and to prefix a minus sign to the remaining figures on the slide.

Following upon this, it is evident that the summation of series, either with increasing or decreasing differences is within the range of its performance, and in calculating percentage values, squares and cubes of numbers, has special interest.

Within the powers of the machine, it may be worth pointing out, are the calculations of logarithmic tables, reciprocals, and extraction of square roots. General Hannyngton has shewn that trigonometrical problems may be solved by it with rapidity when the angular functions are of one denomination.

The extraction of square roots may be best described in an illustration, and we will therefore extract the square root of 8,97,65,00,00.

This number is put up on the slide and pointed off with the ivory pins into pairs. The regulator is turned to division, the markers placed to zero, and the quotient figures effaced. Now, as there are five figures in the root, the slide is moved outwards so as to have this number of quotient holes to the right of the handle, when everything is now ready for operation. The nearest square root to 8, is 2; we then move the marker along the slit, on the fixed plate, under the figure 8 to the number 2, and give two turns of the handle, when this number will appear in the first quotient hole, and leave 497 &c. remainder, the slide is moved in one notch, the figure 2+2=4, so that the marker is moved to 4, which will be contained 9 times in 49. The marker in the second slot is placed at 9, and the handle turned 9 times when 9 will appear in the new quotient hole, and 56 will be left as remainder of the second pair or set of figures, the slide is again moved in one notch, the last number 9 on the slide doubled, when the markers already set on are moved to 5 and 8, the next root again being 9; this number is indicated by the marker in the 3rd slot, and the handle turned 9 times, when 9 will appear in the third quotient hole, and 3 will be left as remainder, the slide is moved in again one notch, the last figure on the face doubled, when the markers should indicate 598; 6 being the next root, this number is set on and the handle turned 6 times, when 6 will appear in the quotient holes, and 4 will remain out of the 3rd set of figures on the slide, the last figure set on is again doubled, so that 5992 is indicated on the face, and the slide moved in, when we find the dividend less than the divisor, so that the next number of the root is 0. The root is, therefore, 29960 and 48400 is left on the slide as remainder.

The following method may also be interesting. The theory of this process depends on the following theorems in arithmetical progression.

If the first term of a series be 1, and the difference 2, the sum of any number of terms composing this series, will be equal to the square of the same number of terms, thus; $1+3+5+7+9+$ &c. and the last term of the series increased by unity, will give double the number of terms in the series.

To extract the square root of 2209 by second differences, we proceed thus:—This number is put up on the slide, the regulator turned to division, and the number divided into pairs as before, and the slide moved outwards so as to have 2 quotient holes to the right. From the first set of figures we subtract successively 1, $1+2=3$, $3+$

2=5, 5+2=7, this number being greater than the number on the slide, we move it inwards one notch, the figure 7 is changed to 8 on the face, and we commence again in the second slot by setting up as before, when the subtractive figures are 81, 83, 85, 87, 89, 91, (the first figure being altered from 8 to 9) and 93, when the figures on the quotient disks will be 47, and no remainder left on the slide.

The following method of obtaining the continuous squares of numbers, depends upon the rule, that:—

If the difference between any two numbers be small when compared with either of them, the ratio of their squares may be obtained by doubling this difference; that is, if x be small as compared with a, instead of writing $(a+x)^2=a^2+2ax+x^2$, we may say that $(a+x)^2 = a^2+2a+2$, when the difference is 1:—so that if any high number be set up on the face and multiplied by itself, we shall obtain the square of that number on the slide, by moving the marker in the units' place another figure in advance, and giving two turns of the handle we add twice the original number, plus 2, to the number already on the slide. Now, if we do this for a great number of times without rectifying the result, the error will exceed the limits of admissibility, and, therefore, the values of x^2 should be calculated and the correction added, say at every tenth calculation.

By assimilating this formula to the cubes and higher powers of numbers, the error increases much faster. But in this way we can perform successive involutions without the aid of a second machine, and which is not without importance when the increments are small.

I am indebted to General Hannyngton for the following useful method for obtaining the continuous squares of numbers:—

Putting Δ for the difference between any two consecutive numbers, we find $\Delta n^2 = 2n+1$, so that we first set up on the face A A any number n, the product of which when multiplied by itself will appear on the slide B B; we then make the figures on the face equal to $2n+1$, when by one turn of the handle the next square will appear. By afterwards setting on the continuous difference 2, we shall obtain the squares successively of the following numbers; thus, if we set up 7201 and multiply by itself, the slide will shew 51854401, and 7201 will also appear in the quotient holes, the markers are moved to 14403 (which is equal to $2n+1$) and by another turn of the handle we obtain the square of 7202, we move the marker in the units' place to 5, when the figures on the face will be equal to 7202+2+1, when another turn of the handle will give the next square, n being the number, the square of which has last appeared on the slide.

If the summation of third differences is made on one machine, and transferred to the face of a second machine, we can rapidly obtain the successive cubes of numbers.

In this way we could extend considerably the squares and cubes of numbers, beyond those contained in Barlow's tables, with complete accuracy.

In shewing how to construct tables of reciprocals, I may quote from the notes on the construction of a table of reciprocals by Lieut.-Col. Oakes, inasmuch as this extensive table was re-computed on the machine by General Hannyngton.* This table contains the reciprocals of all numbers to 100,000 with their differences, so that from these tables we may obtain the reciprocals of numbers as far as 10,000,000. In these tables a peculiar advantage is met with; that the decimal point is not supplied, so that the reciprocals are general whether the number in hand be a decimal or not, the decimal point is therefore to be supplied by the computer according to the value under consideration.

CONSTRUCTION OF TABLES OF RECIPROCALS,
BY LIEUT-COL. OAKES, A.I.A.

Numbers.		Logs of Diffs.	Nat. Nos. of Diffs.	Reciprocals.	Reciprocals of the Half and Quarter Nos.	Numbers.	
	62501	.2041130					
	62500	2041200		.00001600	.00003200		
	Diffs of Logs.	4082330		.00000000	.00006400		
62499	139	2469	256004	0256004			
98	139	2608	12	0512016	1024032	31249	½ No.
97	139	2747	20	0768036			
96	139	2886	29	1024065	2048130	31248	½ No.
95	139	3025	37	1280102	4096260	15624	¼ No.
94	139	3164	45	1536147	3072294	31247	½ No.
93	139	3303	53	1792200			
92	139	3442	61	2048261	4096522	31246	½ No.
91	139	3581	70	2304331	8194044	15623	¼ No.
90	139	3720	78	2560409	5120818	31245	½ No.

* These tables may be obtained at Messrs. F. & N. Spon's, Charing Cross.

"Beginning, suppose with the reciprocal of 62500, we write in the right hand margin the complement logarithms of 62500 and 62501, each to 7 places, and without indices. The sum of these is an initial value, to which adding the differences of the logs. of 62499 and 62501, or, in general, the difference of the logs. of $(n-1)$ and $(n+1)$, we readily obtain the logarithms of the difference required, and of the successive differences. The numerical differences being then taken out, the reciprocals of the numbers are obtained by summation."

By the machine it is evident that the variable differences may be set on, and the summation performed faster than the simple addition could be carried out by hand.

In certain cases we require the Napierian Logarithms of numbers which are not included in any published table. These may be calculated by setting on the face AA the modulus 2·3025851, and multiplying by the common logarithms.

In this way the Napierian Logarithms of $\frac{C}{c}$ have been calculated.

Hutton's Mathematical Tables contain the Napierian Logarithms of fractional numbers from 1, increasing by 0·1 to 10·0, which no doubt may prove serviceable in some cases for obtaining Dielectric Resistances from loss of charge, and for calculating the values of $\frac{D}{d}$ in Sir William Thomson's formula for speeds.

A little reflection will shew that 1·01 and 1·02 have a difference in their logarithms, which is so great as to comprehend nearly all conceivable values between 1 and 2, so that we must look for an extension of this table as regards the number of figures after the decimal point, if we desire to apply them.

In extending this table it is obvious that the multiplication of the modulus into the different denary logarithms would be a somewhat tedious operation.

The following simple methods given in Hutton's tables are admirably adapted for machine calculation in obtaining Napierian logarithms by differences, with a rapidity which could hardly be surpassed by an expert mental computer.

1st. When the given number is between 1 and 10.

From the given number subtract the next less tabular number, divide the remainder by the said tabular number, increased by half the remainder, add the quotient to the said tabular number, and the sum will be the logarithm of the number proposed.

In the table here given of Napierian Logarithms we take the logarithm of 1·03, which in Hutton's table = 0.0295588; and we wish, we may suppose, to tabulate these logarithms to differences of .001, &c.

NAPIERIAN LOGARITHMS.

Nat. Nos. N	½ Diffs. δ	Logarithms.	$\frac{1}{N} + \delta$	Nat. Nos. N	½ Diffs. δ	Logarithms.	$\frac{1}{N} + \delta$
1.030		0.295588		1.0300		0.029588	
31	.0005	.0305292	.000970	11	.00055	.0806262	.0010674
32	10	314987	19399	12	60	07222	11654
33	15	324672	29084	13	65	08202	12614
34	20	334347	38759	14	70	09171	13583
35	25	344017	48426	15	75	10140	14552
36	30	353671	58088	16	80	11109	15521
37	35	363319	67781	17	85	12079	16491
38	40	372957	77369	18	90	18048	17460
39	45	382537	86999	19	95	14017	18429
40	50	392206	96618	20	.00100	14987	19899

From this table it is obvious, that by putting up the initial Log._ϵ on the slide and summing the reciprocals for the successive values $N + \delta$, we may grind out a table of Napierian Logarithms as fast as we please. For this purpose, Oakes' tables will be found highly convenient.

We set on the plate $1{\cdot}03 \times {\cdot}0005 = 1{\cdot}0305$, and on the slide we put up 1, drawing the slide out previously, so as to obtain a sufficient number of quotient holes in the result, and perform the division. The result is recorded, and the operation repeated for the following logarithms; the quotient added to the log._ε of 1·030 will be the log._ε of 1·031, &c., &c.

2nd. When the number exceeds 10—

We find the logarithm as in the first case, supposing all the figures after the first to be decimals, then to that logarithm add 2·3025851 multiplied by the index of the power of 10, according as the given number contains 2,3,4, &c. integers: thus,

$\text{Log}_\varepsilon\ 1031 = 0{\cdot}0395292$

Add	2·3025851	= 2·3331143 =	log. 10·31
Add	3 × 2·3025851	= 4·6356994 =	„ 103·1
Add	3 × 2·3025851	= 6·9382845 =	„ 1031

So that, as Hutton's Tables contain the logarithms of the first 1200 numbers, we may by this method easily obtain the Napierian logarithm of any number with three places of decimals below 1·2.

Copper Tests.—The constants required for Copper Tests are those involved in correcting for temperature and specific conductivities. Another correction arises from the fact of the resistance coils themselves being adjusted at a temperature differing more or less from the temperature of the core or cable to be tested. As long as the resistances under consideration are small, these differences will be scarcely significant, but when these resistances are great it is desirable to eliminate these errors. Let us imagine a set of resistance coils correct at 65° F., which are found to be at 60° F., when testing coils at 49° F. or 75° F., differences of temperature which are by no means unusual, and it is at once apparent that this last correction will entail an additional labour of no small extent on the computer.

At the core factory, when testing at 75° F., we can easily obtain the correct values by a very simple method. A resistance coil of exactly 100 units at 75° F. is kept constantly at this temperature, and its value carefully compared with the resistance box previously to testing the core. Let us suppose that the 100 units adjusted on the box equal 99.2 units, then we shall have to multiply the measured resistances of the sections of core successively by $\frac{100}{99.2}$. If we set up on the face of the machine the reciprocal of .992, we may, by multiplying by the observed resistances, obtain the correct resistances, the extra labour being scarcely felt.

At the cable factory a table of constants for all the probable differences of temperature can be easily made, and considering the importance of knowing accurately the temperature of a cable, and the certainty of its determination from reliable copper tests, this extra expenditure of labour is amply compensated by the importance of its results.

When correcting the temperature to 75° F., if the temperature be lower than 75° F., the temperature co-efficient corresponding to the difference is put on the fixed plate, and the cable or core resistances become the multipliers. If the temperature be above 75° F., the reciprocal of the co-efficient is used.

To calculate tables of specific conductivities, we set on the fixed plate the resistance corresponding to the weight and temperature specified, and multiply by the reciprocals of the required per-centage values.

SPECIFIC CONDUCTIVITIES

Corresponding to Resistances of a Conductor weighing 130 lbs. per Nautical Mile.

130 lbs. pure Copper=9·1722 B. A. Units per N. M. at 75° F.

	0	1	2	3	4	5	6	7	8	9
85	10.79	10.78	10.77	10.75	10.74	10.73	10.72	10.70	10.69	10.65
86	10.67	10.65	10.64	10.63	10.62	10.60	10.59	10.58	10.57	10.55
87	10.54	10.53	10.52	10.51	10.49	10.48	10.47	10.46	10.45	10.43
88	10.42	10.41	10.40	10.39	10.38	10.36	10.35	10.34	10.33	10.32
89	10.31	10.29	10.28	10.27	10.26	10.25	10.24	10.23	10.21	10.20
90	10.19	10.18	10.17	10.16	10.14	10.135	10.12	10.11	10.10	10.09
91	10.08	10.07	10.06	10.05	10.03	10.02	10.01	10.00	9.99	9.98
92	9.97	9.96	9.95	9.94	9.93	9.92	9.91	9.89	9.88	9.87
93	9.86	9.85	9.84	9.83	9.82	9.81	9.80	9.79	9.78	9.77
94	9.76	9.75	9.74	9.73	9.72	9.71	9.70	9.69	9.67	9.66
95	9.65	9.64	9.63	9.62	9.61	9.60	9.59	9.58	9.57	9.56
96	9.55	9.54	9.53	9.52	9.51	9.50	9.49	9.48	9.47	9.46
97	9.46	9.45	9.44	9.43	9.42	9.41	9.40	9.39	9.38	9.37
98	9.36	9.35	9.34	9.33	9.32	9.31	9.30	9.29	9.28	9.27
99	9.26	9.255	9.25	9.24	9.23	9.22	9.21	9.20	9.19	9.18
100	9.17									

Calculations for Loss of Charge.—We may write the formula, in terms of the per centage loss on C in this way:—$\left(\frac{1}{C} \times C\text{-}c\right) 100$, so that we have merely to multiply the reciprocal of the immediate discharge by the difference between this discharge, and that noted at the end of the time of insulating, usually one minute during which the cable or core is held free, the per centage value will be obtained by moving the decimal point two figures further to the right.

When C-c is a low number the result can be obtained by the simple inspection of a table of reciprocals, the multiplication being carried on mentally.

In this way I have drawn up a table for differences of 1 to 9 on all the Divisions of a Thomson's Galvanometer, so that all we have to do is to look in the column "Charge" for the immediate discharge, and under the number corresponding to the difference will be found the per centage loss.

TABLE,

For shewing rates of Loss for Static Charge, in percentage of the original charge for difference:—

Charge.	1	2	3	4	5	6	7	8	9	10
325	0.3077	0.6154	0.9231	1.2308	1.5385	1.8461	2.1538	2.4615	2.7692	3.0769
224	0.3086	0.6173	0.9259	1.2346	1.5432	1.8518	2.1605	2.4691	2.7778	3.0864
323	0.3096	0.6192	0.9288	1.2384	1.5480	1.8576	2.1672	2.4768	2.7864	3.0864
322	0.3106	0.6211	0.9317	1.2422	1.5528	1.8634	2.1789	2.4845	2,7950	3.1056
321	0.3115	0.6231	0.9346	1.2461	1.5577	1.8692	2.1807	2.4922	2.8038	8.1153
320	0.3125	0.6250	0.9375	1.2500	1.5625	1.8750	2.1875	2.5000	2.8125	3.1250
319	0.3135	0.6270	0.9404	1.2539	1.5674	1.8809	2.1944	2.5078	2.8213	3.1348
318	0,3145	0.6289	0.9434	1.2579	1.5724	1.8868	2.2013	2.5158	2.8302	3.1447
317	0.3155	0.6309	0.9464	1.2618	1,5773	1.8928	2.2082	2.5237	2.8391	3.1546
316	0.3165	0.6329	0.9494	1.2658	1.5823	1.8988	2.2152	2.5317	2.8481	3.1646
315	0.3175	0.6349	0.9524	1.2698	1.5873	1.9048	2.2222	2.5397	2.8571	3.1746
314	0.3185	0.6369	0.9554	1.2739	1.5924	1.9108	2.2293	2.5478	2.8662	3.1847
313	0.3195	0.6390	0.9585	1.2789	1.5975	1.9169	2.2364	2.5559	2.8754	3.1949
312	0.3205	0.6410	0.9615	1.2820	1.6026	1,9231	2.2436	2.5641	2.8846	3,2051
311	0.3215	0.6431	0.9646	1.2862	1.6077	1.9292	2.2508	2.5723	2.8932	3.2154
310	0.3226	0.6452	0.9677	1.2903	1.6129	1.9355	2.2581	2.5806	2.9032	3.2258

Tables for the per centage loss of Charge corresponding to different periods of time, and with different initial rates of loss, and similar tables calculated to shew the loss corresponding to different temperatures would be found very acceptable to the computer, and ensure an enormous saving of labour.

The former could be supplied by a table of the ratios for the values of log. $\frac{C}{c}$, and from the same table, the initial per centage loss being given, we may readily construct another table for the time, in which any equimultiple of this loss shall take place.

TABLE OF COMMON AND NAPIERIAN LOGARITHMS,

For calculating Resistances from loss of Charge and for comparing Resistances, and for ascertaining the time required to fall to any multiple of its initial loss.

Loss per Cent.	Ratio $\frac{C}{c}$	Log. $\frac{C}{c}$	Log.$_\epsilon$ $\frac{C}{c}$	Ratio of Logs.
1	1.010	.0043214	.0099504	
2	1.0204	.0087704	.0198027	2.0295
3	1.031	.0132587	.0305293	3.0681
4	1.042	.0178677	.0411419	4.1347
5	1.053	.0224284	.0516433	5.1901
6	1.064	.0269416	.0620353	6.2345
7	1.075	.0314085	.0723207	7.2681
8	1.087	.0362295	.0834215	8.3837
9	1.099	.0409977	.0944007	9.4871
10	1.111	.0457141	.1052606	10.5785
11	1.124	.0507668	.1168937	11.7477
12	1.136	.0553783	.1275132	12.8149
13	1.149	.0603200	.1388919	13.9584
14	1.163	.0655797	.1510028	15.1756
15	1.176	.0704073	.1621188	16.2927
16	1.190	.0755470	.1739534	17.4821
17	1.205	.0809870	.1864795	18.7409
18	1.220	.0863598	.1988508	19.9842
19	1.235	.0916670	.2110711	21.2123
20	1.250	.0969100	.2231435	22.4256

The ratios of log. $\frac{C}{c}$ will also shew the relative resistances of Cores or Cables having different rates of loss for the same time.

Following upon this we can easily see that if we set on the face A A, the initial ratio of log. $\frac{C}{c}$ and multiply successively by the temperature co-efficients for correcting Dielectric resistances, we can rapidly compute tables for loss of Charge at different temperatures.

Inductive Capacities.—In calculating tests of Inductive Capacity, the Constant is set up on the face of the Machine, and multiplied by the discharges from the Coils of Core or Cable, when we obtain the absolute capacities.

When the sections are about the same length, or give discharges which can be read with the same shunt, the capacities can be worked out as rapidly as they can be taken off.

If different shunts be used with the Condenser and Core or Cable, it will of course be better to correct the Condenser Discharge to the same shunt as the Core or Cable discharges are noted with.

A table for correcting the values of the deflections on the scale of a Thomson's Galvanometer would be very serviceable, inasmuch as we should then be able to dispense with the present necessity of adjusting our shunts so as to obtain the Discharges on nearly the same point of the Scale, and, which is more imperative, the higher are the multiplying powers of the shunts.

The Inductive Capacities for Cores of different dimensions can be worked out by the machine, and with very little trouble we could obtain an extension of those valuable tables published by Mr. Latimer Clark and Mr. Sabine. The rate of variation being directly as the co-logarithm of $\frac{D}{d}$, or inversely as the log. $\frac{D}{d}$, we multiply the con stant which is set on the machine in the first case by the complement of the log. $\frac{D}{d}$, and in the other case by the reciprocal of log. $\frac{D}{d}$.

Dielectic Resistances.—The constant $\phi \times \sigma \times n$ is set up on the fixed plate, and multiplied by the reciprocals of the deflections obtained on different sections of core, when we obtain the absolute resistances on the upper figure holes of the slide, the multiplier also appearing in the quotient holes.

In applying the corrections for temperature, the co-efficient should be set on the face A A; but when it is necessary to divide by the co-efficient, the reciprocal of this number should be set on, when we have only to multiply by the resistance for the results at the required temperature.

In computing tables for temperature corrections, and similar tables which consist in expanding a given number, the values which are made to appear on the slide must be transferred to the face for the next value, and so on; but if the logarithm of the given number be set on, every turn of the handle will give us the logarithm of a new term of the expansion. In this we can scarcely claim any advantage for the machine beyond ensuring accuracy in the results.

Tables of Electrification Ratios could be rapidly computed by putting on the face the deflection noted at the end of the first minute or period of contact, and multiplying by the reciprocals of the deflections at the end of the succeeding intervals. In these cases however, we must not forget the corrections necessary to be introduced, when the deflections and the galvanometer constant are on widely different parts of the scale.

In dealing so minutely with these numerical operations, my apology must be that the short cuts so familiar to us in calculating are extended to the machine, and that they are only developed by an acquaintance with its working, and in these respects I can add my humble endorsement to the statements of Major-General Hannyngton and Dr. Zillmer.

The machine requires peculiar methods, and in operating with it we have to present our formulæ in a condition suited to its ready performance. The constants in all cases must be determined from the law of variation indicated in each particular case.

In conclusion, I may remark that in every instance I have found it extremely useful, and in most cases of very great assistance. The object of my bringing this before you rests on the assurance that the first step to betaken in bringing electrical testing within the limits of exact science must be to reduce the mental drudgery of calculating, for we must admit that the time occupied in testing bears a small proportion to the time spent on working out the results.

Mr. W. A. Gilbee, of South Street, Finsbury (the agent for the Thomas de Colmar machines), kindly placed two of the machines before the meeting, which facilitated the comprehension of their action in the numerical operations referred to.

DISCUSSION ON THE PAPER.

The President said, when he first heard of this paper he had some doubts, however interesting the Colmar machine might be, whether it was in itself suitable for this Society; but the more he had seen and heard about it, the more he was satisfied the subject was one of great interest to Telegraph Engineers; they had so much to do with calculations of an intricate kind, that he was quite sure the meeting would support him in proposing a vote of thanks to Mr. Warren, for his interesting paper. He would now call upon gentlemen to offer observations on the paper, and he would ask General Hannyngton, who had given a great deal of attention to this machine, to open the discussion.

General HANNYNGTON, F.S.S., F.I.A., said, it was not in his power to add to what Mr. Warren has done so well. He had shown many useful applications of the machine, and those applications were so numerous, that no one person would pretend to say he knew all about it. He (General Hannyngton) had used it himself for many years, but he still regarded himself as a learner. It might require some ingenuity to adapt the machine to the various purposes to which it could be applied, and he had no doubt of its value in electrical calculations. They all knew that even where calculations were not of an arduous nature, or such as to occasion any great strain upon the mind, after some hours' work the head would get weary, whereas this machine always remained perfectly cool.

Mr. HARBEN said the establishment with which he was connected had had six of these machines in operation for many years, and he supposed they had more of them in use than any other individuals. He should say they had made from half to three-quarters of a million of calculations by these machines over a number of years. In the first three months of their use they saved their cost three-fold in the amount of labour saved. Previous to their introduction into the office, the clerks employed in calculations were completely exhausted after a time. They heard of the machine being in use in the Registrar-General's Office at Somerset House, which led them to try it, and since then it had been in operation every day. He had known calculations which took 100 hands six months to work, which were now done by the machine, and they had never found it faulty in any respect.

With ordinary intelligence and ingenuity, there was no difficulty in manipulating the machine, and he felt quite sure it would be of incalculable value to Telegraph Engineers in the saving of time it effected, and leaving them more time to devote to other operations, instead of their brains being racked by intricate calculations. The practice in his establishment was to do the work with one machine and check it with another, so as to avoid the possibility of error. He hoped the result of this paper would be the more extensive use of this machine. He merely gave his own experience, and he was certain if Telegraph Engineers used it, they would find it an invaluable benefit.

Dr. Royston Pigott, F.R.S., said he had the pleasure of using three of these machines for the last four years, and a friend of his had used them for seven years, and he informed him he had been able to make calculations during that time for five hours a day which would have taken at least twenty clerks to have accomplished. He would be sorry to say anything in disparagement of this machine, but he would impress upon beginners, the necessity of taking great care that they did not spoil them. He recollected, in his own early days with the machine, on one occasion he got it locked fast, and he had to take it to pieces before it would work again.

With regard to the elaborate paper they had heard this evening, there was one remark he would make as to the purposes to which this machine was applicable—that was the extraordinary power of the machine in changing its operation. If they multiplied a long sum by a given multiplier, they could by reversing the stop change the operation instantaneously without going through it again. He had found other uses of the machine in the employment of natural sines and tangents. He had one machine which would work up to twenty figures; and he found he could work by natural sines and tangents more rapidly than by logarithms.

Mr. Peter Gray, F.R.A.S., said he was unable to say a great deal about this machine from personal experience, but General Hannyngton lent him one of his machines for some weeks, and as far as his avocations permitted he had tried it in a great many operations. He might mention, as showing the impression it produced upon him, and his opinion of its capabilities, that when the Board under whom he was engaged were desirous of making an acknowledgment for some service he had rendered, and being allowed to decide the form it should take, he elected to have one of these machines, so that he hoped soon to have one of his own. It occurred to his mind that the machine was capable of a great many applications. It required some consideration perhaps as to the best way in which the formulæ could be put; but perhaps the most obvious way of proceeding was not always best for the machine, and he apprehended it was only scientific arithmeticians who could make the best use of the machine. To find out the various applications, and apply them in the best manner, required a scientific arithmetician. The advantage gained was not only rapidity of calculation, but the means of proving the accuracy, which was a very important thing.

Mr. Richardson remarked, that something had been said about the machine getting out of order. With ordinary care, there is no greater liability to disarrangement of its parts than with any other machine of a similar kind. The only thing was, that with a considerable amount of usage, the parts most subject to damage, were the small springs, of which there were a great many, and which held the figure plates in their position. Of course it depends upon the number of times they had to be turned round, but they were so placed on the plate that they could be easily replaced if broken; and he believed the springs were supplied by the agent over here at a moderate price; and the machine was easily put to work again. He thought one source of damage was not always getting the moveable plate exactly in position before the machine was worked: and that gave a play which did not allow the teeth to come into the position they should. With ordinary care it was as little liable to get out of order as any other machine of the same kind and size. If they were made in England, he thought they would work with greater freedom. He believed they were all made in France, but some parts might be improved upon, if they were made in this country.

Colonel Walker, Superintendent of the Grand Trigonometrical Survey of India, (responding to the President's invitation) said hitherto he had not used this machine, because in India he had such a large number of computors, who could be obtained at comparatively small wages, he had had no necessity to do so; but since he had been in England he had not had equal facilities in the shape of computers. He had borrowed one of General Hannyngton's machines, which saved him a great deal of labour and gave accurate results. He was thinking of employing it in India, where, notwithstanding they could get native computers who were very skilful, he thought it could be used with advantage.

The President asked General Hannyngton if he had found the machine liable to get out of order?

General Hannyngton replied, not at all; on the contrary, the machine was very easily kept in order, and with ordinary care would not get out of order. The simplicity of the machine, considering its capabilities, was most remarkable. He might be a little of an enthusiast about it, but he thought if it was introduced into the navy, ships might be navigated without much writing, which was of great importance in a gale of wind.

Colonel WALKER concurred in the observations of General Hannyngton, that the machine had great capabilities for working navigation, and, what was more important, it would give great accuracy.

Mr. WARREN said he had little to remark in reply. The principal point raised was as to the liability of the machine to get out of order. In the establishment with which he was connected they had one of these machines about the middle of last November, and at first he was not pleased with the results, but he was so fascinated with the idea of getting rid of laborious mental calculations, that he determined to persevere. With regard to the machine getting out of order, the only parts liable to do so were the springs: sometimes they get out of order. That depended upon the number of calculations they had to make. Of course a machine would not last in working order for an indefinite period; but the only parts he had found go wrong were the springs, which could be easily replaced.

The following Candidates were balloted for and duly elected:—

AS MEMBERS:—

Matthew Gray, India Rubber, Gutta Percha and Telegraph Works Company.
J. C. Laws, Telegraph Construction and Maintenance Company.
Professor Williamson, London University.

AS ASSOCIATES:—

Edwin Ashton, Post Office Telegraphs, Camden Town.
Andrew Bell, Post Office Telegraph Stores, London.
E. Beckinsole, Telegraph Construction and Maintenance Company.
Alexander Bain.
Louis J. Crossley, Halifax, Yorkshire.
Charles E. Collings, Post Office Telegraphs, Plymouth.
Frank Carlisle, Post Office Telegraphs, Plymouth.
George Henry Comfort, Post Office Telegraphs, Nottingham.
Thomas Denmead, Post Office Telegraphs, Exeter.
George Field, Post Office Telegraphs, Brighton.
Henry Fischer, ditto Telegraph Street
John Grant, Secretary, Anglo-American Telegraph Company.
George Henley, Islington.
Henry Harborow, Marylebone.
A. W. Heaviside, Post Office Telegraphs, Newcastle.

Frederick Hawkins, Silvertown.

John Jenkin, Post Office Telegraphs, Newark.

John Henry Knight, ditto Doncaster.

C. H. Kerry, ditto Bristol.

Robert London, Telegraph Construction and Maintenance Company.

John Neale, Telegraph Engineer, North Staffordshire Railway.

G. Noble Partridge, Post Office Telegraphs, Exeter.

Arthur Radcliffe, Birmingham.

E. T. Rolls, London and North Western Railway.

Hylton Spagnoletti, Marylebone.

Alexander Siemens, 3, Great George Street.

Albert Tubb, Post Office Telegraphs, Southampton.

William Grigg Taylor, Telegraph Contruction and Maintenance Company.

As Foreign Members:—

M. Breguet, Paris.

Hon. William Orton, New York.

The meeting then adjourned till the 24th April.

The Meeting appointed to be held on Wednesday, the 24th April, was unavoidably postponed to Friday, the 26th April.
