On Clock Errors and Wireless Time Signals. By Professor R. A. Sampson, Astronomer Royal for Scotland.

The data appended include a digest of observed errors of the clock Riefler No. 258 at the Royal Observatory, Edinburgh, from 1915 to 1920 October, and the observed comparisons of this clock with the scientific time signals sent out by wireless from the Eiffel Tower from 1914 to 1920. They are published as a contribution to the discussion of the reliability of time determination, and the ascription to their proper sources of the errors that occur in it. Besides, they bear upon certain statements and views which I expressed in an address, "On the Determination of Longitude by Wireless Telegraphy" (*M.N.*, 1920 May), among the Geophysical Discussions. But in the present paper no argument is based upon the results, and only such notes are added as are required to make clear their construction and bearing.

The first part, consisting of errors of the solar clock Riefler No. 258 alone, may be considered as directed to the question of the proper method of plotting or smoothing clock errors, so as to ascertain as well as possible from the whole run of clock corrections noted at any observatory what part really belongs to the going of the clock and what is extraneous to it. If the clock error be understood as meaning the departure of observation from the indication corresponding to an ideal fixed rate embracing the whole group of observations, sources that may contribute to this error are the following:—

(*a*) actual fluctuations of rate in the clock, whether transitory or long continued, slow, rapid, or instantaneous;
(*b*) faults of the chronographic system, by which the record of the clock or the record of the observation is made with a lag which varies from one observation to another;
(*c*) errors in determination of the instrumental corrections of the Transit Circle;
(*d*) errors due to catalogue places of the stars observed;
(*e*) anomalies, if any, due to atmospheric causes;
(*f*) accidental error of observing;
(*g*) personality of observers.

Out of this list the present communication may be considered as directed first to (*a*), and second to (*g*) in the form of the comparison of clock times as accepted at Edinburgh and Paris.

From various clock errors that have been published, and analysed by different writers, I have found it as a rule very difficult to draw any conclusions. They usually deal with selected runs, and cover short periods of time. There is nothing to show that the coefficients of change that are found to apply could be considered permanently representative. It is much to be desired that a simple standard method of plotting or smoothing should be agreed upon, one that could be applied continuously and permanently to the whole sequence of clock errors as they are determined, and the indications of which admit of being readily interpreted so as to supply a comparison of the same clock at two epochs, or of two different clocks with one another. Recognising that no clock goes permanently without fault, the simplest of all suppositions is that of a dead smooth rate broken suddenly and replaced by another, different but also constant. The graph of the clock corrections would then be a rectilinear figure with sharp angles. If the observed clock corrections are plotted and such an analysis applies at all, it is an easy matter to assign the corners of this figure—it is a thing done with certainty; whereas if curvature, even of the simplest parabolic kind, is admitted, there will be many cases of doubtful judgment; and the rest of the calculation is of the simplest possible kind. There will then be three data to assign, in order to describe the going of the clock: (1) the dates at which the rate changes, (2) the fixed rates held between these dates, and (3) the mean departure of observation from the rectilinear graph expressing (1) and (2). An analysis of this kind applied to the Edinburgh clock is given in the table below. The fixed rate is called the *base rate* of the clock between any two dates of change; the clock is kept at constant temperature, and when the barometric pressure within the case is altered in order to bring the clock to time, the base rate is deduced from the observed rate by applying the correction 1 mm. = $+{}^{s}\cdot0167$ per day. This coefficient was derived by experiment. On a few occasions the control of temperature broke down. In cases where the break of temperature was small, it is allowed for at the scale 1° C. = $+0^{s}\cdot04$ per day, being a coefficient also derived by experiment; larger breaks are treated as interruptions of the series. The departure, No. (3) above, presumably includes the whole of the errors (*b*)–(*g*) enumerated on p. 89, besides anything due to fluctuations in the going of the clock which are out and beyond a fixed base rate; but excepting that part, if any, of (*d*), which is seasonal, and so runs into successive nights' observations in the same degree.

The following is the arrangement of the table. It divides naturally into sections marked by interruptions of the running. The first goes from 1915 Jan. 0 to 1916 Feb. 19, when an accidental disturbance of the case, throwing the clock off beat and causing a large losing rate to be taken on, gave an occasion for stopping and cleaning it. During this period the base rate is given relative to a barometric pressure of 585 mm. After Mr. Cottingham had cleaned the clock the second section runs from 1916 March 27 to 1917 Nov. 7. The base rate is now relative to a barometer of 600 mm., so that after cleaning the clock may be said to have gone faster by $0^{s}\cdot25$ per day than before (and still faster relatively to the losing rate taken on after disturbance of the case). The first two groups of this run are treated as unsettled, and are excluded from the means. This section of the run was terminated by an accident which fused a wire within the clock, preventing it from sending any signals but not otherwise disturbing it. It was opened, the pendulum was allowed to stop, locked and raised from its agate supports, and the wire replaced, and on closing up it was found that the clock had taken on a large losing rate; the base rate thereafter is accordingly taken relative to a barometer of 630 mm., representing a change of $0^s\cdot50$ per day. It has run under these circumstances from 1917 Nov. 14 to the present date, and the subsequent divisions into sections are merely matters of convenience. They are taken at 1918 Dec. 31, 1919 Dec. 23, and for the present publication 1920 Oct. 30.

The process of deriving the numbers is the following:—The clock error as given, unsmoothed, from T.C. observations of each night is marked on a graph. This graph is regarded as representing a series of straight lines meeting at sharp angles, and the positions of the corners or intersections corresponding to changes of rate are put in by eye. The plotted error is given by the straight lines joining these corners. Whenever an observation is available, the "erratic" is the observed error *minus* the plotted error; the slope of the plotted error gives the rate of any group, and this rate, corrected to reduce it to standard barometric condition (and for small changes of temperature, if any), is the base rate. No cause can be assigned for changes of the base rate from one group to the next, and such as they are they must be considered as faults in the clock, or of its circumstances. The groups appear to have a definite mean length and the changes of base rate a definite mean value; each has also a fairly definite maximum, running to about two or three times the mean; accumulation of changes of rate results in the base rate ranging on each side of its mean in each section by a certain span. The values of the mean erratics, and their ascription to their proper causes, is not the subject of the present paper, but they are recorded, as well as the number of T.C. determinations upon which they rely, to show that they are of proper amounts. Each T.C. determination depends, as a standard, upon ten clock stars and at least two polars. The ephemeris places have been reduced to the system of the Preliminary General Catalogue of Boss.

It appears to me that this analysis gives a good idea of the behaviour of the clock. The test of its applicability is the duration of the groups, each group being supposed to include a sufficient number of T.C. determinations.

[Table

Riefler No. 258, *Base Rate and Erratics: collected.*

From	1. Date.	2. Duration of Group.	3. Base Rate [585 mm. 17°·6].	4. Change of Rate.	5. Mean Erratic.	6. No. T.C. Observations.
		d	s	s	s	
	Jan. 0					
1915 1		26	+·051		±·052	16
	26			−·021		
2		41	+·030		·028	16
	Mar. 8			+·030		
3		16	+·060		·033	8
	24			−·070		
4		12	−·010		·027	7
	Apr. 5			+·054		
5		17	+·044		·017	11
	22			−·030		
6		18	+·014		·027	6
	May 10			+·015		
7		12	+·029		·020	5
	22			+·024		
8		9	+·053		·017	3
	31			−·022		
9		9	+·031		·016	5
	June 8			−·037		
10		11	−·006		·015	9
	19			+·021		
11		20	+·015		·034	5
	July 9			−·006		
12		7	+·009		·030	5
	16			−·003		
13		22	+·006		·015	9
	Aug. 7			−·017		
14		7	−·011		·026	5
	14					
	—	—	—		—	
	19					
15		20	+·039		·024	10
	Sept. 8			−·035		
16		5	+·004		·007	3
	13			−·004		
17		11	·000		·016	5
	24			+·002		
	—	—	+·002		—	—
	27			+·016		
18		13	+·018		·026	11
	Oct. 10			−·047		
19		28	−·029		·039	10
	Nov. 7			+·036		
20		19	+·007		·030	14
	26			+·046		
21		6	+·053		·025	2
	Dec. 2			−·017		
22		28	+·036		·026	9
	30			−·053		
1916 1		8	−·017		·023	4
	Jan. 7			+·021		
2		10	+·004		·023	3
	17			−·064		
3		10	−·060		·018	5
	27			+·076		
4		6	+·016		·010	3
	Feb. 2					
	—	—	—		—	—
	4					
5		5	−·002		·030	4
	9			+·037		
		10	+·035		±·010	4
	19					

R. Base Rate and Erratics: collected.

After cleaning by E.T.C.	1. Date.	2. Duration of Group.	3. Base Rate [600 mm. 17°·6].	4. Change of Rate.	5. Mean Erratic.	6. No. T.C. Observations.
		d	s	s	s	
1916 7	Mar. 27	19	−·255		±·040	12
8	Apr. 15	7	−·234	+·021	—	—
9	22	6	−·161	+·073	·040	3
10	28	12	−·128	+·033	·060	2
11	May 10	20	−·117	+·011	·040	11
12	30	28	−·142	−·027	·036	10
13	June 27	24	−·186	−·044	·020	8
14	July 21	13	−·146	+·040	·020	8
15	Aug. 3	17	−·099	+·047	·020	2
	20			+·018		
	—	—	—	—	—	—
16	Sept. 1	6	−·081		·027	3
17	7	18	−·102	−·021	·031	8
18	25	14	−·117	−·015	·057	6
19	Oct. 9	22	−·141	−·024	·035	13
20	31	8	−·170	−·029	·035	4
21	Nov. 8	24	−·157	+·013	·056	5
22	Dec. 1	13	−·108	+·039	·013	3
23	14	14	−·093	+·015	·023	6
24	28	9	−·092	+·001	·020	3
	Jan. 6					
	—	—	—	—	—	—
1917 1	Feb. 13	13	−·015		·020	3
2	26	11	−·011	+·004	·020	4
3	Mar. 9	21	−·025	−·014	·036	11
4	30	10	−·053	−·028	·030	2
5	Apr. 9	17	−·052	+·001	·066*	8
6	26	9	−·035	+·017	043	6
7	May 5	10	+·017	+·052	—	—
8	15	13	−·029	−·046†	·084	5
9	28	7	−·054	−·025	·027	3
10	June 4	12	−·067	−·013	·033	6
11	16	7	−·037	+·030	·035	2
12	23	6	−·069	−·032	·030	4
13	29	15	−·033	+·036	·028	4
14	July 14	16	−·013	+·020	·043	4
	30					
	—	—	—			

* One erratic $-{}^{s}\!\cdot\!24$.   † Workmen fixing fan in clock chamber.

R. Base Rate and Erratics: collected—continued.

After cleaning by E.T.C.	1. Date.	2. Duration of Group.	3. Base Rate [600 mm. 17°·6].	4. Change of Rate.	5. Mean Erratic.	6. No. T.C. Observations.
		d	s	s	s	
	Aug. 22					
1917 15		24	+·049		·029	10
	Sept. 15			+·022		
16		11	+·071		·054	5
	26			+·043		
17		8	+·114		·008	4
	Oct. 4			−·032		
18		14	+·082		·063	6
	18			−·012		
19		9	+·070		·010	2
	27			−·037		
20		11	+·107		±·030	3
	Nov. 7					
—	R. opened to replace fused wire.					

R. Base Rate and Erratics: collected.

No.	1. Date.	2. Duration of Group.	3. Base Rate [630 mm. 17°·6].	4. Change of Rate.	5. Mean Erratic.	6. No. T.C. Observations.
		d	s	s	s	
	Nov. 14					
1917 21		14	+·140		±·083*	4
	28			+·033		
22		5	+·066		·030	2
	Dec. 3			−·074		
23		12	+·042		·025	4
	15			−·024		
24		18	−·002		·050	5
	Jan. 2			−·044		
1918 1		6	−·061		·030	4
	8			−·059		
2		8	+·001		·000	2
	16			+·062		
3		12	+·009		·030	2
	28			+·008		
	—	—	—	—	—	—
	Apr. 1					
4		8	−·051		·005	2
	9			+·040		
5		34	−·011		·031	7
	May 13			+·002		
6		15	−·013		·060	5
	28			+·019		
7		20	+·006		·023	6
	June 18			−·009		
8		18	−·003		·045	2
	July 6			+·008		
9		19	+·005		·020	2
	25			+·005		
10		5	·000		·053	3
	30			−·016		
11		28	−·016		·033	6
	Aug. 27			+·028		
12		29	+·012		·068	4
	Sept. 25			·000		
13		47	+·012		·046	10
	Nov. 11			−·002		
14		10	+·010		·063	4
	21			+·036		
15		8	+·046		·025	2
	29			−·029		
16		16	+·017		·055	4
	Dec. 15			−·046		
17		16	−·029		·043	3
	31					

* One erratic $+^{s}\cdot19$.

R. Base Rate and Erratics : collected.

No.	1. Date.	2. Duration of Group.	3. Base Rate [630 mm. 17°·6].	4. Change of Rate.	5. Mean Erratic.	6. No. T.C. Observations.
		d	s	s	s	
	Jan. 2				·040	4
		20	−·018			
1919 1				−·009		
	22				·000	2
		17	−·027			
2						
	Feb. 8					
	—	—	—	—	—	—
	19					
3		10	−·013			
	Mar. 1			−·041 *		
4		22	−·054		·033	4
	23			−·023		
5		34	−·077		·031	7
	Apr. 26			−·032		
6		18	−·109		·017	3
	May 14			−·026		
7		12	−·135		·053	3
	26			+·040		
8		14	−·095		·020	2
	June 9			−·032		
9		28	−·127		·042	6
	July 7			+·012		
10		18	−·115		·020	5
	25			+·009		
11		15	−·106		·038	5
	Aug. 9			−·011		
12		27	−·117		±·050	8
	Sept. 5			+·036		
13		27	−·081			
	Oct. 2					
	Oct. 2					
14		19	−·072		±·058	6
				+·025		
	21					
15		6	−·047		·013	3
				−·015		
	27					
16		15	−·062		...	...
				+·013		
	Nov. 11					
17		23	−·049		·042	6
				+·020		
	Dec. 4					
18		19	−·029		·032	5
				−·012		
	23					
1920 1		23	−·041		·064	5
	Jan. 15			+·013		
2		15	−·028		·047	6
	30			+·011		
3		32	−·017		·064	16
	Mar. 2			+·037		
4		20	+·020		·060	6
	22			−·017		
5		18	+·003		·033	3
	Apr. 9			+·015		
6		21	+·018		·044	5
	30			+·013		
7		10	+·031		·053	4
	May 10			−·039		
8		18	−·008		·043	7
	28			+·020		
9		10	+·012		·050	2
	June 7			−·022		
10		10	−·010		·043	6
	17			+·010		
11		5	·000		·055	2
	22			+·033		
12		18	+·033		·040	6
	July 10			+·029		
13		16	+·004		·038	4
	26			+·007		
14		40	+·011		·027	10
	Sept. 4			+·042		

* Temperature disturbed.

R. Base Rate and Erratics: collected—continued.

No.	1. Date.	2. Duration of Group.	3. Base Rate [630 mm. 17°·6].	4. Change of Rate.	5. Mean Erratic.	6. No. T.C. Observations.
		d	s	s	s	
1920 15	Sept. 13	9	+·053	−·025	·065	2
16	22	9	+·028		·035	4
	25*	...	...	...	...	...
17	30	5	+·081	−·014	...	...
18	Oct. 12	12	+·067	−·001	·033	4
19	30	18	+·066		·037	10

Base Rate and Erratics: Summary.

1. Section.	2. Barometric Standard.	3. Mean Base Rate.	4. Range of Base Rate.	5. Greatest Change.	6. Mean Change.	7. Mean Duration.	8. Mean Erratic.	9. Average No. T.C. Observations.
		s	s	s	s	d	s	
1915 Jan. 0 –1916 Feb. 19	585 mm.	+·016	·120	·076	±·031	15	±·024	7
		cleaned						
1916 Apr. 22 –1917 Nov. 7	600 mm.	+·056	·300	·052	±·025	14	±·035	7
		opened to replace fused wire						
1917 Nov. 14 –1918 Dec. 31	630 mm.	+·016	·201	·074	±·026	16	±·039	4
1919 Jan. 2 – Dec. 23	630 mm.	−·071	·124	·041	±·023	19	±·033	5
1919 Dec. 23 –1920 Oct. 30	630 mm.	+·017	·122	·042	±·020	16	±·044	6

The foregoing results, relating to the run of the standard clock of the Observatory, have been compressed as much as possible, because the object was to convey in a small compass a complete summary of continuous performance. There now follow the W.T. comparisons with Paris. It is desirable these should be given in much more detail, because very little has been published about such observations so far. But the whole material is too voluminous for the present publication, and it is hoped that a specimen page of the detail, accompanied by an abstract and summary of the whole, may give a reliable impression. Its interest lies in its bearing on the question of the consistency of two determinations of time, that is, of the phase of the earth's rotation, each made with all care at different places and under different circumstances. It is a question at the base of longitude determination, but from an astronomical point of view longitude itself, as being a quantity wholly terrestrial, is less important than the more abstract question of consistency. As before, no discussion is appended. The data are offered as a contribution; conclusions

* Temperature disturbed.

should not be drawn till the cumulative outcome from similar comparisons at several places are available.

The comparisons run from 1914 March to the end of October of the current year 1920, with a few short interruptions. They are made by means of the scientific time signals, or time verniers, exclusively. They were made every day, until pressure of war circumstances enforced a restriction, and they were then made generally only when T.C. observations for time were also obtained at the Observatory; daily observations were resumed in the present year. The outcome of the observation "Paris *minus* Edinburgh," with sign + for the Edinburgh clock slow, may be considered to embrace the following elements:—

(*a*) error in the reputed relative longitude of Paris and Edinburgh;
(*b*) errors in the reputed time at Paris;
(*c*) the like at Edinburgh.

The longitude adopted for Edinburgh is $12^{m}\ 44^{s}\cdot2$ W.

If the results converged upon a consistent constant mean, it would be attributed naturally to (*a*). As regards (*b*), the Paris time taken is that transmitted in connection with the W.T. signal, without applying any correction. With regard to (*c*), the operation of comparison is the following:—The reading of the clock Riefler No. 258 is made upon the chronograph; it is also plotted as described in the preceding pages. Riefler drives a slave clock which makes a contact from its pendulum at the lowest point of its swing, which is registered as a tick in the telephone in the wireless room; coincidences between the time vernier and this tick are noted by ear, an arrangement being provided for reducing them to suitable strength. This plan introduces into the observation the lag between the chronograph indication and tick of the slave clock. Some experiences of the determination of this lag with the microchronograph are given in *Mon. Not.*, 1918 June, p. 610, "On the Measurement of Time to the Thousandth of a Second." The lag will change where there is a change in the adjustments, but appears to be very steady under ordinary unchanged circumstances. It might be anticipated also that some allowance for personality would enter; but many experiments with two observers taking the same ticks with duplicate telephones, showed that they always agreed as to where the coincidences fell. There is therefore no personality to be allowed for.

After these explanations the arrangement of the table from which the appended extract is taken explains itself. The extract covers the section 1915 Oct. 8 to Nov. 29, and appears to me fairly representative of the whole. When the observation is corrected for lag and Edinburgh time taken as plotted, the outcome as given by column 7 would be presumed to be cleared from errors so far as one observatory is able to assign them. Following the extract is a summary and abstract of the whole table, showing the results section by section. The whole of the run is supposed to be on a comparable footing, and division into sections is an arbitrary matter governed by convenience. The aim with which it is made is to allow formation of a judgment as to whether or not these comparisons promise a satisfactory convergence upon a definite constant result.

On reading the numbers through, I think it will be felt that such a convergence is fairly decisive, in spite of a rather wide range. The general mean, Paris *minus* Edinburgh, is $+^{s}\cdot060$. The lowest value shown over a year is $+^{s}\cdot02$, and the highest are $+^{s}\cdot12$ and $+^{s}\cdot11$ in 1914 and 1920 respectively. The latter is produced by a long series of large values running from June to September, some of which seem anomalous. It must be recalled that the Paris times employed are provisional, being those sent out at the time of observation, and therefore dependent during cloudy weather upon extrapolation. It may be presumed that revised values would make the sequence somewhat smoother.* But it would hardly sensibly alter the mean, as may be inferred by noting that the general mean when the Edinburgh clock errors are taken directly as observed is $+^{s}\cdot056$, which is sensibly the same as that given by the plotted errors, $+^{s}\cdot060$.

The least satisfactory feature of the comparison is the persistence of values substantially different from the general mean over substantial periods of time, as the low values of 1916 and the high values from June to September of the present year. Another feature that will require scrutiny is a fairly pronounced tendency to show larger values in the middle of the year than at the ends. The series, however, is hardly long enough to decide whether the latter appearance is a real seasonal fault or merely an accident. When more material has been published it will be easier to tell where to look for the causes of anomalies. It ought to be possible by exchange of experience at different observatories to avoid such semi-systematic divergences; the best plan would be to record daily at several observatories the receipt of the same signals over considerable intervals of time. Comparisons for short durations are inconclusive.

The present position is a curious one, and invites improvement. The clock errors at a single observatory are less accordant with one another from day to day than a scrutiny of the individual T.C. observations would lead one to expect; and the comparison of clock errors of two observatories show still greater discordances, and such as require a long span of time to efface their effects in the mean.

Thus the mean erratic at Edinburgh as shown by the previous table is $\pm^{s}\cdot035$; the average departure from mean, section by section, shown below in the comparison of Paris and Edinburgh, is $\pm^{s}\cdot06$, being a little more than $\sqrt{2} \times$ the former value, which one would expect on introducing the separate erratics of the two observatories; but if we took the departure, not section by section, but from the general mean, it is evident that the amount would be much increased.

* This is borne out by employing the corrections for 1920 Jan. 1–March 18, published by M. Bigourdan in *Comptes Rendus* (1920), t. 171, p. 645.

EXTRACT FROM TABLE.

W.T. Comparisons. Paris and Edinburgh.

1915.	1. Observed Signal.	2. Lag.	3. Corrected Signal.	4. Observed Clock Error.	5. Plotted Clock Error.	6. Paris *minus* Edinburgh. (3)-(4).	7. (3)-(5).
	s	s	s	s	s	s	s
Oct. 8	+·44	+·08	+·36	...	+·37	...	−·01
9	+·51		+·43	...	+·40	...	+·03
11	+·44		+·36	+·41	+·40	−·05	−·04
12	+·41		+·33	...	+·38	...	−·05
13	+·38		+·30	+·31	+·36	−·01	−·06
14	+·39		+·31	+·35	+·34	−·04	−·03
15	+·44		+·36	+·39	+·32	−·03	+·04
16	+·38		+·30	+·34	+·30	−·04	·00
18	+·38		+·30	...	+·26	...	+·04
19	+·38		+·30	...	+·24	...	+·06
20	+·35		+·27	...	+·22	...	+·05
21	+·32		+·24	+·22	+·20	+·02	+·04
22	+·29		+·21	...	+·18	...	+·03
25	+·21		+·13	...	+·12	...	+·01
26	+·22		+·14	+·05	+·10	+·09	+·04
27	+·21		+·13	...	+·08	...	+·05
28	+·22		+·14	...	+·06	...	+·08
29	+·22		+·14	·00	+·04	+·14	+·10
30	+·22		+·14	−·04	+·02	+·18	+·12
Nov. 1	+·21		+·13	...	·00	...	+·13
2	+·12		+·04	+·02	−·02	+·02	+·06
3	+·05		−·03	...	−·04	...	+·01
5	−·07		−·15	...	−·08	...	−·07
6	−·04		−·12	...	−·10	...	−·02
7	...		...	−·15	−·15	...	...
8	−·01		−·09	...	−·12	...	+·03
9	−·01		−·09	...	−·10	...	+·01
10	−·03		−·11	−·09	−·08	−·02	−·03
11	+·04		−·04	−·03	−·05	−·01	+·01
12	+·02		−·06	−·08	−·03	+·02	−·03
13	−·01		−·09	+·03	−·01	−·12	−·08
15	+·09		+·01	+·02	+·04	−·01	−·03
16	+·06		−·02	+·08	+·07	−·10	−·09
17	+·12		+·04	+·06	+·09	−·02	−·05
18	+·20		+·12	+·09	+·11	+·03	+·01
19	+·19		+·11	+·08	+·14	+·03	−·03
20	+·22		+·14	+·11	+·16	+·03	−·02
22	+·27		+·19	+·16	+·21	+·03	−·02
23	+·27		+·19	+·23	+·23	−·04	−·04
24	+·29		+·21	...	+·25	...	−·04
25	+·34		+·26	+·23	+·28	+·03	−·02
26	+·36		+·28	+·31	+·31	−·03	−·03
29	+·46		+·38	...	+·42	...	−·04

The means of column 6 and column 7, in each case ${}^{s}{\cdot}00$, as well as the average variation from these means, $\pm{}^{s}{\cdot}05$ and $\pm{}^{s}{\cdot}04$ respectively, are carried to the Summary that follows.

Summary of Table.

W.T. Comparisons. Paris minus *Edinburgh.*

Section.	Observed Clock Errors. No. of Days.	Observed Clock Errors. Means for Section and [Year].	Observed Clock Errors. Average Variation from Mean.	Plotted Clock Errors. No. of Days.	Plotted Clock Errors. Means for Section and [Year].	Plotted Clock Errors. Average Variation from Mean.
		s	s		s	s
1914 Mar. 14–May 2	30	+ ·11	± ·05	40	+ ·10	± ·06
May 4–June 19	21	+ ·12	·07	38	+ ·12	·08
June 20–Aug. 2	22	+ ·17	·06	34	+ ·15	± ·06
		[+ ·132]			[+ ·121]	
1915 Mar. 12–May 5	23	+ ·03	± ·04	37	+ ·03	± ·04
May 6–June 25	23	+ ·08	·04	41	+ ·08	·04
June 26–Aug. 18	20	+ ·06	·02	39	+ ·07	·02
Aug. 19–Oct. 7	28	+ ·05	·04	41	+ ·06	·03
Oct. 8–Nov. 29	24	·00	·05	42	·00	·04
Nov. 30–Dec. 30	6	+ ·03	± ·03	20	+ ·10	± ·06
		[+ ·044]			[+ ·053]	
1916 Jan. 3–Feb. 19	22	+ ·01	± ·04	37	+ ·01	± ·03
Mar. 17–Apr. 26	17	+ ·02	·03	33	+ ·04	·07
Apr. 27–June 19	19	·00	·06	40	+ ·02	·06
June 20–Aug. 20	19	+ ·02	·07	41	+ ·02	·05
Aug. 31–Oct. 28	22	+ ·04	·06	36	+ ·03	·06
Oct. 30–Dec. 30	17	·00	± ·08	42	·00	± ·08
		[+ ·015]			[+ ·020]	
1917 Jan. 1–Mar. 9	17	− ·03	± ·05	35	− ·05	± ·05
Mar. 12–May 24	23	+ ·03	·08	34	+ ·02	·08
May 26–Sept. 1	22	+ ·07	·04	32	+ ·06	·04
Sept. 3–Nov. 27	18	+ ·03	·06	30	+ ·03	·07
Nov. 29–Dec. 27	5	− ·02	± ·10	10	+ ·02	± ·04
		[+ ·023]			[+ ·016]	
1918 Jan. 1–Jan. 28	6	− ·06	± ·07	8	− ·04	± ·08
Mar. 25–July 9	12	+ ·09	·08	17	+ ·08	·06
July 27–Aug. 30	5	+ ·19	·01	5	+ ·17	·03
Oct. 4–Dec. 31	11	·00	± ·06	12	+ ·01	± ·06
		[+ ·052]			[+ ·048]	
1919 Jan. 2–Apr. 26	14	+ ·06	± ·06	15	+ ·07	± ·06
July 9–Oct. 2	15	+ ·07	·09	18	+ ·09	·10
Oct. 6–Dec. 29	23	+ ·05	± ·07	25	+ ·04	± ·05
		[+ ·050]			[+ ·061]	
1920 Jan. 8–Apr. 25	27	+ ·01	± ·07	41	− ·03	± ·09
Apr. 26–June 13	15	+ ·08	·07	42	+ ·06	·06
June 14–Aug. 3	16	+ ·19	·14	42	+ ·21	·13
Aug. 4–Sept. 22	13	+ ·13	·16	42	+ ·19	·14
Sept. 23–Oct. 31	13	+ ·17	± ·05	28	+ ·14	+ ·04
		[+ ·101]			[+ ·114]	

General Mean.

1914–20	568	+ ·056	997	+ ·060

Note on the Longitude of Adelaide. By G. F. Dodwell, Government Astronomer.

Thanks to the kindness of General Ferrié, rhythmic signals were sent out from Lyons between June 21 and July 5. It was found possible to receive these signals at Adelaide. A comparison with the times received at Greenwich gives the following results:—

	h	m	s
June 23	9	14	19·95
24			20·15
25			20·11
28			20·03
29			19·90
30			19·92
July 1			19·94
4			20·03
5			19·91
Mean	9	14	19·99

Allowing for time of transmission $0^s{\cdot}04$, this makes the longitude of Adelaide

$$9^h\ 14^m\ 19^s{\cdot}95,$$

which may be compared with the adopted value,

$$9^h\ 14^m\ 20^s{\cdot}07.$$

A series of Annapolis signals received at Adelaide and Greenwich from July 6 to 28 gives

$$9^h\ 14^m\ 19^s{\cdot}79,$$

while a second series from August 8 to 19 gives

$$9^h\ 14^m\ 19^s{\cdot}78.$$

These are, however, not direct comparisons, as Adelaide received the signals sent at 3^h Greenwich Civil Time, and Greenwich those at 17^h. But the regularity of the Annapolis signals makes the results worthy of record.