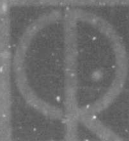


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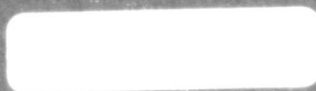
Some Results of Tests on Thunderstorm Detectors With a Small Range of Coverage

K.A. SEMENOV

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SOME RESULTS OF TESTS ON THUNDERSTORM DETECTORS
WITH A SMALL RANGE OF COVERAGE

Translation of

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s malym radiusom deistviia

by

K. A. Semenov

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WITH A SMALL RANGE OF COVERAGE

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Experimental data on thunderstorm discharges recorded within a radius of 10-20 km by instruments with a variety of designs are compared and analyzed in the present paper.

At present, a large number of designs for instruments have been proposed in various countries for the detection of thunderstorms and for a count of the number of discharges generated by thunderstorms. Thus, for example, Horner briefly describes the essential features of eleven such instruments appearing between 1943 and 1957 [1].

Among the examples of counters studied by Horner, we may single out designs proposed and used in England, USA, France, Japan, the Republic of South Africa, and other countries. After 1957, the creation of new designs and the use of instruments of earlier design was continued [2, 3, 4, 5, 6, et al].

In order to introduce a definite organization and planned development into the matter of selecting a suitable type of sferics receiver, international organizations have adopted a number of recommendations. Thus, for example, in 1953 the International Advisory Committee on Radio carried out a recommendation to compare a variety of sferics receivers in order to evaluate their relative virtues and deficiencies. This comparison began in 1955. It was concluded after a series of tests that the instrument

designed by Sullivan and Wells [7] was the most suitable. This same design, in a somewhat modified form, was later recommended by the World Meteorological Organization.

Despite these recommendations, attempts have continued in various countries to find a simpler and more reliable design for the counters. Some of these designs have been originated at the Main Geophysical Observatory in Leningrad. The present paper examines the results of tests on these designs and compares and analyzes experimental data on lightning strokes recorded within a radius of 10-20 km by instruments with a variety of designs, viz., a semiconductor sferics receiver PRG-1 [5, 6] and an electrostatic sferics receiver EG-1 [6, 9]. The fundamental standard is the field intensity instrument (PNP) [10]. In addition, the strokes were detected by an instrument which records the current from a lightning rod (PTO) [10]. The lightning rod is placed 10 m above ground level.

Two EG-1 instruments, one PRG-1 (designated PRG₁ in the tables), two PNP instruments, and one PTO were connected at the beginning of the 1962 thunderstorm season. Another PRG-1 (designated PRG₂ in the tables) was introduced into the study in August.

The EG and PRG₁ instruments operated around the clock. The strokes were detected by the counters and recorded on tape (PRG₂). The PNP and PTO were turned on only when storms approached closely. One PNP operated during the entire season at primary sensitivity and the other operated at secondary sensitivity. The ratio between the primary and secondary sensitivities was roughly 1:70 (in 1961 this ratio was 1:10).

During thunderstorms above or near the observation station, the strokes were recorded by all instruments in synchronization on two MPO-2 oscillographs. In order to

determine better the timing of the recording on the oscillographs, an observer made reference time marks on photographic film and, in addition, the time was marked every other second by contact clocks. The type of stroke (cloud-to-cloud or cloud-to-ground) and the time at which the sound of thunder was first heard at the observation station were recorded in the same way.

Table 1

Month	Instrument		EG ₁	Instrument			Instrument				PRG ₂	PRG ₂	PRG ₂
	PRG ₁	EG ₁		PRG ₁	PRG ₁	PRG ₃	PRG ₃	PRG ₁	PRG ₂	PRG ₃			
June	301	297	1.0	418	242	1.7							
July	718	799	1.1	1028	505	2.0							
August	129	101	0.8	165	99	1.7	135	210	99	110	1.3	2.1	1.6
September	83	95	1.1	56	29	1.9	56	81	29	76	1.4	2.8	1.1
Season	1231	1292	1.0	1667	875	1.9	221	291	128	186	1.3	2.3	1.4

Table 1 presents the data gathered in 1962. It gives the number of strokes received by the instruments during the same period of time and the ratio between the strokes received by different instruments.

It is well known that the electromagnetic field decreases in inverse proportion to the distance from the radiation source, while the electrostatic field decreases in inverse proportion to the cube of the distance. Although the experimental data shows that this function for the electrostatic field does not hold close to the source [6], it decreases far more rapidly than the electromagnetic field even at a short distance from the source. Based on these considerations, it was assumed that the PRG and EG

would not receive strokes from the same thunderstorm in the same manner, i.e., the instrument receiving the electrostatic component (EG) must pick up fewer strokes, especially at a large distance.

The comparison data showed that both instruments detected an almost identical number of strokes during the season (Table 1). When the data on the coincidence or omission of strokes was compared, greater similarity was noted between the data of the EG and the PRG than between the PNP and the PTO, which detect a change in the electrostatic field (see Tables 7 and 8).

In this connection it should be noted that the EG instrument primarily receives the electromagnetic radiation from a stroke.

A comparison of data obtained in 1961-1962 with PRG instruments having an identical threshold of response showed a sharp difference in the number of strokes received. A comparison between the number of strokes received and the height of the antenna base above ground level showed an almost linear dependence between the number of strokes received and the height of the antenna (Figure 1, curves 2 and 3). Figure 1 (curve 1) also gives the proportion of the number of strokes during thunderstorms over the observation station. The graph shows that the difference in the number of strokes received decreases abruptly, but is unchanged at heights of 8.5 and 12 m. Some decrease in the number of strokes received at 12 m may be due to the difficulty of synchronizing the recordings on the PRG₁ and PRG₅ instruments.

In 1961, the PRG₁ was determined to have an effective operating radius R_{ef} [6] of 18.5 km. R_{ef} was determined for other sferics receivers from the proportion of the number of strokes and the area S_{ef} of PRG₁.

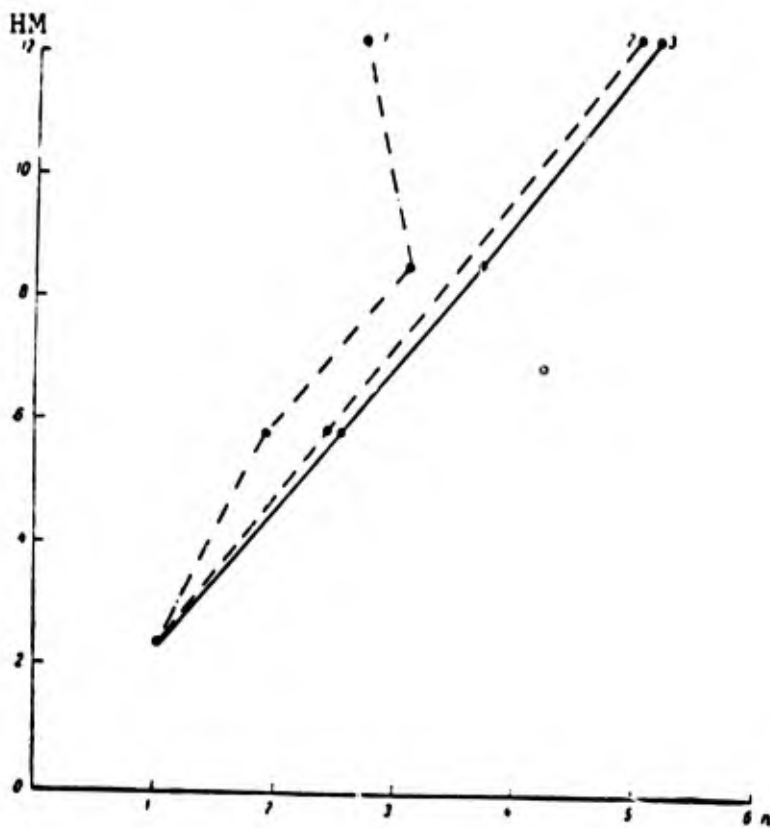


Figure 1. Graph of the number of strokes received versus the height of the antenna base above ground level.

1. Thunderstorm above the observation station;
2. all thunderstorms;
3. ratio of heights ($H = 2.3$ m is taken as a unit).

If we know the number of strokes, R_{ef} , and the period of time during which these strokes were recorded, we can determine the intensity of a thunderstorm. It turns out that the intensity decreases as R_{ef} increases (Table 2).

The intensity N when restricted to a single height H can be given by the expression

$$N_2 = N_1 \sqrt{\frac{H_1}{H_2}}. \quad (1)$$

Let us compute the intensity N_2 of a thunderstorm for the following assigned values: $N_1 = 3.0 \cdot 10^{-3}$ strokes/km² hour, $H_1 = 12.2$ m, and $H_2 = 2.3$ m.

$$N_2 = 3.0 \cdot 10^{-3} \sqrt{\frac{12.2}{2.3}} = 6.9 \cdot 10^{-3} \text{ strokes/km}^2 \text{ hour.}$$

An intensity N_2 of $6.2 \cdot 10^{-3}$ was actually obtained (Table 2).

Table 2

Instrument	Height of antenna base H above ground level, m	Length of reduction cable, m	Threshold of operation, v	R_{ef} km	S_{ef} km ²	August			Season			August		
						N	Hour	$N \cdot 10^{-3}$	N	Hour	$N \cdot 10^{-3}$	N	Hour	$N \cdot 10^{-3}$
PRG ₃	2.3	10	1.5	9.7	293	385	744	1.7	1144	624	6.2	377	60	21
PRG ₄	5.8	10	1.5	15.1	716	939	744	1.8	939	336	3.9	888	50	21
PRG ₅	12.2	14	1.5	21.8	1492	2232	744	2.0	5038	1128	3.0	1818	60	20

Table 2 presents the data of several variations for computing the mean intensity N for three PRG instruments. These same data are plotted in Figure 2, curves 1, 2, and 3. Curve 1 was derived by computing N for 31 days (or 744 hours) in August 1961. Curve 2 was computed by taking only days in which the instruments recorded strokes, i.e., days with a thunderstorm, while curve 3 gives the intensity for 60 synchronized hours of instrument operation.

The instrument with $R_{ef} = 9.7$ km was taken as the base. Hours in which this instrument did not record strokes, but in which strokes were recorded by the other two, were not taken into consideration. From a comparison of these data one may conclude that the average intensity over the entire

area covered by the instruments for the entire thunderstorm period can be obtained by an instrument independent of the height of its antenna above ground level.

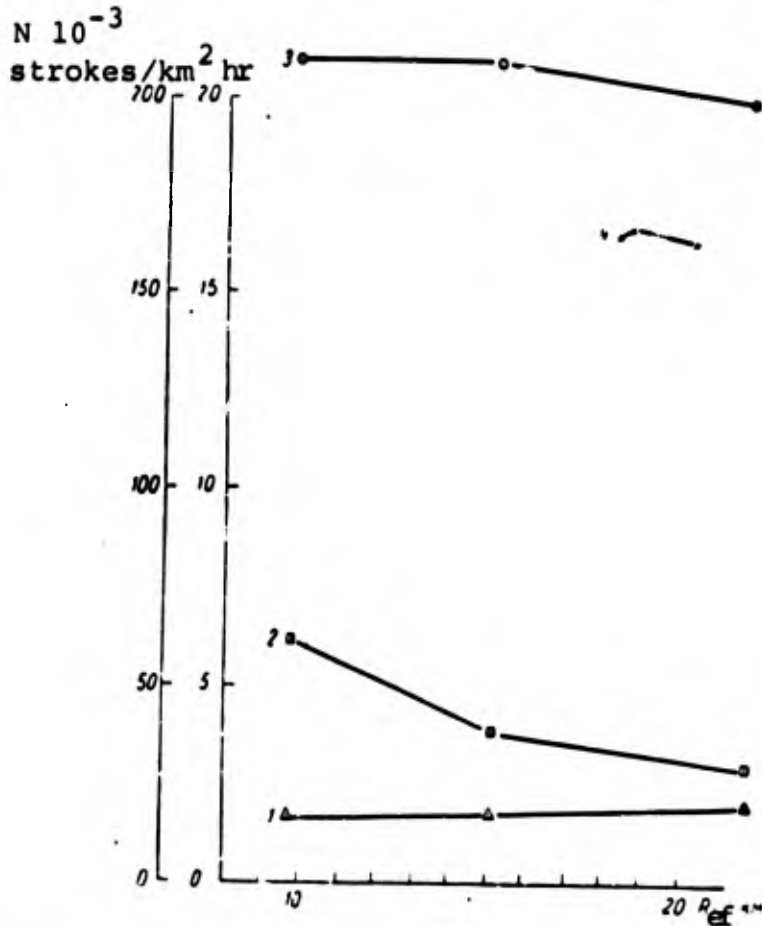


Figure 2. Graph of the intensity of thunderstorms, based on the data of sferics receivers with different radii of operation. (The right hand numbered scale on the y-axis is for curves 1, 2, and 3; the left hand scale is for curve 4).

1. Intensity for the whole thunderstorm period;
2. intensity for days with a thunderstorm;
3. intensity for 60 synchronized hours of thunderstorms;
4. intensity of thunderstorms above the observation station.

The intensity of thunderstorms shown by curve 3 is an order higher than the intensity for the whole thunderstorm period. This is explained by the fact that most of the

strokes were recorded by the instruments during these 60 hours of thunderstorms, while during the other 684 hours, there either were no thunderstorms or their intensity was very low (Table 2). At the same time, during the course of the 60 hours with thunderstorms, there were substantial intervals of time without thunderstorms. On this basis, one can conclude that the actual intensity of the thunderstorms, i.e., the intensity over the area occupied by the thunderstorms, was substantially higher than that shown in curve 3.

Table 3 presents the data on the intensity of thunderstorms in 1961, as obtained by a different method and with different instruments for thunderstorms over or in the vicinity of the observation station. The data of the PRG₁, PNP, and EG₁ were used to determine the time interval t' between succeeding strokes. Then the average value \bar{t} was determined. The data for the season are presented in Figure 2, curve 4. Table 3 gives the intensity of a heavy thunderstorm on 16 July which continued without interruption for more than two hours. The value of N was determined by the formula

$$N = \frac{3600}{5\bar{t}} \quad (2)$$

Table 3

Instrument	Height of antenna base H above ground level, m	Length of reduction cable, m	Threshold of operation, v	R _{eff} km	S _{eff} km ²	Season		16/VII 1961			n' strokes/sec		
						n	Sec	N·10 ⁻³	n	\bar{t} sec	N·10 ⁻³	Season	16/VII
PRG ₁	8.5	13.5	1.5	18.5	1075	3340	20	167	414	16	210	93	117
PNP ₂	—	—	—	18.2	1040	3340	21	165	290	15	230	92	128
EG ₁	9.0	35	0.5	20.3	1294	3340	17	164	163	13	210	91	117

The last two columns of Table 3 contain the comparative data on the recomputation of the intensity of thunderstorms in Voeikovo for all the thunderstorms around the world. According to Krumm's [12] conversion of Whipple's [11] 1929 data and Krumm's [13] 1959 data, the mean area \bar{S} occupied by thunderstorms equals 192 and $216 \cdot 10^4$ km², respectively. Assuming that $\bar{S} = 2 \cdot 10^6$ km², the number of strokes n' per second for the whole world is computed by the formula

$$n' = \frac{N\bar{S}}{3600}. \quad (3)$$

The values of n' presented in Table 3 show that the intensity of thunderstorms in the northern latitudes is close to the average value derived by Brooks [13] (100 strokes/sec), while the other cases exceed this value. If we take the value of S derived by Whipple, n' is reduced by a factor of roughly 2.5.

In operating the PRG, there were cases where nearby strokes were not recorded. Table 4 presents the data for 1961-1962 on the reception and omission of strokes for which the distance was determined (within a range of 20 km). The omissions can obviously be explained as weak signals that are below the instrument's threshold of operation. However, no relationship was discovered between the omission of strokes and the field intensity ΔE during the discharge because strokes were recorded at comparatively small values of ΔE and were omitted for large field intensity values.

The second factor explaining omissions in the reception of strokes can be assumed to be the difference in the spatial alignment of the lightning channel of a cloud-to-cloud stroke with respect to the receiving antenna of the sferics receiver [8], considering the lightning channel

to be an emission antenna in this case. This can be supported by the data of observations (Table 5) which show that most of the omissions are cloud-to-cloud strokes. A final solution to this problem requires that strokes be recorded by instruments with different alignment of the receiving antennas which are placed at various levels above the surface of the earth.

Table 4

Instrument	Number of Cases				Number of Cases			
	Recorded	Not recorded	Recorded, %	Not recorded, %	Recorded	Not recorded	Recorded, %	Not recorded, %
	1961 r.				1962 r.			
PNP ₁	129	2	98	2	166	1	99	1
PNP ₂	349	8	98	2	155	36	81	19
PRG ₁	423	64	87	13	93	71	57	43
PRG ₂	—	—	—	—	30	19	61	39
EG ₁	309	24	93	7	96	68	58	42
EG ₂	—	—	—	—	98	62	61	39
PTO	417	17	96	4	145	8	95	5

Table 6 gives the number of cases in which strokes were recorded by different instruments. Tables 7 and 8 were composed on the basis of Table 6.

Table 7 gives the percent of coincidence and Table 8 gives the percent of variance of strokes, out of the total number of strokes recorded by the various instruments.

As a result of these tests, preliminary conclusions may be drawn regarding the selection of a spherics receiver design which can be used both for counting the strokes within a definite range and indicating the thunderstorm

Table 5

In- stru- ment	Cloud-to-cloud			Cloud-to-ground			Cloud-to-cloud + cloud-to-ground		
	Record- ed	Not re- corded	Per- cent	Record- ed	Not re- corded	Per- cent	Record- ed	Not re- corded	Per- cent
1961 r.									
PNP ₁	20	1	$\frac{95}{5}$	11	0	$\frac{100}{0}$	31	1	$\frac{97}{3}$
PNP ₂	151	14	$\frac{92}{8}$	31	1	$\frac{97}{3}$	185	15	$\frac{92}{8}$
PRG ₁	155	31	$\frac{83}{17}$	42	3	$\frac{93}{7}$	197	34	$\frac{85}{15}$
EG ₁	117	4	$\frac{97}{3}$	21	1	$\frac{95}{5}$	138	5	$\frac{96}{4}$
PTO ₁	76	0	$\frac{100}{0}$	17	0	$\frac{100}{0}$	93	0	$\frac{100}{0}$
PTO ₂	67	9	$\frac{88}{12}$	21	1	$\frac{95}{5}$	88	10	$\frac{90}{10}$
1962 r.									
PNP ₁	44	0	$\frac{100}{0}$	45	0	$\frac{100}{0}$	89	0	$\frac{100}{0}$
PNP ₂	42	5	$\frac{89}{11}$	39	8	$\frac{83}{17}$	81	13	$\frac{86}{14}$
PRG ₁	28	11	$\frac{72}{28}$	15	1	$\frac{94}{6}$	43	12	$\frac{78}{22}$
PRG ₂	6	5	$\frac{54}{46}$	8	0	$\frac{100}{0}$	14	5	$\frac{74}{26}$
EG ₁	29	9	$\frac{76}{24}$	15	1	$\frac{94}{6}$	44	10	$\frac{81}{19}$
EG ₂	31	7	$\frac{82}{18}$	15	1	$\frac{94}{6}$	46	8	$\frac{85}{15}$
PTO ₁	11	0	$\frac{100}{0}$	12	0	$\frac{100}{0}$	23	0	$\frac{100}{0}$
PTO ₂	22	1	$\frac{96}{4}$	3	0	$\frac{100}{0}$	25	1	$\frac{96}{4}$

*) The percentage of strokes recorded is given in the numerator and the percentage of strokes not recorded is given in the denominator.

Table 6

	PNP ₁	PNP ₂	PRG ₁	PRG ₂	EG ₁	PTO ₁	PTO ₂
PNP ₁	—	256	140	44	151	139	101
PNP ₂	658	—	194	48	220	160	133
PRG ₁	363	216	—	46	241	164	140
PRG ₂	73	42	37	—	33	40	36
EG ₁	346	215	215	45	—	102	143
PTO ₁	160	162	194	27	122	—	—
PTO ₂	135	79	70	18	70	—	—

Table 7

	PNP ₁	PNP ₂	PRG ₁	PRG ₂	EG ₁	PTO ₁	PTO ₂
PNP ₁	—	40	35	56	34	86	74
PNP ₂	40	—	35	48	32	62	52
PRG ₁	35	35	—	77	52	44	26
PRG ₂	56	48	77	—	56	63	42
EG ₁	34	32	52	56	—	36	27
PTO ₁	86	62	44	63	36	—	—
PTO ₂	74	52	26	42	27	—	—

Table 8

	PNP ₁	PNP ₂	PRG ₁	PRG ₂	EG ₁	PTO ₁	PTO ₂
PNP ₁	—	0	3	3	7	1	1
PNP ₂	60	—	28	31	35	37	43
PRG ₁	62	37	—	21	28	44	58
PRG ₂	41	21	2	—	10	34	53
EG ₁	59	33	20	34	—	42	58
PTO ₁	14	1	12	2	22	—	—
PTO ₂	26	4	16	5	15	—	—

situation in a given territory. Here we considered simplicity of design, convenience and reliability of operation, and the frequency response of the instrument. It is absolutely necessary to take this last factor into account when selecting this type of instrument.

Field tests over a number of years indicate that preference must be given to the PRG type instrument on the basis of its simplicity and the reliability of design.

References

1. Horner, F. The design and use of instruments for counting local lightning flashes, Proc.Inst.Elec. Engrs. 107B(34):321-330,1960.
2. Kaiser, H. and H. G. Schulze. Lightning counters and their use for the location of thunderstorm centers, Z.Meteorol. 14(2):50-55,1960[in German].
3. Müller-Hillebrand, D. Lightning counter and results obtained in Sweden during the thunderstorm period 1958, Teknisk-Vetenskaplig Forskning 30(6): 1-16,1959
4. Nevalainen, U. Lightning stroke counters in Finland, Puhelin 11(6),1961[in Finnish].
5. Znamenskiĭ, A. A. Recording of thunderstorms by means of the PRG-1 semiconductor lightning stroke counter, Trudy GGO 110:67-74,1960[in Russian].
6. Makhotkin, L. G. and K. A. Semenov. Statistics of thunderstorm discharges, Trudy GGO 146:39-47,1963 [in Russian].
7. Sullivan, A. W. and J. D. Wells. A lightning stroke counter, Bull.Am.Meteorol.Soc. 38(5):291-294,1957.

8. Malan, D. J. Radiation from lightning discharges and its relation to the discharge process. Recent advances in atmospheric electricity, Conference on Atmospheric Electricity, 2nd, Portsmouth, N. H., May 20-23, 1958, Proceedings, 1958, pp. 557-563.
9. Lydzar, P. S. Semiconductor lightning stroke counters, Trudy GGO 157:54-58, 1964 [in Russian].
10. Imianitov, I. M. Pribory i metody dlia izucheniia elektrichestva atmosfery (Instruments and Methods of Studying Atmospheric Electricity), Moscow, Gos-tekhnizdat, 1957.
11. Whipple, F. J. N. and F. J. Scrase. Point discharge in the electric field of the earth. An analysis of continuous records obtained at Kew Observatory, Geophys. Memoirs (Met. Office, London) 7(68): 1-20, 1936.
12. Krumm, H. C. Der weltzeitliche Tagesgang der Gewitterhäufigkeit (The UT variation of diurnal thunderstorm activity). Doctoral dissertation, Meteorology and Geophysics Institute, University of Mainz, 1959.
13. Brooks, C. E. P. The distribution of thunderstorms over the globe, Geophys. Memoirs (Met. Office, London) 3(24):145-164, 1925.