A survey of the levels of lightning and thunderstorm activity in Sierra Leone

B. Nicholl

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SUMMARY

A brief description of the lightning stroke counter, developed by the Electrical Research Association (E.R.A.) is followed by the location of the thunderstorm day (T.S.D.) listening stations and the lightning stroke counter stations throughout Sierra Leone. Tabulated results of thunderstorm days, for the period January 1963 - December 1964 and from thirty-nine stations, are compared with lightning count (L.C.) figures from eight counters operating throughout most of the same period. Using these figures an attempt is made to describe the pattern of thunderstorm and lightning activity over the country during the various seasons. The monthly variation in the number of T.S.D. and spread of thunder over the country, and the diurnal variation in the time at which thunder is heard, are given and the latter is compared with the diurnal variation in rainfall.

Consideration of future work suggests that T.S.D. and L.C. figures for a longer period of time should be collected. Some improvement in the design of the counter is needed so that calibration can be carried out by semi-skilled operators. Since the E.R.A. counter registers both cloud-to-cloud and cloud-to-ground strokes, it would be useful to install a number of Malan counters which register only cloud-to-ground strokes. Limited observations suggest that the frequency of C/G strokes is much less than the frequency of C/C strokes.

The results from the eight lightning counters indicate that lightning counts occur on days when thunder is not reported from

any nearby station. Further work is needed to determine the cause of these extraneous counts.

In the Appendices, an estimate of the effective range of the lightning counter is made together with the effect of ambient temperature on the sensitivity calibration. Hourly count rates for the Freetown instrument are given and from which typical patterns of thunderstorms are obtained.

A SURVEY OF THE LEVELS OF LIGHTNING AND THUNDERSTORM ACTIVITY IN SIERRA LEONE.

B. NICHOLL.

M.Sc. THESIS JUNE 1965.

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S U M M A R Y

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CONTENTS

1. INTRODUCTION

1.1. GENERAL

In a developing country it is important that the natural resources of the country should be used to the full. In Sierra Leone, these include such minerals as diamonds, iron ore and bauxite, and market produce which includes some cocoa, palm kernels and palm oil. The country is broadly divided into two sections; the Freetown peninsula and the rest of the country - usually referred to as 'up-country'. The Freetown peninsula, which is the most highly developed part of the country, accounts for only 256 sq. mls. out of a total area of 27,925 sq. mls. It has none of the resources listed above but, being situated on the coast, it contains the only ports which can be used for shipping exports to overseas customers. Any large scale expansion of industry which depends upon the natural resources of the country will require a system of electric power generation and distribution which will supply electric power to the areas where these resources are to be found. The present policy is to build small, uneconomical power stations at widely scattered parts of the country. Often these are in small towns where the demand, which is mainly for domestic purposes, is too small for any generating plant to run efficiently. It is becoming more obvious that the possibility of a transmission and distribution system, linking together present and future power stations, must be considered.

Sierra Leone is a feebly urbanised country. Freetown has a population of 128,000 and the only other major town outside the Freetown peninsula is BO with a population of between 40,000 and 50,000. There are few other towns with populations of more than 10,000 and the estimated total population of 2,183,000 is scattered over the country giving a population density of 78 / sq. ml. Whilst this is the fifth highest density in Africa, it is very low when compared with the figure of 200 / sq. ml. found in the United Kingdom. It means that much of the country is still unpopulated and is covered with bush and forest. If an electric power transmission and distribution system is developed it would seem that the overhead line would be more economical than the underground cable. This would be true for both transmission and distribution. This is, in fact, the method used at the present time.

Sierra Leone is in the area of the world having the highest incidence of thunderstorms (1). The results of this survey will show that this varies in intensity in different parts of the country. If overhead transmission and distribution lines are to be used to carry power to different parts of the country, a very careful choice of power line routes and location of generating stations could lead to a saving in running costs and a reduction in the number of faults caused by lightning. Other factors such as the situation of load demand centres and the nature of the land surfaces will have to be considered, but the incidence and distribution of thunderstorms and lightning will be of major importance.

1.2. METHODS OF ASSESSING THUNDERSTORM AND LIGHTNING ACTIVITY

Thunderstorm and lightning activity can be assessed in two ways. The incidence of thunder can be measured by counting the number of days during which thunder is heard. By international agreement any calendar day on which thunder is heard is called a thunderstorm day (T.S.D.)[2] irrespective of the duration or intensity of the thunderstorm. This is particularly misleading in the present survey since, in Sierra Leone, it sometimes happens that a single thunder cloud is seen to develop in the mid-afternoon, later producing one or two thunderclaps and then dispersing. This will count equally with a day during which severe thunderstorms continue for long periods throughout the day. In the present work there is one deviation from the international agreement. A T.S.D. is reckoned from 0800 hrs. on one calendar day to 0800 hrs. on the following day. This arrangement has been used in other surveys [1] and is a more convenient method when recordings are being made by voluntary observers and not by trained meteorological staff.

In order that more accurate measurements of the incidence of thunderstorms can be made, and to overcome the difficulty already mentioned, a number of lightning stroke counters have been designed [3]. The counter described by PIERCE [4] has already been used in Sweden, Norway and Finland [5], in Southern Rhodesia [6] and in work in other parts of the world. So that the present results can be compared with world wide figures [7] this instrument was chosen for the present survey [8]. It also has the advantage of cheapness and, being battery operated, it is independent of external electricity supplies. A detailed description of the counter is given on pages X

1.3. ACCURACY OF RESULTS

Previous workers in this field [1] have been able to use only trained meteorological observers for recording T.S.D. readings. Since there are only six official meteorological stations, manned by trained observers, in Sierra Leone such limitations are impossible. Lay observers have had to be used but certain factors have reduced the personal effect in assessing the data. Outside Freetown there is a little background noise to be confused with thunder. Watchmen are on duty throughout the hours of darkness and at most stations there has been a 24 hour watch for storms. Two checks upon the accuracy of the T.S.D. reports have been made. At seven Stations two or more observers have made independent monthly reports. These have usually agreed within 90 %. Further, when each station is ranked according to its annual total of T.S.D. for each of the two years covered by the survey, there is significant agreement between the rank order for each year (see Table 1 page 6 . Since many stations had a change in personnel during the period this indicates a general pattern of thunderstorm distribution and some degree of accuracy of recording. In addition, Table 2 page 7 suggests that, within the limitation of the small number of stations recording T.S.D. readings over a longer period of time (10 years), the 1963 - 1964 results follow closely the average figures for the years 1951 - 1960. Consequently, it is felt that the data offered in the following pages is probably within the 90% accuracy suggested by KREFT [1] and others.

To assess the accuracy of the lightning stroke counter results is more difficult. It is certain that the range of the counter is greater than the range over which thunder is heard. The average range of the counters used in this work is assessed at 20 mls, (Appendix 2 page 69) so the number of T.S.D. used in the L.C. Table 12 page 64 - 65 is that recorded by any station within this range of the counter.

The E.R.A. counter is known to be affected by H.T. transmission lines but, since there is no such line near any of the counters, this will not influence the accuracy of the results of the present survey. However, the counters have registered on days when thunder has not been reported. On one occasion the Freetown instrument was known to be counting some strokes from a storm estimated to be 100 mls. distant from the counter. In arriving at a figure for the average lightning count / thunderstorm day (Table 13 page 66) it is noted that the closest agreement between number of count days and number of thunderstorm days is obtained if the days on which the count was less than 5 are ignored. Whilst this is an arbitary figure, it has been used by other workers in this field (9) and does appear to give this close agreement already mentioned.

The author of this report is convinced that the greatest source of error in using the E.R.A. counter lies in the difficulty in calibrating the instrument correctly. One small amendment to the circuit was made (page 74 fig. 10) which made calibration a little easier, but this point needs attention in future designs for counters.

Station No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Ranked 1963	18	39	13	32	12	37	29	6	25	28	13	34	6	35	11	30	21
Ranked 1964	24	39	18	33	31	38	17	5	10	2	13	27	14	35	18	37	11
d	-6	0	-5	-1	19	-1	12	1	15	26	0	7	-8	0	-7	-7	10
d^2	36	0	25	1	361	1	144	1	225	626	0	49	64	0	49	49	100

Station No.	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Ranked 1963	36	31	24	26	17	1	9	20	2	32	27	38	10	16	23	22	13
Ranked 1964	34	26	28	32	22	25	14	36	1	30	7	29	12	6	9	18	16
d	2	5	-4	-6	-5	-24	-5	-16	1	2	20	9	-2	10	14	4	-3
d^2	4	25	16	36	25	576	25	256	1	4	400	81	4	100	196	16	9

Station No.	35	36	37	38	39	n = 39
Ranked 1963	4	19	3	5	8	
Ranked 1964	3	23	3	8	21	
d	1	-4	0	-3	-13	
d^2	1	16	0	9	169	$d^2 = 3700$

If R = Spearman's Rank Correlation Coefficient,

$$R = 1 - \frac{6\ d^2}{n^3 - n}$$

$$= 1 - \frac{6 \times 3700}{39^3 - 39}$$

$$R = 0.625$$

$$\text{Student } t = R\ (n - 2) / (1 - R^2)$$

$$= 0.63\ \ 37 / (1 - 0.63^2)$$

$$t = 4.95$$

Since this is greater than the 1% level of t with 37 degrees of freedom (2.7)[10] it indicates a significant degree of agreement. This suggests that the T.S.D. records for the two years conform to a similar pattern of relative severity.

Table 1. RANK ORDER OF STATIONS SHOWING T.S.D. 1963 - 1964

AVERAGE T.S.D. 1963 - 1964

	J	F	M	A	M	J	J	A	S	O	N	D
FREETOWN	4	3	6	4.5	13	22	10	5.5	12	19	17.5	6
LUNGI	1.5	1.5	2.5	4.5	19	20.5	12	5.5	16	20.5	21.5	5.5
BONTHE	2.5	6	9	7.5	25.5	19.5	7.5	6	12	20.5	20	12
BO	3	8	15.5	13	25	24	16.5	8	20	27	21.5	8.5
KABALA	3	2.5	7.5	11.5	19	23	17.5	7.5	18.5	21	9	3.5
DARU	4	10.5	15.5	10.5	24.5	22.5	16	9.5	19	25	16.5	7.5
Total	18	31.5	56	51.5	126	131.5	79.5	42	97.5	133	106	43
Mean	3	5.2	9.3	8.6	21	21.9	13.2	7	16.3	22.2	17.8	7.2
Mean %	9.7	18.3	30	28.6	67.7	73	42.6	22.6	54.4	71.6	59.4	23.2

AVERAGE T.S.D. 1951 - 1960

	J	F	M	A	M	J	J	A	S	O	N	D
FREETOWN	1	1	3	7	15	15	6	2	11	12	11	3
LUNGI	2	3	5	13	25	25	12	7	20	27	24	8
BONTHE	6	7	13	18	27	22	6	5	16	23	26	12
BO	3	7	14	20	26	23	11	8	20	26	25	8
KABALA	2	3	8	14	21	24	15	12	22	28	15	4
DARU	3	8	15	22	24	22	11	9	23	28	24	7
Total	17	29	58	94	138	131	61	43	110	144	125	42
Mean	2.8	4.8	9.7	15.7	23	21.8	10.2	7.2	18.3	24	21	7
Mean %	9	17.1	31.3	52.3	74.2	72.6	32.9	23.2	61	77.5	70	22.6
63/64 %	9.7	18.3	30	28.6	67.7	73	42.6	22.6	54.4	71.6	59.4	23.2

Table 2. COMPARISON T.S.D. 1951 - 1960 and 1963 - 1964

2. DESCRIPTION OF EQUIPMENT USED

2.1. LIGHTNING STROKE COUNTER

The instrument used for counting the number of lightning flashes is the E.R.A. Lightning Stroke Counter first described by PIERCE and later modified by GOLDE. It is the instrument chosen by the C.I.G.R.E. Study Committee No. 8 for lightning measurements in various parts of the world.

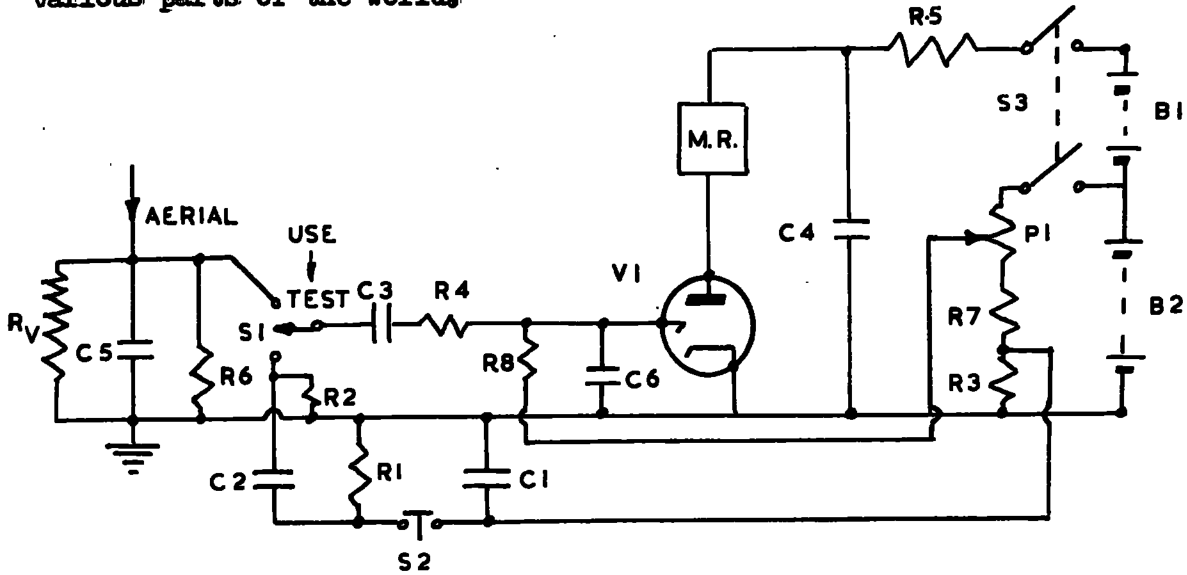


Fig. 1. CIRCUIT OF E.R.A. LIGHTNING COUNTER.

Component values

R_1, R_2, R_6, R_8	10 MΩ
R_3	1 MΩ
R_4	2.2 MΩ
R_5	0.15 MΩ
R_7	3 MΩ
R_V	Voltage-dependent resistance.

P_1	5 MΩ	B_1	Ever-Ready B 126, 90 V.
C_1	10,000 pF	B_2	Ever-Ready B 107, 90V.
C_2	220 pF	M.R.	Ever-Ready LOOC
C_3	470 pF	V_1	Hivac XC 23
C_4	8 μF		
C_5	100 pF		
C_6	47 pF		

In principle the counter consists of a cold-cathode gas filled triode V_1 operating a discharge circuit R_5C_4 through an electromagnetic message register M.R. thus recording the lightning stroke. A test circuit C_1 R_1 C_2 R_2 enables an impulse voltage of 20 V., taken from resistance R_3, to be applied to the condenser C_1 and so allows the trigger potential of V_1 to be set, by means of the sensitivity control potentiometer P_1, to a value 10 V. below the static strike voltage. In this way the sensitivity of the counter is determined.

The signal received from the aerial array is passed to a resistance - capacitance filter R_4 C_3 having a maximum transmission in the range 500 c/s to 1000 c/s. The output voltage from the filter is applied to the trigger electrode of the valve. Since this electrode is already at a potential of 10 V. below strike voltage, any signal from the aerial greater than this value will cause the valve to become conductive. This allows the condenser C_4, already charged from the battery circuit, to be discharged through the valve and the message register, and one operation is recorded. The value of resistance

R_5 is fixed so that the valve becomes non-conductive immediately following the discharge so enabling condenser C_4 to be recharged in readiness for the next operation.

A resistance R_6 and a capacitance C_5 are connected between aerial and earth to prevent excessive static voltage being accumulated on the aerial. The voltage-dependent resistor R_V protects the apparatus from excessive voltages on the aerial. Only on one occasion was this resistor damaged and this from a C/G strike 200 yds. distant from the installation.

2.2 AERIAL ARRAY

Details of this are shown in Fig. 2 page 11 . It consists of six parallel copper wires, each 45 ft. long and 1/8 th. inch diameter, spaced 6 inches apart and joined in good electrical contact at each end. One end of the aerial is held, by means of two 33 Kv insulators, at ground level and the other end at a height of 30 ft. supported on a wooden electric power line pole. The pole rests on a metal earth plate 4 ft. x 2 ft. and 6 ft. below ground level from which an earth connection to the counter is made. The connection between the aerial and the instrument is made by heavily insulated conductor so that the total resistance between aerial and earth terminals at the counter is never less than 3 MΩ. In order to maintain this high value of insulation resistance, the insulators are protected from the rain by two rain shields and are painted with a resin compound. At each site the aerial array is situated well

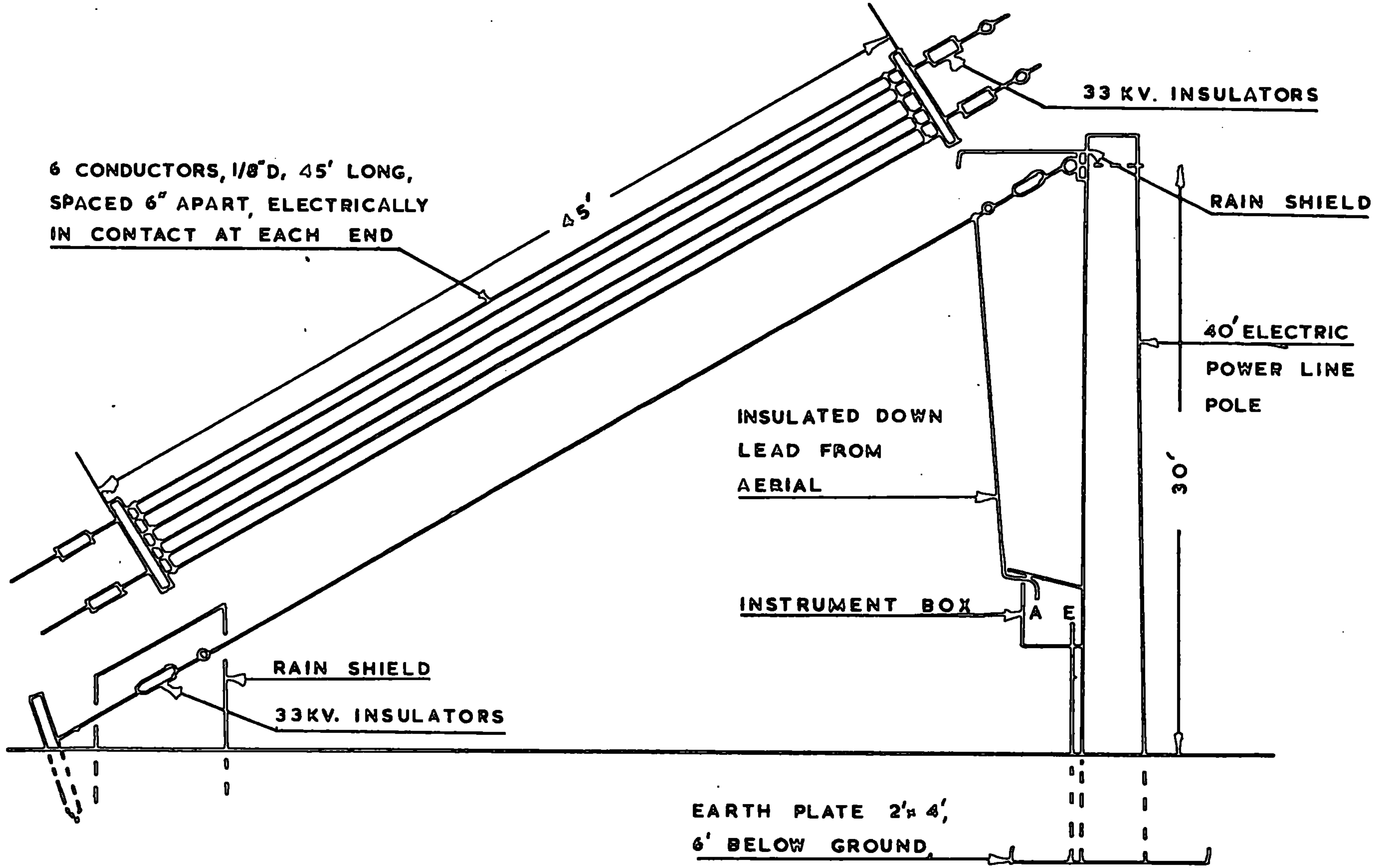


FIG. 2. AERIAL ARRAY FOR E.R.A. LIGHTNING STROKE COUNTER

away from tall structures or trees with a separation of at least twice the height of the structure between obstacle and aerial. It should also be at least 1000 ft. distant from any high-tension transmission line. In Sierra Leone the latter condition was easy to satisfy since there are few transmission lines of any description.

After the experience gained in installing the first three counters, (at Freetown, Yengema and Bo), the aerial array was changed to one in which the wires were held parallel to the ground and at a height of 15 ft. from it. This was found to be necessary because of the difficulty of obtaining and handling 40 ft. power line poles in remote up-country districts of Sierra Leone. The counters at Rokupr, Lakka, Makeni, Kenema and Daru operated from this type of aerial, but in all other respects were similar to the other installations. Fig. 3 page 15 shows a typical arrangement of the latter type being the one at Rokupr.

2.3 CALIBRATION OF COUNTER

General

The trigger voltage of the valve is approximately 60 V. By altering the sensitivity control a potential 10 V below this is applied to the trigger electrode.

In order to calibrate the instrument a test circuit can be switched on using switch S_1 and, by pressing switch S_2, the extra 10 V is applied to the trigger electrode. The counter should now operate. Should the counter not register the main trigger potential must be increased by rotating the sensitivity control P_1.

Calibration Procedure

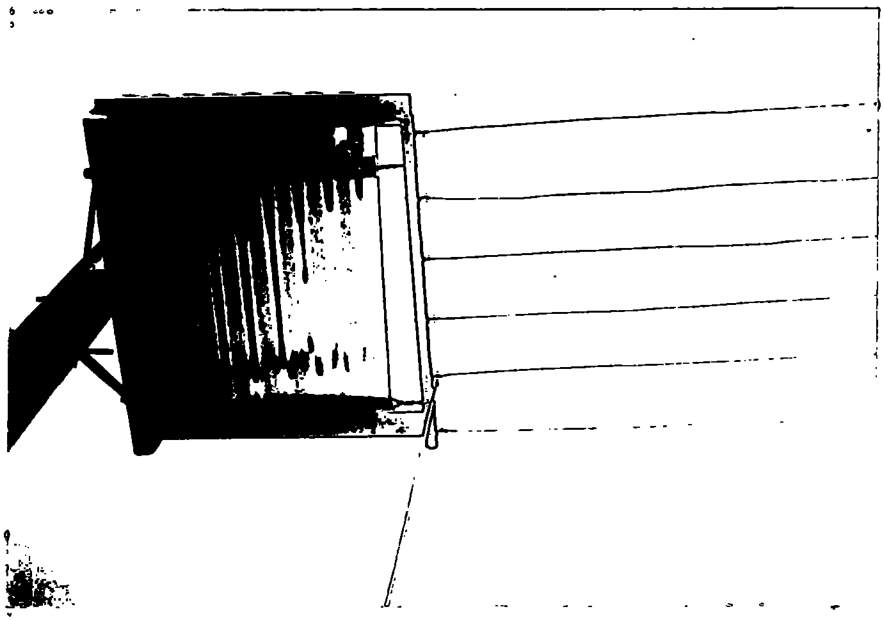
With switch S_1 turned to 'test' switch S_2 is pressed ten times at intervals of 5 seconds whilst slowly rotating the sensitivity control. When the counter operates on alternate presses the instrument is calibrated correctly. In practice it was found to be very difficult to obtain alternate operations. Appendix 3 suggests that out of ten presses any number of counts between three and seven should be accepted. This procedure was adopted at all stations. Since the test voltage is obtained from a fixed tapping on the resistance chain P_1 R_7 R_3 it is dependent upon the voltage of the battery and frequent calibration is therefore necessary.

In practice the above procedure was found to be very difficult since even the slightest movement of the sensitivity control knob could throw the instrument completely out of calibration.

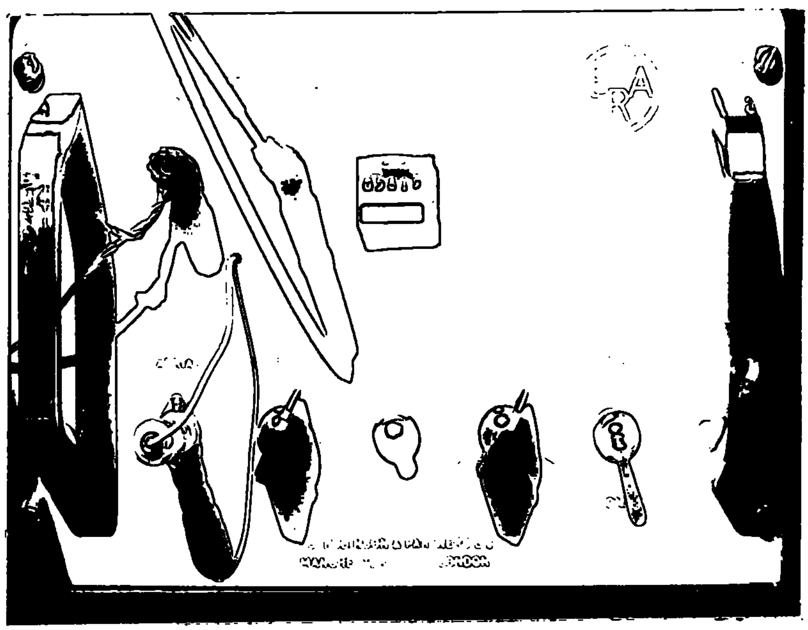
On two occasions the newly erected installation was correctly calibrated at a time when the surrounding air temperature was high, and each time the instrument failed to register nearby lightning occuring during the cooler hours of darkness. On inspection the following morning the counter was found to be under-sensitive. Further work (Appendix 3 page 73) suggests that the E.R.A. Counter is dependent upon temperature and that at a temperature of about 26° C the instrument is unstable and calibration is impossible. For these reasons all counters used in the present survey were calibrated at 0800 hours G.M.T.

FIG. 3. COUNTER INSTALLATION AT ROKUPR

THIS INSTALLATION HAS THE AERIAL PARALLEL TO THE GROUND AND 15' FROM IT. IN ALL OTHER RESPECTS IT IS IDENTICAL TO THE ONE SHOWN IN FIG. 2 PAGE 11.



INSULATED SUPPORT FOR AERIAL SHOWING RAIN SHIELD.



E.R.A. LIGHTNING STROKE COUNTER

FIG. 3. CONT. COUNTER INSTALLATION AT ROKUPR

3.1 LOCATION AND DESCRIPTION OF T.S.D. RECORDING STATIONS

Map Ref.	Station	Lat.N.		Long.W.		Alt. above S.L.	Description of Station
C 1/1	Freetown	8	28	13	16	1100 ft.	Double station
C 1/2	Guma	8	21	13	14	30	Engineering
C 1/3	Lungi	8	38	13	14	83	Meteorological
C 1/4	Kissy	8	28	13	12	10	Medical
C 1/5	Newton	8	20	13	1	40	Agricultural
C 1/6	Hastings	8	23	13	9	50	Missionary
C 1/7	Pepel	8	25	13	4	55	Technical
C 2/1	Masanki	8	18	12	48		Agricultural
B 2/1	Kambia	9	7	12	55	65	Double station
B 2/2	Rokupr	9	1	12	57	26	Agricultural
C 2/2	Rotifunk	8	14	12	40		Medical
C 2/3	Bauya	8	11	12	34		Medical
D 2/1	Bontho	7	31	12	31	10	Meteorological
C 2/4	Marampa	8	41	12	28	200	Technical
B 2/3	Batkanu	9	4	12	24		Postal
D 2/2	Mattru	7	37	12	11	73	School
D 2/3	Luawa	7	37	12	7		School
D 3/1	Kpotema	7	50	11	59		School
D 2/4	Sorabu	7	47	12	1		Medical
C 2/7	Njala	8	6	12	5	167	Double station
C 3/1	Magburaka	8	43	11	56	300	School
C 2/5	Makeni	8	53	12	3	275	Multiple station
C 2/6	Teko	8	49	12	2	270	Government
D 3/2	Pujehun	7	22	11	43	73	Government
D 3/3	Torma Bum	7	27	11	55	30	Agricultural
D 3/4	Bo	7	58	11	45	334	Multiple station
D 3/5	Bumpe	7	54	11	54		School
D 3/6	Tikonko	7	53	11	47		Missionary
E 3/1	Sulima	6	58	11	34	12	Medical
B 3/1	Kabala	9	35	11	33	1522	Double station

D 3/7	Kenema	7	52	11	11	500	School
C 3/2	Dodo	8	9	11	10	1000	Forestry
C 4/3	Segbwema	8	0	10	57	700	Missionary
C 3/3	Wordu	8	37	10	57		School
D 4/1	Daru	7	59	10	50	630	Meteorelogical
D 4/2	Jojoima	7	53	10	47		Missionary
C 4/1	Pondembu	8	6	10	41	640	Agricultural
C 4/2	Sandaru	8	24	10	42	1000	Missionary
C 4/4	Kailahun	8	17	10	34	960	Double station

Table 3. LOCATION AND DESCRIPTION OF T.S.D. STATIONS

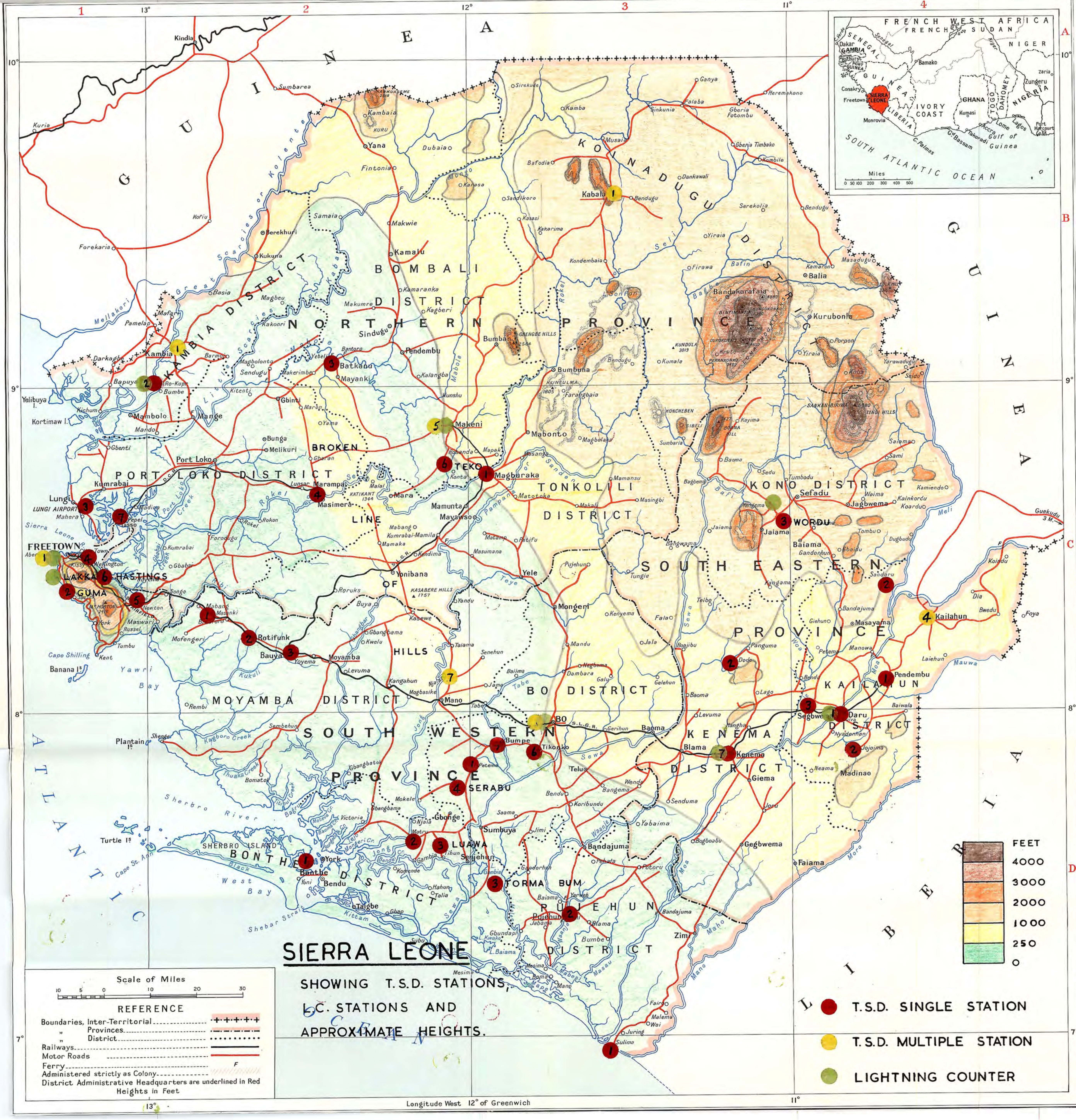
Of the sixty five stations originally in the survey twenty two have sent a complete set of reports for the period January 1963 to December 1964. Twenty six stations have sent insufficient data to be included in this report and the remaining seventeen stations have reported for not less than twenty one months in the two years. In this case the number of T.S.D. in the missing months have been estimated from the figures from nearby stations. Some of the stations which, because of insufficient data, were not included in drawing the isopleths, reported for the first year of the survey. Their T.S.D. total for that year is given in brackets on Fig. 5a page 26a.

The map references given in column 1 above refer to the square numbers on the map shown on page 20.

3.2 LOCATION AND DESCRIPTION OF LIGHTNING COUNTER STATIONS

Station	Lat.N.		Long.W.		Alt. above S.L.	Description of station
Freetown	8	28	13	16	1100 ft.	University College
Yongema	8	39	11	4	1282	Diamond Mines
Bo	7	58	11	45	334	Secondary school
Lakka	8	24	13	15	S.L.	Elec.Eng. residence
Rokupr	9	1	12	57	26	Research station
Makeni	8	53	12	3	275	Agricultural station
Daru	7	59	10	50	630	Army depot
Kenema	7	52	11	11	500	Elec. power station

Table 4. LOCATION AND DESCRIPTION OF LIGHTNING COUNTER STATIONS


SIERRA LEONE
SHOWING T.S.D. STATIONS, L.C. STATIONS AND APPROXIMATE HEIGHTS.
T.S.D. SINGLE STATION
T.S.D. MULTIPLE STATION
LIGHTNING COUNTER
FEET
4000
3000
2000
1000
250
0
Scale of Miles
10 5 0 10 20 30
REFERENCE
Boundaries, Inter-Territorial
" Provinces
" District
Railways
Motor Roads
Ferry
Administered strictly as Colony
District Administrative Headquarters are underlined in Red
Heights in Feet
Longitude West 12° of Greenwich
GUINEA
LIBERIA
ATLANTIC OCEAN
NORTHERN PROVINCE
SOUTH EASTERN PROVINCE
SOUTH WESTERN PROVINCE
KAMBIA DISTRICT
BOMBALI DISTRICT
KOINADUGU DISTRICT
PORT LOKO DISTRICT
TONKOLILI DISTRICT
KONO DISTRICT
KAILAHUN DISTRICT
KENEMA DISTRICT
BO DISTRICT
MOYAMBA DISTRICT
BONTHE DISTRICT
PUJEHUN DISTRICT
FREETOWN
LAKKA
HASTINGS
GUMA
Makeni
TEKO
Magburaka
Kabala
Kailahun
Pendembu
Daru
Kenema
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TORMA BUM
Moyamba
Mano
Segbwema
WORDU
Sefadu
Bonthe
Batkanu
Kambia
Rotifunk
Bauya
Port Loko
Masimera
Sulima
FRENCH WEST AFRICA
FRENCH SUDAN
SOUTH ATLANTIC OCEAN
Gulf of Guinea
GHANA
IVORY COAST
NIGERIA

4. STATEMENT OF RESULTS

4.1. Appendix 1 (Tables), page 42 , Table 8 D, lists the monthly T.S.D. figures for 1963 - 1964 together with the mean values for the same period. The only results which are listed in this table are from stations recording for at least twenty-one months out of the two year period. Where one such station failed to submit a report for any month, an estimated figure has been included and is underlined in the table of T.S.D. This estimation has been made on the basis of the number of T.S.D. reported from nearby stations and from monthly patterns of distribution over the country.

4.2. Many stations reported the time of day during which thunder was heard. If thunder occurred at any time during the hour, this was counted as one T.S. hour. Table 9 , page 46 , tabulates the diurnal variation in the time of thunder heard.

4.3. An estimate of the spread of thunder is made in Table 10 , page 47 . The number of stations reporting thunder on the same day is expressed as a percentage of the total number of stations operating on that day.

4.4. The daily lightning counts are given in Table 11 , pages 48 - 63 .

	J	F	M	A	M	J	J	A	S	O	N	D	RAIN SEASON JUN/OCT	DRY SEASON NOV/MAY	MID RAINS JUL/SEP	PRE & POST RAINS MAY JUN OCT NOV	YEAR TOTAL
FREETOWN	12.9	10.5	19.4	15.0	42.0	73.4	32.2	17.8	40.0	61.3	58.4	19.4	46.9	25.4	30.0	58.8	33.5
GUMA	6.5	3.5	1.6	0	25.8	31.6	14.5	8.1	21.6	30.6	15.0	9.7	21.3	8.7	14.7	25.8	14.0
LUNGI	4.8	7.6	8.1	15.0	61.3	68.4	38.7	17.8	53.4	66.1	71.6	17.8	48.9	26.6	36.7	66.9	35.9
KISSI	9.7	7.6	14.5	15.0	54.9	40.0	29.0	12.9	25.0	29.0	28.3	12.9	27.2	20.4	22.3	38.1	23.2
NEWTON	6.5	12.3	22.6	23.4	51.6	41.7	17.8	21.0	43.4	45.1	63.4	14.5	33.8	27.8	27.4	50.5	30.3
HASTINGS	1.6	1.8	8.1	5.0	29.0	41.7	8.1	14.5	13.3	33.8	25.0	12.9	22.3	11.3	12.0	32.4	16.2
PEPEL	6.5	10.5	9.7	13.3	53.3	58.4	46.8	21.0	30.0	53.3	53.4	12.9	41.9	22.8	32.6	54.6	30.8
MASANKI	16.1	15.8	32.2	36.6	53.3	73.4	48.4	56.5	56.6	71.0	66.6	22.6	61.2	34.7	53.8	66.1	45.8
KAMBIA	4.8	7.0	17.8	13.3	61.3	66.6	42.0	22.6	55.0	66.1	48.3	16.1	50.5	24.5	39.9	60.6	35.1
ROKUPR	3.2	0	9.7	25.0	67.7	81.6	35.5	25.8	73.4	79.0	65.0	21.0	59.1	27.4	44.9	73.3	40.6
ROTIFUNK	6.5	8.8	22.6	28.3	62.9	73.4	30.6	24.2	46.6	69.3	58.4	16.1	48.8	29.1	33.8	66.0	37.3
BAUYA	8.1	10.5	17.8	21.6	51.6	46.6	21.0	12.9	35.0	32.2	21.6	3.2	29.5	19.2	23.0	38.0	24.3
BONTHE	8.1	21.1	29.0	25.0	82.1	65.0	24.2	19.4	40.0	66.1	66.6	38.7	42.9	38.7	27.9	70.0	41.9
MARAMPA	3.2	8.8	22.6	21.6	29.0	46.6	16.1	1.6	33.3	33.8	31.6	1.6	26.3	16.9	17.0	35.3	20.8
BATKANU	4.8	1.8	19.4	26.6	61.3	70.0	45.1	33.8	53.4	61.3	48.3	6.5	52.7	24.1	44.1	60.2	36.0
MATTRU	3.2	12.3	21.0	10.0	53.3	61.6	16.1	24.2	28.3	16.1	30.0	3.2	29.3	19.7	22.9	40.3	23.3
LUAWA	8.1	22.8	27.4	26.6	43.5	36.6	58.0	46.8	48.3	50.0	50.0	12.9	47.9	27.3	51.0	45.0	35.9
KPETEMA	4.8	17.6	17.8	13.3	33.8	38.4	21.0	16.1	18.3	46.8	18.3	3.2	28.1	15.5	18.5	34.3	20.8
SERABU	4.8	19.3	22.6	13.3	35.5	43.4	11.3	4.8	35.0	53.3	43.4	21.0	29.6	22.8	17.0	43.9	25.6
NJALA	8.1	14.0	12.9	28.3	50.0	45.0	30.6	21.0	38.4	33.8	35.0	12.9	33.8	23.0	30.0	41.0	27.5
MAGBURAKA	12.9	17.6	32.2	25.0	33.8	41.7	22.6	24.2	18.3	40.4	43.4	4.8	29.4	24.2	21.7	39.8	26.4
MAKENI	6.5	26.3	25.8	25.0	54.9	45.0	21.0	25.8	45.0	80.6	56.6	12.9	43.5	29.7	30.6	59.3	35.5
TEKO	6.5	14.0	53.3	38.4	85.5	46.6	45.1	33.8	55.0	59.6	48.3	14.5	48.0	37.2	44.6	60.0	41.7
PUJEHUN	6.5	7.6	29.0	36.6	66.1	61.6	33.8	14.5	36.6	74.1	66.6	27.4	44.1	34.3	28.3	67.1	37.5
TORMA BUM	6.5	10.5	22.6	20.0	46.8	43.4	24.2	21.0	33.3	40.4	33.3	19.4	32.5	22.7	26.2	41.0	26.8

Tablo 5. % T.S.D. / MONTH and SEASONAL - Average 1963 - 1964

	J	F	M	A	M	J	J	A	S	O	N	D	RAIN SEASON JUN/OCT	DRY SEASON NOV/MAY	MID RAINS JUL/SEP	PRE & POST RAINS MAY JUN OCT NOV	YEAR TOTAL
BO	9.7	28.1	50.0	43.4	80.6	80.0	53.3	25.8	66.6	87.0	71.6	27.4	62.5	44.4	48.6	79.8	51.9
BUMPE	4.8	15.8	24.2	18.3	38.7	48.3	24.2	6.5	20.0	42.0	41.7	0	28.2	20.5	16.9	42.7	23.7
TIKONKO	6.5	24.6	42.0	28.3	58.0	61.6	33.8	12.9	41.7	80.6	43.4	16.1	46.1	21.3	29.5	60.9	37.5
SULIMA	0	0	8.1	5.0	43.5	28.3	9.7	8.1	21.6	38.7	43.4	25.8	39.3	17.3	13.1	38.5	19.4
KABALA	9.7	8.8	24.2	38.4	61.3	76.6	56.5	24.2	61.6	67.7	30.0	11.3	57.3	26.2	47.4	58.9	42.5
KENEMA	9.7	38.6	29.0	38.4	80.6	63.4	46.8	30.6	43.4	61.3	41.7	19.4	49.1	36.8	40.3	61.8	41.9
DODO	11.3	17.6	27.4	43.4	45.1	40.0	43.5	48.4	38.4	54.9	43.4	22.6	45.0	30.1	43.4	45.9	36.3
SEGBWEMA	11.3	21.1	30.6	23.4	62.9	46.6	33.8	16.1	46.6	50.0	38.4	17.8	38.6	29.4	32.2	49.5	33.2
WORDU	11.3	14.0	30.6	21.6	50.0	46.6	38.7	27.4	58.4	67.7	51.6	17.8	47.8	28.1	41.5	54.0	36.3
DARU	12.9	36.8	50.0	35.0	79.0	75.0	51.6	30.6	63.4	80.6	55.0	24.2	60.2	41.8	48.5	72.4	49.5
JOJOIMA	8.1	40.4	42.0	21.6	38.7	38.4	30.6	17.8	55.0	48.4	40.0	17.8	38.0	29.8	34.5	41.4	33.2
PENDEMBU	14.5	21.1	35.5	26.6	62.9	68.4	79.0	87.0	76.6	69.3	36.6	24.2	76.1	31.6	80.9	59.3	50.1
SANDARU	14.5	42.1	58.0	41.7	67.7	61.6	43.5	22.6	48.3	74.1	48.3	27.4	50.0	42.8	38.1	62.9	45.9
KAILAHUN	14.5	38.6	38.7	33.3	58.0	46.6	24.2	9.7	48.3	74.1	46.6	25.8	40.6	36.5	27.4	56.3	38.2
												MEAN %	42.5	26.8	33.2	52.5	33.4
												SPREAD	21.3 to 76.1	11.3 to 44.4	12.0 to 80.9	25.8 to 79.8	14.0 to 51.9

Table 5 cont. % T.S.D. / MONTH and SEASONAL - Average 1963 - 1964

	RAIN SEASON JUN/OCT		DRY SEASON NOV/MAY		MID RAINS JUL/SEP		PRE & POST RAINS MAY JUN OCT NOV		YEAR TOTAL	
FREETOWN	27991 103	272	7550 68	111	18909 56	338	14536 92	158	35541 171	208
BO	14082 112	126	25649 93	276	3508 67	52	24050 92	262	39731 205	194
LAKKA			12853 70	184			15740 66	238	19370 87	222
ROKUPR	701 42	17	1027 42.5	24					1728 84.5	204
DARU	37840 105	360	37122 75	495	9598 55	174	47668 78	612	74962 180	416
KENEMA	8456 60	141	1835 65	3	2450 35	70			10291 125	82
YENGEMA	16395 96.5	170	13382 111	121	6696 50.5	133	17586 88	200	29777 207.5	145
MEAN		204		189		156		287		200

Table 6. SEASONAL LIGHTNING COUNT / T.S.D. Average 1963–1964

KEY

TOTAL L.C. TOTAL T.S.D.	L.C. T.S.D.

5. DISCUSSION OF RESULTS AND DISTRIBUTION OF THUNDERSTORMS

5.1. GEOGRAPHICAL DISTRIBUTION OF ANNUAL TOTALS

a. All parts of Sierra Leone experience a high incidence of thunderstorm days. The highest mean count for the period under review was 190 at BO, whilst the lowest mean count was 52 at GUMA. Two stations reported over 50% of the days of the year as T.S.D., a further seven stations over 40% T.S.D., seventeen stations over 30% T.S.D., eleven stations over 20% T.S.D. and two stations over 10% T.S.D. The highest individual annual total was 197 at TEKO in 1963. That these figures are high will be appreciated when they are compared with the annual means taken from some of the world's major cities, (Fig. 5).[2]

	T.S.D.	%		T.S.D.	%
CALCUTTA	90	25	SYDNEY	28	7.7
SAIGON	84	23	HAMBURG	23	6.3
BANGKOK	58	15.9	ROME	21	5.8
BUENES AIRES	39	10.7	LONDON	16	4.4
CHICAGO	37	10.1	TOKYO	13	3.5
NEW YORK	31	8.5	CAIRO	3	0.8

FIG. 5. ANNUAL MEAN T.S.D. FOR SOME MAJOR CITIES

5.1.
b. With results available for only two years, it is not possible to draw with any accuracy isoceraunic lines showing places of equal number of thunderstorm days by using mean T.S.D. figures. Observations over a much longer period of time would be needed before this could be done. A more reliable guide to the geographic distribution of thunderstorms is achieved by using the rank order, based on mean T.S.D. figures, to draw the isopleths and to take the mean values of T.S.D. for the

stations falling on or near each line for the magnitude of the line. The map of these isopleths is shown in Fig. 5a , page 26a . The individual mean number of T.S.D. for each station is shown alongside of the station.

There are two areas of high thunderstorm incidence following lines running in a general direction of north-south. The first is along a line passing through ROKUPR, MASANKI and BONTHE. Rokupr, in the north, is adjacent to the RIVER SCARCES, MASANKI is in an area having many rivers and BONTHE, being on SHERBRO ISLAND, is also surrounded by changes of land/water surface.

The second high line is in the east of the country, passing through SANDARU, DARU, south of PENDEMBU, following the line of the MOA RIVER. The lowest isopleth is that passing through GUMA, KISSI and HASTINGS. These are all low lying areas, at the foot of the COLONY HILLS, and on, or near, the coast. Thunder from more distant storms will not be heard at these stations. Whilst FREETOWN is not very distant from any of these places, the Freetown observation post is on the HAVELOCK PLATEAU at a height of 1100 ft. and so distant thunder is more easily heard. This difference between adjacent sites underlines the difficulty in assessing thunderstorm activity using the T.S.D. method.

Moving to the east from Freetown, the number of T.S.D. decreases beyond the Colony Hills but begins to increase as the area of rivers and wet ground is reached. It decreases again over the lower, drier, middle part of the country and then increases once again as the hills

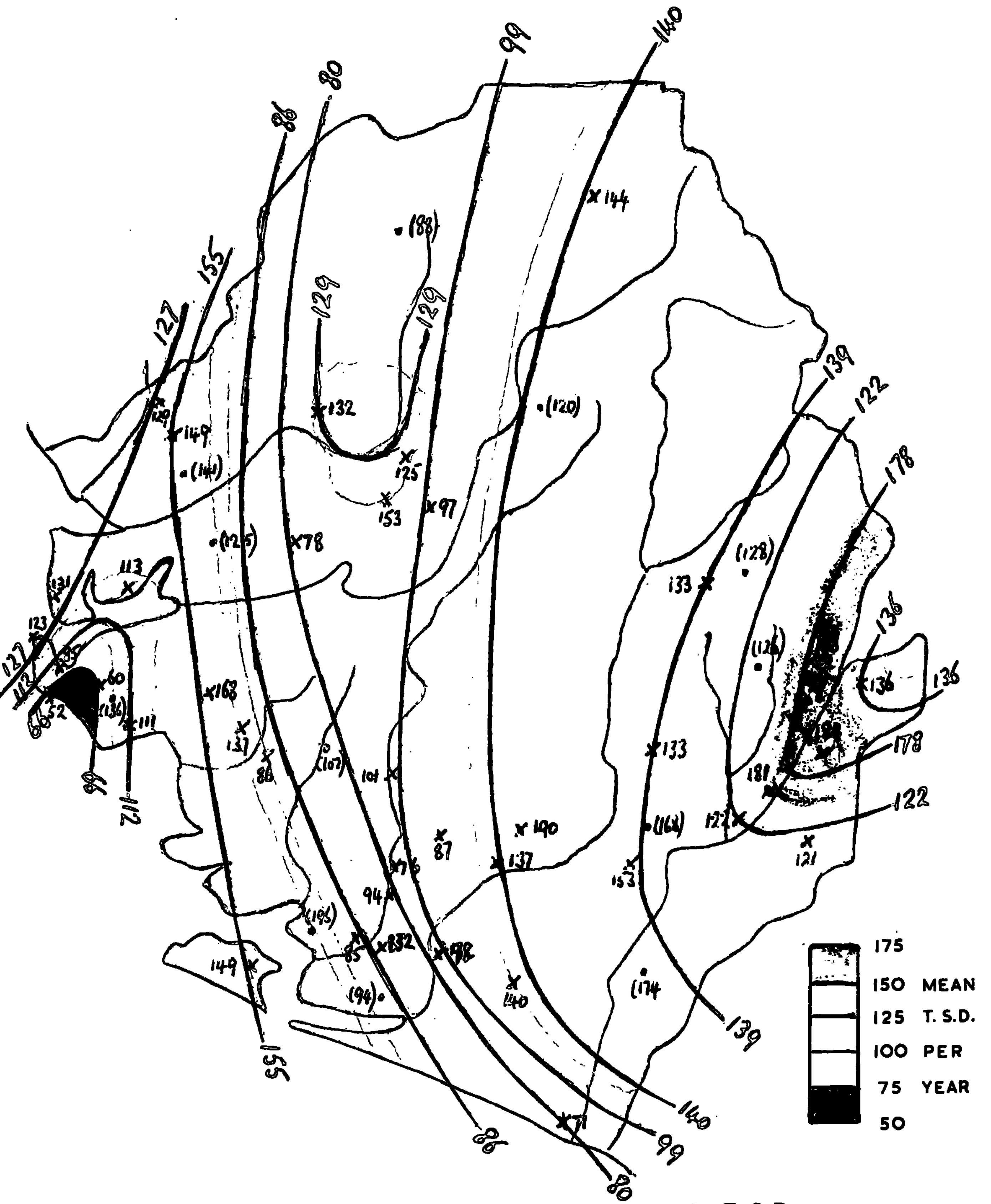


FIG. 5A. ISOPLETHS OF MEAN ANNUAL T.S.D.

of the east are reached beyond BO. Thunderstorm incidence is high to the east of the TINGI HILLS and in the area of the LOMA MOUNTAINS in the north east. Since this area is scarcely populated, it is difficult to obtain reliable T.S.D. records.

Although none of the lightning counters was operating for the whole of the period under review, Table 6 , page 24 , shows that DARU has the highest lightning count per thunderstorm day (L.C./T.S.D.) figure whilst FREETOWN, BO, LAKKA and ROKUPR have a similar, but lower, L.C./T.S.D. rate. This would suggest that the thunderstorms are both more frequent and more intense in the eastern part of the country.

5.1.
c. One other difference between the east and the west of the country is shown in Figs. 6 and 7 , pages 28 and 29 . The monthly variation in the west (marked A in Fig. 6) is of the general pattern illustrated in Fig. 7 A . The number of T.S.D./month is lowest in January and increases to a maximum in June, whilst in the east, Fig. 7 B , the first maximum is reached in MAY. A general minimum is reached in August with a second maximum in October. The generally higher December T.S.D. figures for stations in Zone B suggest that the rains and thunderstorms end later in the eastern part of the country than in the west.

5.2. SEASONAL VARIATION IN DISTRIBUTION OF THUNDERSTORMS

Sierra Leone has two distinct seasons, the dry season from November to May, and the wet (or rain) season for the rest of the year. From

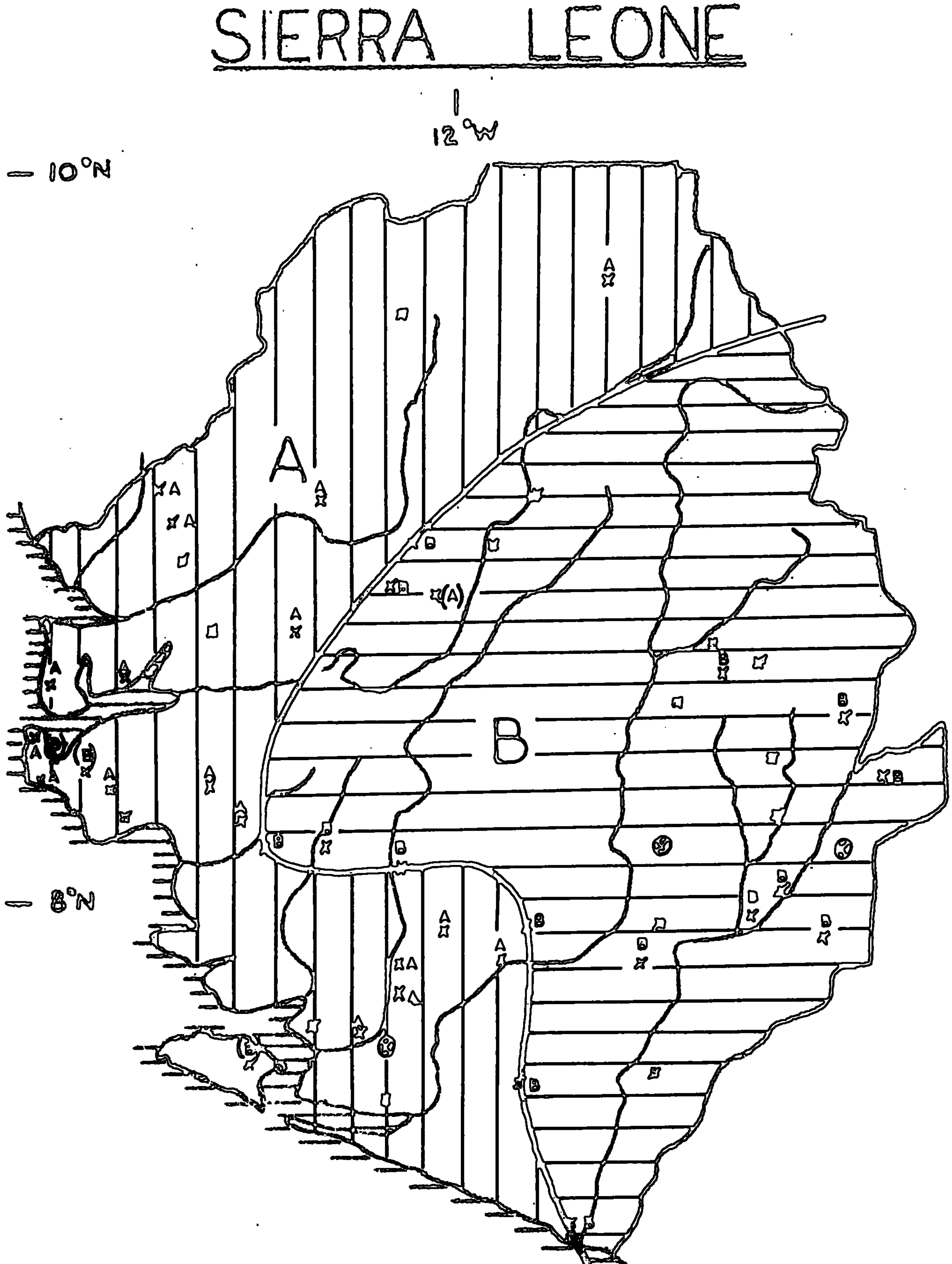


Fig.6. ZONES OF MAXIMUM T.S.D.

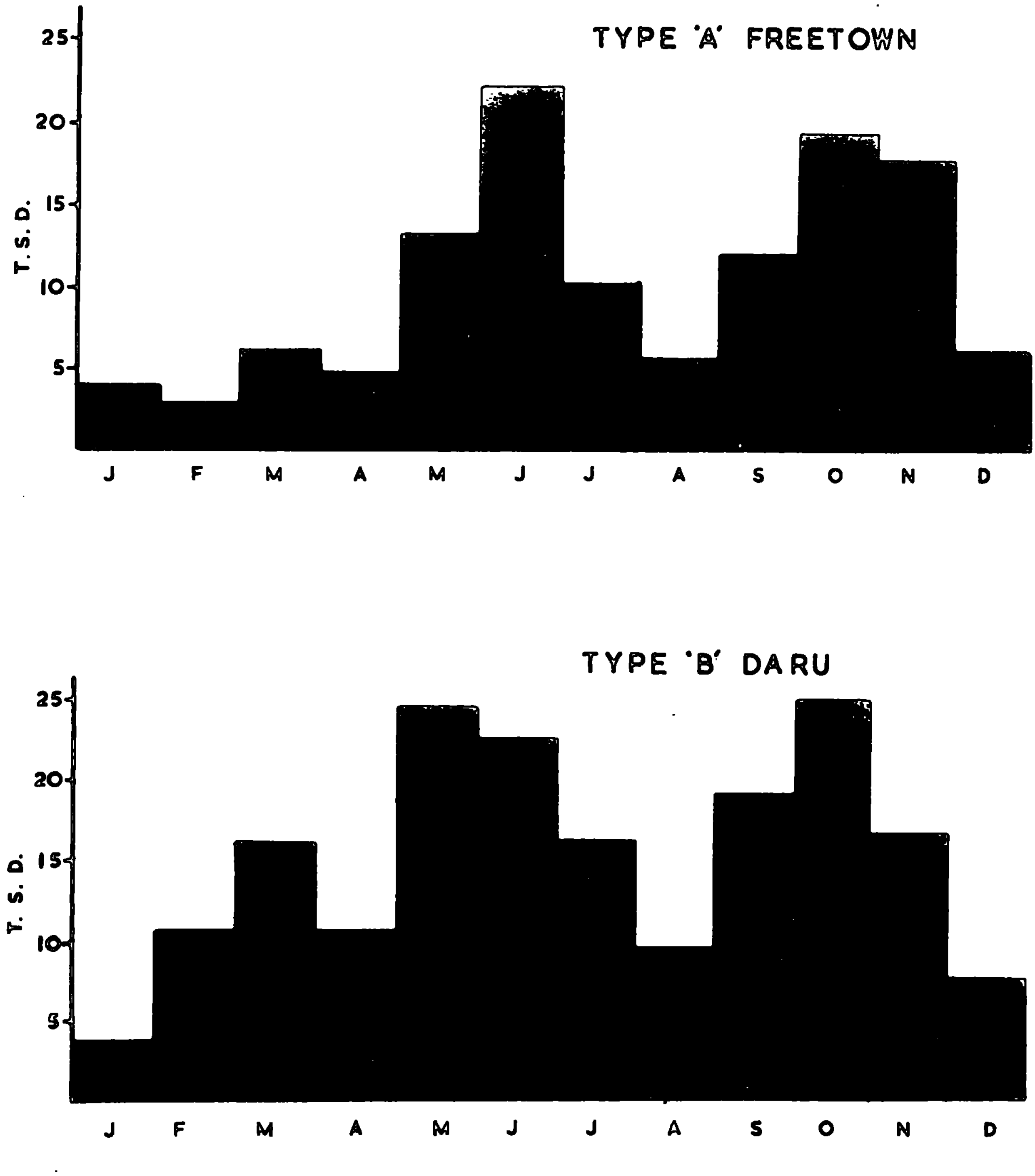


FIG. 7. TWO TYPES OF ANNUAL VARIATION IN T.S.D.

a total annual rainfall of 157 ins., for Freetown, 132 ins. fall during the months June to October (11).

5.2. JANUARY - MAY (DRY SEASON)

a. This is the part of the year with the lowest number of thunderstorms. The mean value for the country is 26.8% T.S.D. with a range of 11.3% to 44.4% for individual stations. When storms occur they are not generally widespread, having a mean spread of 28.7% of stations recording thunder on any single day. Thunder is heard most frequently in the later hours of the day, with the maximum rate of thunder heard during any single hour occurring between 1900 - 2000 hrs. and 2100 - 2200 hrs. G.M.T. Relatively high rates are recorded during the early hours of the morning during the first months of the year. The mean L.S./T.S.D. for the whole of the dry season (November - May) is 189.

JANUARY has the lowest incidence of thunder (8.1% T.S.D.) of any part of the year. The few storms which do occur are generally late at night (maximum 2100 - 2200 hrs.) or in the early hours of the morning (0300 - 0400 hrs.); they are more frequent in the latter part of the month and are often localised storms. 80% of these storms have a spread of less than 10%. One or two storms are both widespread (60 - 69 %) and heavy (mean L.C./T.S.D. 203) and are known locally as the 'bush-washing' storms. They are more frequent in the up-country area (Zone B) and local farmers will await the arrival of these storms before starting to cut down the bush in preparation for the season's planting.

FEBRUARY, MARCH & APRIL have increasing numbers of thunderstorm days, becoming more widespread and occurring earlier in the day (maximum 1900 - 2100 hrs.). Rainfall figures indicate that many of these days when thunder is heard are days without rain. It is during this period when thunder will be heard for a very brief period during the afternoon or early evening without any rain falling. The L.C./T.S.D. is low for February (97) but increases in March (155) and April (256).

MAY shows a sharp increase in the incidence of thunder, having a mean value for the country of 54.1% T.S.D. The storms are now more widespread with 1.6% of days having thunder reported from over 90% of the recording stations, and are occurring earlier in the day (maximum 1700 - 1800 hrs.). It has already been said that the eastern part of the country (Zone B) reaches its maximum incidence of thunder during this month. Rain is becoming more frequent (Freetown mean for May 7 ins.) and many of the thunderstorms are very intense with heavy rainfall. The mean L.C./T.S.D. for May is 256 with individual day counts as high as 2540 recorded at DARU.

5.2. JUNE - OCTOBER (RAIN SEASON)

b. This is the season when rain becomes more widespread and continuous. 84% of Freetown's annual rainfall occurs during this period. Thunderstorms are becoming less frequent and reaching a minimum for all stations in August (23.2% T.S.D.). Thunder is heard earlier in the day with a maximum rate between 1700 - 1800 hrs. and a minimum rate between 0400 - 0600 hrs. When thunderstorms do occur they are more widespread than in the dry season, having a mean spread of 43% with a maximum spread of 94% and a minimum spread of 3%. Thus, from the results of this survey, it would appear that thunder is heard on every day during this season at one or more stations. The mean L.C./T.S.D. for the season is 204.

It is in <u>JUNE</u> that the western half of the country (Zone A) has its maximum incidence of thunderstorms whilst the number of T.S.D. in Zone B is still high. This is responsible for the high mean value of T.S.D. over the whole country for this month (54.4% T.S.D.). The storms are severe (L.C./T.S.D. 282, with a maximum individual day count of 2181 at DARU) and widespread. Over 63% of days in June have thunder reported from more than 50% of the recording stations.

<u>JULY & AUGUST</u> have the maximum rainfall but a low number of thunderstorm days (July 33.6% T.S.D., August 23.2% T.S.D.). The storms are not widespread nor severe (L.C./T.S.D., July 92, August 103). It is during July that the thunder is heard at the earliest times of the day with a maximum rate between 1600 - 1800 hrs.

During <u>SEPTEMBER & OCTOBER</u> the T.S.D. rate increases to a second maximum (56% T.S.D.) in October as the wet season ends. Severe storms are experienced especially towards the end of October. Daily lightning counts of over 1400 have been recorded in Zone B.

5.2. NOVEMBER - DECEMBER (DRY SEASON)

c. These two months show a marked decrease in rainfall but a high incidence of thunder in November and early December. This thunder is again of the 'dry season' type being generally more localised (in December 59.6% of thunder is reported from less than 10% of the recording stations), occurring later in the day (9.8% of the December thunder is heard between 0400 - 0500 hrs.) and being less intense. The mean L.C./T.S.D. for December is the lowest for any month of the year (81). Although the mean T.S.D. for December (16.3% T.S.D.) is higher than that for January (8.1% T.S.D.), the severe bush-washing storms of January do not happen in December.

The normal division of seasons into 'wet' and 'dry' obscures the real pattern of thunderstorm activity in Sierra Leone. May and November are both dry season months but include some of the heaviest thunderstorms of the year. This becomes more apparent if two further sub-seasons are considered.

5.2. MAY, JUNE, OCTOBER & NOVEMBER (PRE & POST RAINS)

d. The wet season begins and ends with severe thunderstorms. During this period the mean number of thunderstorm days is 52.5% T.S.D. (range 25.8% - 79.8%), the mean spread is 54% of stations recording / day and the mean L.C./T.S.D. is 287. It is during this period that the very high daily lightning counts are observed.

MAY	1424,	1940,	2540,	
JUNE	1855,	2181,		
OCTOBER	1496			all recorded at DARU
NOVEMBER	1339			recorded at LAKKA

5.2. JULY - SEPTEMBER (MID RAINS)

e. Although the rain season as a whole has a fairly high incidence of thunderstorms, the period in the middle of the season, July - September, is low in thunderstorms. The mean number of Thunderstorm days is 33.2% T.S.D., the mean spread is only 33.7% and the mean L.C./T.S.D. 156. None of the very high daily counts are recorded during this period.

5.3. SUMMARY

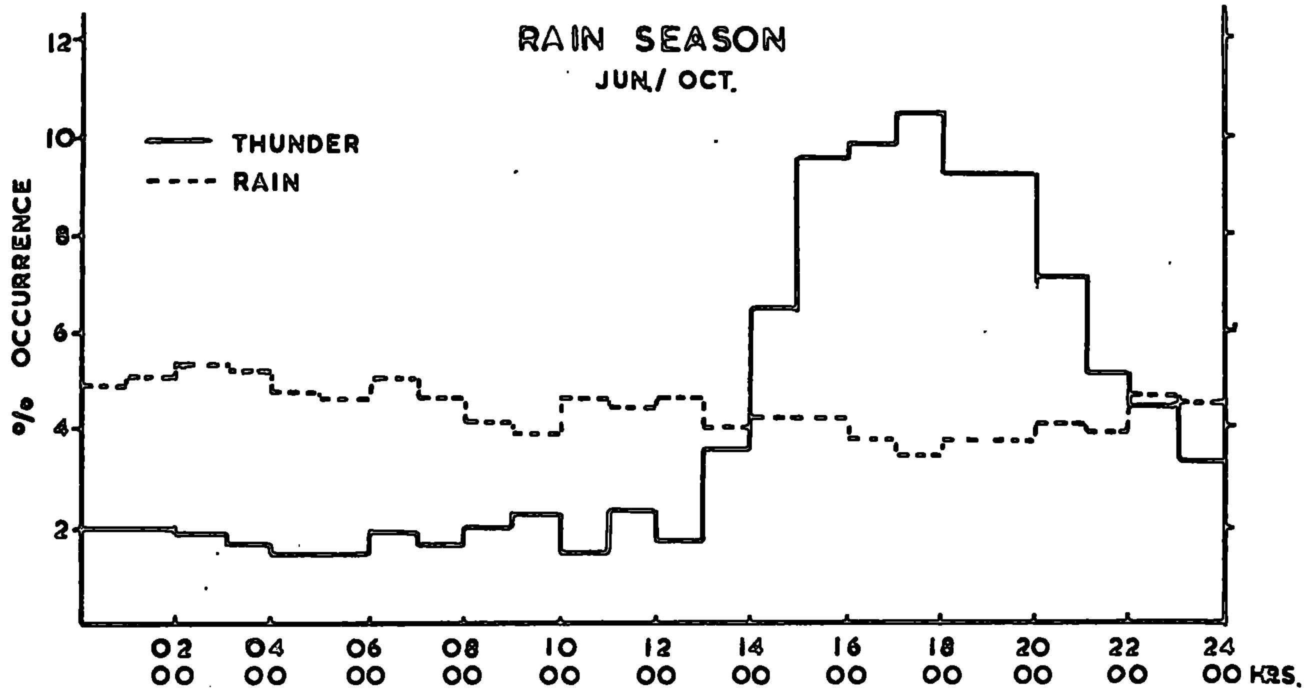
Whilst it must be stressed that the present survey has been carried out over too short a period for any statistically reliable results to be given, the pattern of the thunderstorm season is clear. A few severe storms - the bush-washing storms - occur in January, especially in the eastern hilly area. The incidence of thunder increases in frequency and intensity from a low value in February to a maximum value in May in the east or June in the west, at the beginning of the wet season. Thunder is heard progressively earlier in the day during this period. A sudden decrease in thunderstorms coincides with the main rains of July and August, but the frequency increases to a second maximum in October, at the end of the wet season. The end-of-rains storms again appear later in the day.

This pattern of thunderstorm activity can be associated with the movement of the I.T.C. and the five weather zones of West Africa suggested by Walker [12].

In the dry season the I.T.C. is furthest south and Sierra Leone appears to be within zone A/B. In January zone A covers the country, bringing with it the Harmattan. In February and March the I.T.C. has begun to move northwards and zone B brings with it the possibility of thunder occurring during the afternoon or evening - with or without rain. During May and June zone C has moved over the country and the heavy thunderstorms are associated with disturbance lines. In the wet season zone D brings with it continuous rain. Walker's zone E appears not to influence the climate in Sierra Leone.

5.4. DIURNAL VARIATION IN TIME OF THUNDER HEARD

The diurnal variation in the time at which thunder is heard is compared with that for rainfall in Fig. 8 , pages 36 & 37 [13].
The thunder lines strengthen the view that thunder in the dry season is generally heard later in the day or in the early hours of the morning. Also during this season the maximum time for thunder heard coincides with the time of minimum rainfall. This is characteristic of the presence of Walker's zone B. The relatively high figures for both thunder and rain in the early hours of the morning during the dry season also illustrates the occurrence of heavy thunderstorms with heavy rain.
The graphs for the Pre & Post Rains period show that thunder is



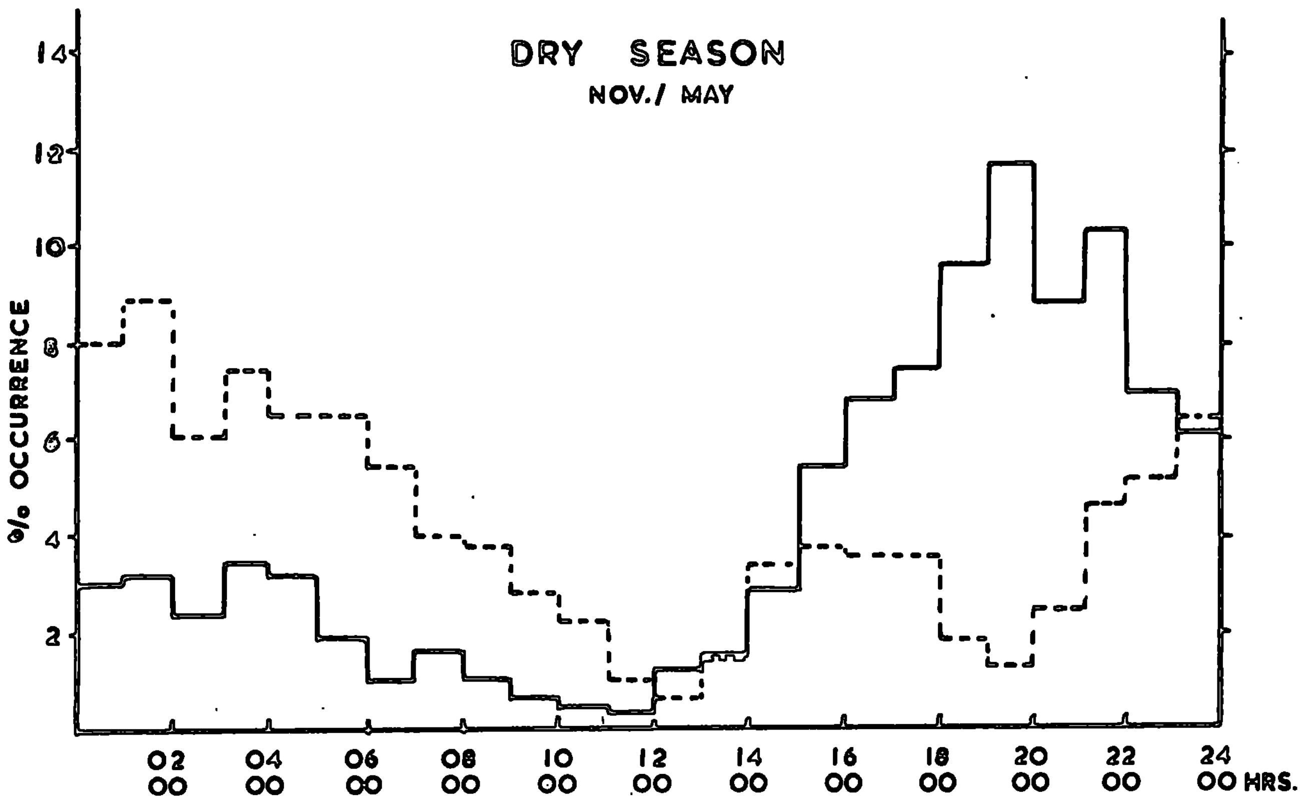
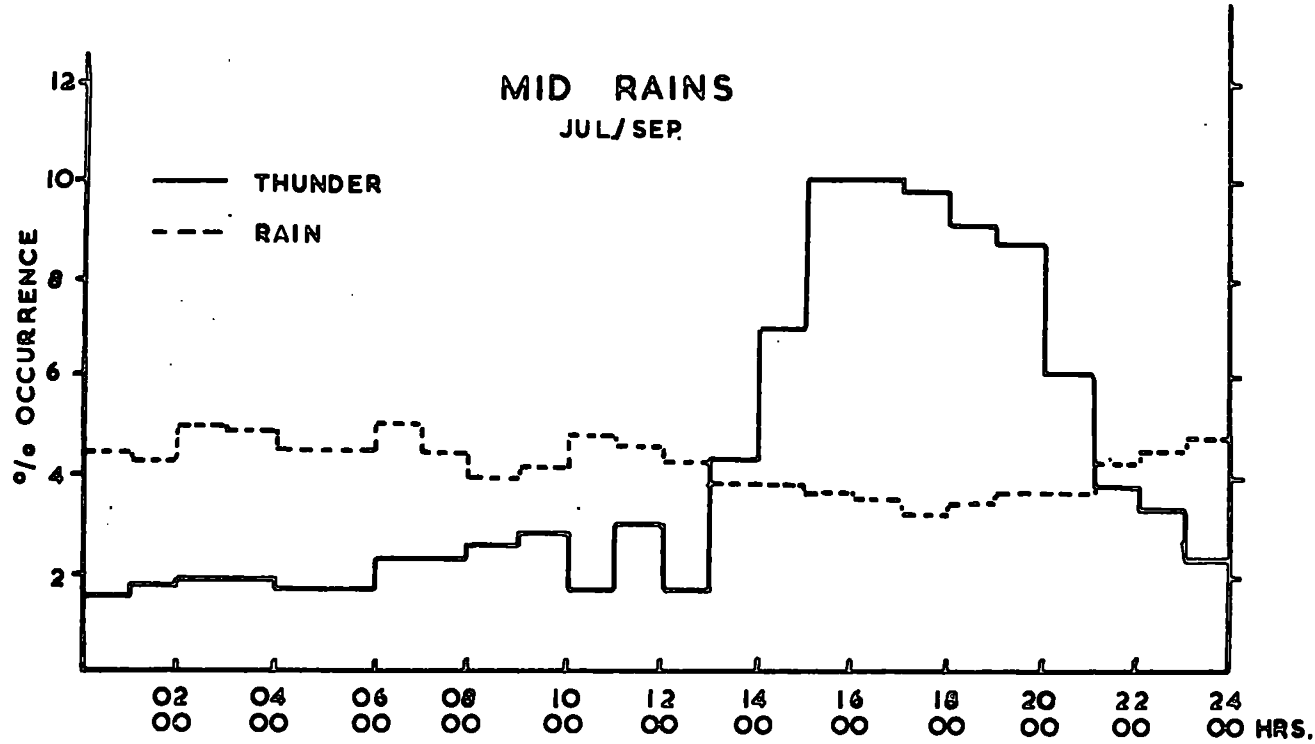


FIG. 8 DIURNAL VARIATION IN THUNDER & RAIN



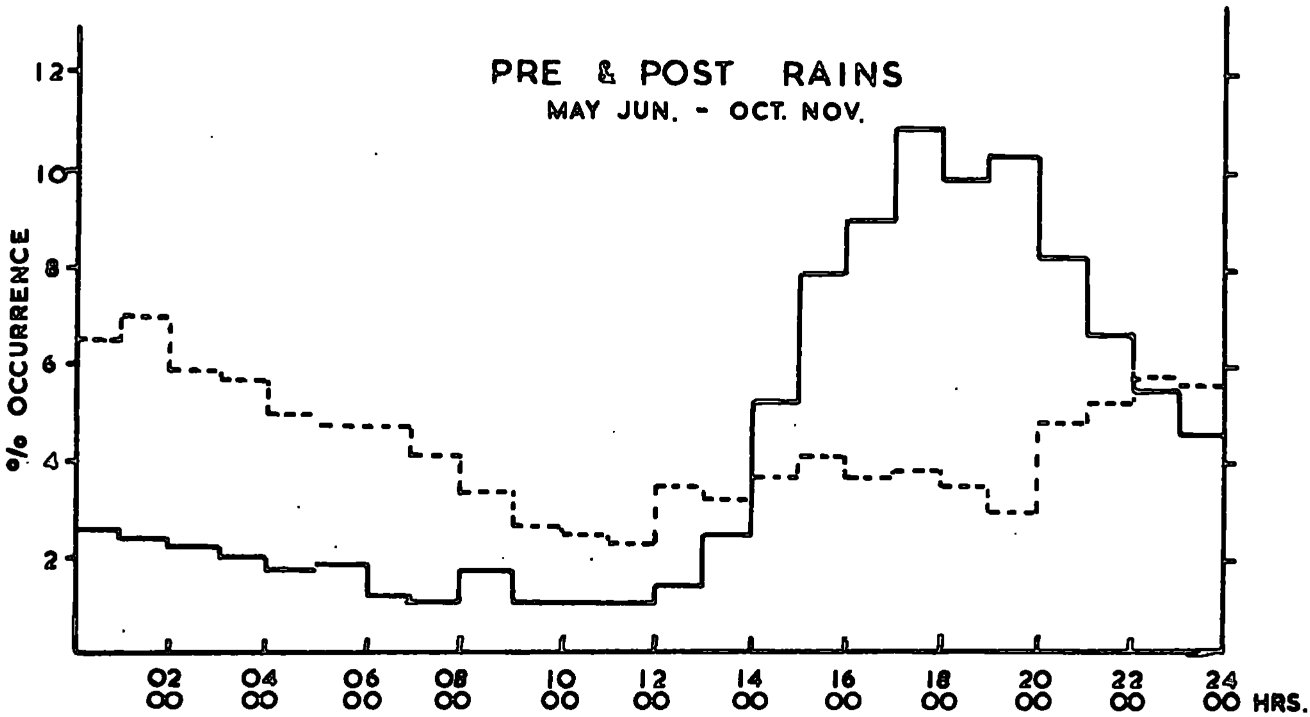


FIG. 8 CONT. DIURNAL VARIATION IN THUNDER & RAIN

		NUMBER OF T.S.D. %			SPREAD %			TIME G.M.T.	
		mean	max.	min.	mean	max.	min.	max.	min.
YEAR		33.4	51.9	14.0	34.7	94	0	1700 - 1800 1900 - 2000	1000 - 1100
RAIN SEASON	JUN/OCT	42.5	76.1	21.3	43.0	94	3	1700 - 1800	0400 - 0600 1000 - 1100
DRY SEASON	NOV/MAY	26.8	44.4	11.3	28.7	92	0	1900 - 2000 2100 - 2200	1100 - 1200
MID RAINS	JUL/SEP	33.2	80.9	12.0	33.7	93	3	1500 - 1700	0500 - 0600 1000 - 1100
PRE & POST RAINS	MAY JUN OCT NOV	52.5	79.8	25.8	54.0	94	2	1700 - 1800	0900 - 1200

Table 7. SUMMARY OF SEASONAL PARAMETERS Average 1963 - 1964

heard in the early evening before the heavy rain storms are occurring. The thunderstorms with heavy rain are frequent during the period 2000 - 2200 hrs. with rain persisting after the cessation of the thunder.

6. FUTURE WORK

6.1. If lightning count and thunderstorm figures for Sierra Leone are to be as reliable as those for other parts of the world, they must be collected for a longer period of time. The Sierra Leone Meteorological Department has only a few official meteorological stations, and so it is essential that the observers used in this survey be organised to continue their recordings.

6.2. Some improvement in the design of the E.R.A. Lightning Counter is necessary. The calibration procedure is too difficult for the type of operator found in a country like Sierra Leone. At the same time, it would be advantageous if some method of ionising the valve could be found which would not be a heavy drain on the batteries.

Since the E.R.A. counter is responsive to both cloud - to - cloud and cloud - to - ground lightning strokes, it would be valuable if a member of MALAN counters [14], which record only cloud - to - ground strokes, could be put into operation in Sierra Leone. From a very limited number of visual counts the present author estimates that only one or two out of every ten lightning strokes are from cloud to ground.

6.3. It is clear that the lightning counters are registering on days when thunder is not reported from any station near the counter. If the number of T.S.D. stations could be increased, especially in areas surrounding the counter sites, these spurious counts might be partly explained. But it is felt that there are other factors influencing the counter. On two occasions the onset of the Harmattan was preceded by four or five days when the counters recorded a low number of counts (see L.C. figures for Freetown, December 21st to 24th and Rokupr, December 24th to 28th 1963).

Further investigations are needed to determine the source of these and other counts not associated with thunder.

	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
REETOWN	6	6	7	8	16	19	12	10	17	15	17	2	135
	2	0	5	1	10	25	8	1	7	23	18	10	110
	4	3	6	4.5	13	22	10	5.5	12	19	17.5	6	122.5
UMA	3	2	1	0	6	7	7	4	7	7	2	1	47
	1	0	0	0	10	12	2	1	6	12	7	5	56
	2	1	0.5	0	8	9.5	4.5	2.5	6.5	9.5	4.5	3	51.5
UNGI	3	3	5	7	19	20	15	10	20	14	22	2	140
	0	0	0	2	19	21	9	1	12	27	21	9	121
	1.5	1.5	2.5	4.5	19	20.5	12	5.5	16	20.5	21.5	5.5	130.5
ISSY	4	3	8	6	17	16	10	7	7	5	7	2	92
	2	0	1	3	17	8	8	1	8	13	10	6	77
	3	1.5	4.5	4.5	17	12	9	4	7.5	9	8.5	4	84.5
EWTON	4	5	11	8	19	18	4	11	19	15	25	2	141
	0	2	3	6	13	7	7	2	7	13	13	7	80
	2	3.5	7	7	16	12.5	5.5	6.5	13	14	19	4.5	110.5
ASTINGS	1	1	5	2	10	12	3	7	3	9	7	2	62
	0	0	0	1	8	13	2	2	5	12	8	6	57
	0.5	0.5	2.5	1.5	9	12.5	2.5	4.5	4	10.5	7.5	4	59.5
EPEL	4	6	6	6	14	13	17	6	8	7	15	1	103
	0	0	0	2	19	22	12	7	10	26	17	7	122
	2	3	3	4	16.5	17.5	14.5	6.5	9	16.5	16	4	112.5
ASANKI	4	2	9	10	15	21	23	21	19	17	17	9	167
	6	7	11	12	18	23	7	14	15	27	23	5	168
	5	4.5	10	11	16.5	22	15	17.5	17	22	20	7	167.5
AMBIA	3	2	4	3	18	16	14	11	15	15	13	2	116
	0	2	7	5	20	24	12	3	18	26	16	8	141
	1.5	2	5.5	4	19	20	13	7	16.5	20.5	14.5	5	128.5
OKUPR	2	0	3	5	16	20	14	1	17	18	13	3	112
	0	0	3	10	26	29	8	15	27	31	26	10	185
	1	0	3	7.5	21	24.5	11	8	22	24.5	19.5	6.5	148.5
OTIFUNK	4	5	10	10	20	19	12	12	18	15	12	3	140
	0	0	4	7	19	25	7	3	10	28	23	7	133
	2	2.5	7	8.5	19.5	22	9.5	7.5	14	21.5	17.5	5	136.5
AUYA	4	6	9	5	11	12	7	6	11	9	4	2	86
	1	0	2	8	21	16	6	2	10	11	9	0	86
	2.5	3	5.5	6.5	16	14	6.5	4	10.5	10	6.5	1	86

Table 8. THUNDERSTORM DAYS - MONTHLY & ANNUAL TOTALS 1963 - 1964

	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
BONTHE	5	10	14	12	25	20	10	11	18	14	19	9	167
	0	2	4	3	26	19	5	1	6	27	21	15	129
	2.5	6	9	7.5	25.5	19.5	7.5	6	12	20.5	20	12	148
MARAMPA	2	5	10	8	9	13	5	1	8	12	10	0	83
	0	0	4	5	9	15	5	0	12	9	9	1	73
	1	2.5	7	6.5	9	14	5	0.5	10	10.5	9.5	0.5	78
BATKANU	3	1	8	10	22	19	16	16	16	15	15	1	142
	0	0	4	6	16	23	12	5	16	22	14	3	121
	1.5	0.5	6	8	19	21	14	10.5	16	19	14.5	2	131.5
MATTRU	2	5	11	5	14	13	7	15	11	5	13	0	101
	0	2	2	1	19	24	3	0	6	5	5	2	69
	1	3.5	6.5	3	16.5	18.5	5	7.5	8.5	5	9	1	85
LUAWA	4	10	15	11	9	8	26	13	9	8	7	3	123
	1	3	2	5	18	14	10	16	20	23	23	5	140
	2.5	6.5	8.5	8	13.5	11	18	14.5	14.5	15.5	15	4	131.5
KPETEMA	3	6	9	5	9	8	7	10	3	13	4	0	77
	0	4	2	3	12	15	6	0	8	16	7	2	75
	1.5	5	5.5	4	10.5	11.5	6.5	5	5.5	14.5	5.5	1	76
SERABU	3	7	9	6	10	12	6	3	12	11	13	1	93
	0	4	5	2	12	14	1	0	9	22	13	12	94
	1.5	5.5	7	4	11	13	3.5	1.5	10.5	16.5	13	6.5	93.5
NJALA	4	5	8	7	13	15	14	10	15	10	12	4	117
	1	3	0	10	18	12	5	3	8	11	9	4	84
	2.5	4	4	8.5	15.5	13.5	9.5	6.5	11.5	10.5	10.5	4	100.5
MAGBURAKA	8	8	14	9	16	12	11	12	6	11	8	0	115
	0	2	6	6	5	13	3	3	5	14	18	3	78
	4	5	10	7.5	10.5	12.5	7	7.5	5.5	12.5	13	1.5	96.5
MAKENI	4	15	13	10	19	13	11	12	16	20	14	0	137
	0	0	3	5	15	14	2	4	11	30	20	8	112
	2	7.5	8	7.5	17	13.5	6.5	8	13.5	25	17	4	124.5
TEKO	4	5	15	13	27	21	25	20	25	22	19	1	197
	0	3	18	10	26	7	3	1	8	15	10	8	109
	2	4	16.5	11.5	26.5	14	14	10.5	16.5	18.5	14.5	4.5	153
PUJEHUN	4	3	14	15	19	16	14	9	18	19	17	3	151
	0	0	4	7	22	21	7	0	4	27	23	14	129
	2	1.5	9	11	20.5	18.5	10.5	4.5	11	23	20	8.5	140

Table 8 cont. THUNDERSTORM DAYS - MONTHLY & ANNUAL TOTALS 1963 - 1964

	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
TORMA BUM	3	3	13	9	18	13	8	10	18	14	14	2	125
	1	3	1	3	11	13	7	3	2	11	6	10	71
	2	3	7	6	14.5	13	7.5	6.5	10	12.5	10	6	98
BO	4	12	16	11	22	19	24	13	22	24	18	4	189
	2	4	15	15	28	29	9	3	18	30	25	13	191
	3	8	15.5	13	25	24	16.5	8	20	27	21.5	8.5	190
BUMPE	3	7	13	7	11	13	7	4	9	6	12	0	92
	0	2	2	4	13	16	8	0	3	20	13	0	81
	1.5	4.5	7.5	5.5	12	14.5	7.5	2	6	13	12.5	0	86.5
TIKONKO	3	8	11	7	15	12	9	6	7	19	15	2	114
	1	6	15	10	21	25	12	2	18	31	11	8	160
	2	7	13	8.5	18	18.5	10.5	4	12.5	25	13	5	137
SULIMA	0	0	3	2	8	5	4	5	9	7	12	5	60
	0	0	2	1	19	12	2	0	4	17	14	11	82
	0	0	2.5	1.5	13.5	8.5	3	2.5	6.5	12	13	8	71
KABALA	6	5	9	11	19	22	20	11	21	17	6	2	149
	0	0	6	12	19	24	15	4	16	25	12	5	138
	3	2.5	7.5	11.5	19	23	17.5	7.5	18.5	21	9	3.5	143.5
KENEMA	6	15	9	7	21	14	17	6	17	14	10	3	139
	0	7	9	16	29	24	12	13	9	24	15	9	167
	3	11	9	11.5	25	19	14.5	9.5	13	19	12.5	6	153
DODO	6	5	11	19	9	8	13	15	11	12	9	3	121
	1	5	6	7	19	16	14	15	12	22	17	11	145
	3.5	5	8.5	13	14	12	13.5	15	11.5	17	13	7	133
SEGBWEMA	6	10	7	7	18	12	15	7	16	15	7	2	122
	1	2	12	7	21	16	6	3	12	16	16	9	121
	3.5	6	9.5	7	19.5	14	10.5	5	14	15.5	11.5	5.5	121.5
WORDU	6	4	10	7	18	17	16	11	21	19	11	0	140
	1	4	9	6	13	11	8	6	14	23	20	11	126
	3.5	4	9.5	6.5	15.5	14	12	8.5	17.5	21	15.5	5.5	133
DARU	7	15	13	10	23	21	21	14	21	20	10	6	181
	1	6	18	11	26	24	11	5	17	30	23	9	181
	4	10.5	15.5	10.5	24.5	22.5	16	9.5	19	25	16.5	7.5	181
JOJOIMA	5	15	10	10	15	12	15	8	19	14	6	3	132
	0	8	16	3	9	11	4	3	14	16	18	8	110
	2.5	11.5	13	6.5	12	11.5	9.5	5.5	16.5	15	12	5.5	121

Table 8 cont. THUNDERSTORM DAYS - MONTHLY & ANNUAL TOTALS 1963 - 1964

	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
PENDEMBU	7	10	10	7	18	22	24	25	23	24	9	8	187
	2	2	12	9	21	19	25	29	23	19	13	7	181
	4.5	6	11	8	19.5	20.5	24.5	27	23	21.5	11	7.5	184
SANDARU	8	18	13	12	23	21	18	9	17	23	12	6	180
	1	6	23	13	19	16	9	5	12	23	17	11	155
	4.5	12	18	12.5	21	18.5	13.5	7	14.5	23	14.5	8.5	167.5
KAILAHUN	8	17	15	11	24	15	13	6	17	19	10	5	152
	1	5	5	9	12	13	2	0	12	27	18	11	119
	4.5	11	12	10	18	14	7.5	3	14.5	23	14	8	135.5
MEAN / MONTH	2.5	4.6	8.0	7.2	16.8	16.3	10.4	7.2	12.8	17.4	13.7	5.1	122
MEAN %	8.1	16.1	25.8	24.0	54.1	54.4	33.6	23.2	42.6	56.0	45.6	16.3	33.4

KEY

FREETOWN	1963 1964 MEAN

Table 8 cont. THUNDERSTORM DAYS - MONTHLY & ANNUAL TOTALS 1963 - 1964

TIME	J	F	M	A	M	J	J	A	S	O	N	D	RAIN SEASON JUN/OCT	DRY SEASON NOV/MAY	MID RAINS JUL/SEP	PRE & POST RAINS MAY JUN OCT NOV	YEAR TOTAL
08–09	0	0	0.5	1.0	2.3	1.1	2.1	2.6	3.0	1.0	2.1	1.9	2.0	1.1	2.6	1.6	1.7
09–10	0	0	0.6	0.1	0.9	1.5	3.4	4.1	1.0	0.8	0.8	2.3	2.2	0.7	2.8	1.0	1.2
10–11	0	0	0.3	0.1	1.0	1.6	2.0	1.4	1.5	0.2	1.1	0.8	1.3	0.5	1.6	1.0	1.1
11–12	0	0	0	0.4	1.0	1.3	2.0	4.8	2.3	1.0	0.6	0.8	2.3	0.4	3.0	1.0	1.2
12–13	1.7	0	0.8	0.7	2.0	1.5	1.0	2.8	1.3	1.2	0.6	2.3	1.6	1.2	1.7	1.3	1.3
13–14	3.1	0	0.7	0.8	3.0	2.3	3.3	7.0	2.7	2.7	2.3	0.4	3.6	1.5	4.3	2.6	2.5
14–15	0	2.1	1.8	1.2	5.9	3.8	5.4	8.8	6.9	7.0	4.3	4.7	6.4	2.9	7.0	5.3	5.0
15–16	8.1	4.2	4.5	4.7	7.7	6.7	9.2	9.9	10.8	10.9	6.2	2.7	9.5	5.4	10.0	7.9	7.9
16–17	1.7	6.5	9.9	5.1	8.5	8.8	10.1	8.7	11.3	9.7	8.6	4.9	9.7	6.7	10.0	8.9	8.9
17–18	5.0	3.2	8.4	8.6	10.1	10.6	11.5	6.9	11.3	11.5	10.8	5.4	10.4	7.4	9.9	10.8	10.5
18–19	4.8	10.3	8.9	13.0	9.4	9.6	8.8	10.2	8.7	8.8	11.7	9.2	9.2	9.6	9.2	9.9	9.7
19–20	11.3	16.6	12.2	14.3	9.9	10.5	7.8	8.7	10.0	9.1	11.5	5.3	9.2	11.6	8.8	10.3	10.2
20–21	0	12.4	12.3	14.6	8.5	8.7	6.0	6.5	5.8	8.2	7.2	6.5	7.0	8.8	6.1	8.2	8.2
21–22	19.4	11.5	11.8	10.7	5.7	7.0	5.1	2.6	3.8	6.5	6.6	6.1	5.0	10.3	3.8	6.5	6.4
22–23	8.1	6.2	8.8	8.6	4.9	5.8	5.2	2.0	2.9	6.0	5.0	6.9	4.4	6.9	3.4	5.4	5.3
23–24	9.6	8.3	5.1	6.8	4.5	5.2	3.0	1.2	3.1	4.2	4.5	3.5	3.3	6.0	2.4	4.6	4.2
24–01	3.1	3.2	2.9	2.0	2.5	2.9	2.2	0.7	1.9	2.1	2.9	4.6	2.0	3.0	1.6	2.6	2.4
01–02	4.8	4.2	3.2	2.2	2.5	2.8	2.0	0.9	2.1	2.0	2.1	3.2	2.0	3.2	1.7	2.4	2.4
02–03	3.1	2.1	2.3	1.8	2.4	2.5	2.6	0.7	2.0	1.9	2.4	3.5	1.9	2.5	1.8	2.3	2.3
03–04	11.3	2.1	1.3	1.2	1.8	1.7	2.4	1.0	1.5	1.8	2.5	4.2	1.7	3.5	1.6	2.0	1.8
04–05	3.4	3.3	1.4	1.0	2.1	1.5	1.6	1.7	1.0	0.9	1.9	9.8	1.3	3.3	1.4	1.6	1.6
05–06	0	1.1	1.9	0.4	2.3	1.3	1.5	1.3	1.2	1.1	2.0	5.8	1.3	1.9	1.3	1.7	1.6
06–07	0	2.2	0.2	0.6	1.2	1.1	1.5	3.3	2.1	1.1	1.3	1.9	1.8	1.1	2.3	1.2	1.4
07–08	1.7	2.1	0.5	0.8	1.5	0.9	2.1	3.0	1.5	0.6	1.3	3.1	1.6	1.6	2.2	1.1	1.4

Table 9. TIME WHEN THUNDER HEARD – Average % 1963–1964

% SPREAD /DAY	J	F	M	A	M	J	J	A	S	O	N	D	RAIN SEASON JUN/OCT	DRY SEASON NOV/MAY	MID RAINS JUL/SEP	PRE & POST RAINS MAY JUN OCT NOV	YEAR TOTAL
0– 9	80.1	50.9	25.8	36.6	–	–	6.5	27.4	5.0	1.6	11.7	59.6	8.2	37.8	13.0	3.3	25.4
10–19	3.2	14.0	22.6	16.7	3.2	1.7	19.4	21.0	5.0	6.5	8.3	14.5	10.8	11.8	15.2	4.9	11.1
20–29	3.2	7.0	9.7	10.0	11.3	10.0	21.0	24.2	18.3	3.2	5.0	3.2	15.4	7.1	21.2	7.4	10.5
30–39	3.2	14.0	16.1	8.3	9.7	8.3	16.1	11.3	18.3	8.1	16.7	8.1	12.4	10.8	15.2	10.6	11.3
40–49	1.6	5.3	9.7	13.4	14.5	16.7	14.5	1.6	13.4	12.9	10.0	1.6	11.8	8.0	9.8	13.5	9.4
50–59	3.2	7.0	8.1	6.7	12.9	21.7	9.7	8.1	18.3	16.1	10.0	8.1	14.7	8.0	12.0	15.2	10.8
60–69	4.8	1.8	3.2	3.3	19.4	16.7	8.1	3.2	10.0	14.5	16.7	4.8	10.4	7.8	7.1	16.8	8.9
70–79	–	–	3.2	3.3	17.7	15.0	3.2	3.2	8.3	16.1	10.0	–	9.1	4.9	4.9	14.8	6.7
80–89	–	–	1.6	1.7	9.7	10.0	–	–	3.3	17.7	11.7	–	6.2	3.5	1.1	12.3	4.7
90–99	–	–	–	–	1.6	–	1.6	–	–	3.2	–	–	1.0	0.2	0.5	1.2	0.5
									Mean Spread %				43.0	28.7	33.7	54.0	34.7

Table 10. SPREAD OF THUNDER HEARD / DAY – Average % 1963–1964

MAY 1963	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
FREETOWN			19 T		20 T	4 T		47 T			4 T	90	50	26	2 T	161 T
YENGEMA	COUNTER INSTALLED 18th.MAY.															
JUNE 1963																
FREETOWN	1102 T	T	101 T	51	54	181 T	60 T	503 T	325 T	22 T	71 T	1070 T	421	341 T	991 T	4 T
YENGEMA	1747 T		T			1 T			T	52 T		T	T	139 T	400 T	
BO	COUNTER INSTALLED 6th.JUNE.					242	684 T	309 T	29 T	36 T	20	622 T	299 T	132	1099 T	83 T
JULY 1963																
FREETOWN	7	34	484 T	176	934 T	247 T	18	108 T	20	120	9		T	77 T	38 T	8
YENGEMA	T		60 T	28	65 T	164 T		38 T	256		T	2	53 T		93 T	221 T
BO	21 T	20	133 T	243 T	352 T	3 T		1 T		17 T	T	T	2 T	160 T	395 T	200 T
AUGUST 1963																
FREETOWN	106	232	697 T	623 T	147 T	16 T	28	87	4	232	126			4	12	34
YENGEMA	401 T	34 T	53 T		200	24	12 T			60 T		140 T	102 T	12 T	6 T	12 T
BO			T	T					23	T	T	7 T				T

Table 11. DAILY LIGHTNING COUNTS May – August 1963, days 1 – 16

MAY 1963	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTAL
FREETOWN	142	126		293 T			473 T	277 T	614 T	T	239 T	135	125 T	9 T	91 T	2947
YENGEMA		312 T	144 T	856 T			114 T	1126 T	T	T	872 T	1 T	33 T	14 T	48 T	3520
JUNE 1963																
FREETOWN	5 T		7	114 T	386 T	1089 T	1 T		9	43	124 T	3	6	56		7140
YENGEMA	325 T	187 T	39 T	432 T	T		6 T	188 T	6 T	26 T	50 T	366 T				4014
BO	1350 T	120 T	16 T			T	12 T	1		70 T	265 T	15	22	20		5446
JULY 1963																
FREETOWN	1	2	14	21	44	T		20 T	53 T	14		18	23 T	26	260 T	2776
YENGEMA	T	1 T	25 T	47					T	1 T	70 T		105 T	40	T	1269
BO	45 T	205 T	20 T	8 T	4 T	T	2		2 T	T	2 T	T	15 T	T	T	1850
AUGUST 1963																
FREETOWN	92 T	141 T	44	34	61	17	91 T	41	167 T	445 T	122	233	187	559 T	65	4647
YENGEMA	46 T		445 T	69				7 T				35 T	7 T	144 T	107 T	1916
BO	10 T	12 T	69 T	T			T				14		23 T	171 T	36	365

Table 11 cont. DAILY LIGHTNING COUNTS May – August 1963, days 17 – 31

SEPT. 1963	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
FREETOWN	959	340	397	171	140	299	798 T	402 T	389	446 T	98	419 T	286 T	104 T	740 T	651 T
YENGEMA		141 T	72 T	58 T	11 T	57 T	272 T (days 7–8)		365 T	401 T	76 T	45 T	122	40 T (days 14–15)		797 T
BO		16 T		T	2	72 T	154 T	4 T	107 T	64 T		22 T	20	62 T	117 T	44 T
OCT. 1963																
FREETOWN	36	19	75 T	16			28 T	24 T			49			15 T		5 T
YENGEMA	33 T	4 T	20 T	106 T	63 T (days 5–6)			282 T	191 T	30 T	25 T	65 T (days 12–13)		309 T	210 T	268 T
BO	18 T	5 T		T	6 T		68 T	45 T	45 T	25	104 T	93 T	104 T	151	300 T	639 T
LAKKA	—— COUNTER INSTALLED 10th.OCTOBER ——													5 T		
NOV. 1963																
FREETOWN	284 T		265 T	269 T	532 T	669 T	141 T	35 T	61 T	286 T	55 T		178 T	236 T	462 T	
YENGEMA	421 T	60 T (days 2–3)		992 T	944 T	201 T	74 T	65 T	100 T		969 T	9 T	3 T	20 T	13 T	66 T
BO	552 T		450 T	261 T	228 T	286 T	244 T	50 T	253 T (days 9–10)		5 T	T	T	T	T	T
LAKKA	550	230	761	693	65	1339	322	152	327	488	129	15	552	539 T	256	1
ROKUPR	—— COUNTER INSTALLED 22nd.NOVEMBER ——															

Table 11 cont. DAILY LIGHTNING COUNTS September - November 1963, days 1 - 16

SEPT. 1963	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTAL
FREETOWN	293 T	228	339	305 T	984	198 T	348	415 T	1642 T	395 T	40 T	190 T	695 T	153		12864
YENGEMA	203 T	198	T	9 T	40 T		10 T	4 T	49 T	407 T	90 T	64 T		1470 T		5001
BO	3 T	18 T	13 T	6 T	9 T	41	53 T	491 T	T	T		T	T			1318
OCT. 1963																
FREETOWN	11 T					152 T	T	44 T			144 T	192 T	557 T	305 T	278 T	1950
YENGEMA	434 T	567 T	60 T		5 T	T	385 T	179 T	308 T	46 T		964 T	440 T	266 T	88	5348
BO	81 T			23 T	60	846 T		13 T	11 T	25 T	491 T	179 T	873 T	456 T	468 T	5129
LAKKA	1 T			23	165	1033	263	1300 T	50	485	571	463	1010 T	511	638	6517
NOV. 1963																
FREETOWN	510 T	320 T	346 T	79 T	32				9			2		16		4787
YENGEMA		105 T	270 T	107 T	34 T	7 T	1 T		35 T	1 T	53 T	14 T		53 T		4617
BO	2 T	T	5 T													2336
LAKKA	194 T	47	3 T	49 T	72	78	223	920	53	375	434	21	1	129		9018
ROKUPR			—	—	—	—	1 T	68	5	20	9	1		2		106

Table 11 cont. DAILY LIGHTNING COUNTS September - November 1963, days 17 - 31

DEC. 1963	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
FREETOWN	200	14 T	14 T	12												
YENGEMA	22 T	8 T	11 T	16 T	127 T	4 T	13 T		10 T			1 T	3 T	13 T		3 T
BO		T	T	T							OUT OF ACTION	OUT OF ACTION	OUT OF ACTION	OUT OF ACTION	OUT OF ACTION	OUT OF ACTION
LAKKA	OUT OF ACTION	OUT OF ACTION	OUT OF ACTION	OUT OF ACTION	OUT OF ACTION	OUT OF ACTION	OUT OF ACTION	OUT OF ACTION	OUT OF ACTION	OUT OF ACTION	OUT OF ACTION	OUT OF ACTION	OUT OF ACTION	OUT OF ACTION	OUT OF ACTION	OUT OF ACTION
ROKUPR	29 T	21 T	7 T	1			1				12	13	3	5	40	11
JAN. 1964																
FREETOWN	7 T	4		7	31											
YENGEMA	9 T	16 T	1 T			16 T	7 T	3 T	1 T		15 T					
BO	95	72	86		27	28	4				78	9	15	27	40	7
LAKKA	1044	5	16	77	150	219	1									
ROKUPR	14	1			8	5			14	7	4		10	10	3	1

Table 11 cont. DAILY LIGHTNING COUNTS December 1963 – January 1964, days 1 – 16

DEC. 1963	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTAL
FREETOWN					10	19	33	26								328
YENGEMA	1 T			1 T	17 T		4 T	8 T			7 T	20 T		21 T	17 T	327
BO	- OUT OF ACTION				299 T				126	130	300	56		252	182	1345
LAKKA						OUT OF ACTION										—
ROKUPR	1							4	2	2	6	27				185
JAN. 1964																
FREETOWN								6	85 T	10	225	6				381
YENGEMA	4 T	16 T							T			2 T	517 T	5 T	9 T	621
BO	5	24	23	2	2	7		46	189	116	369	265 T	877 T	81	9	2422
LAKKA																1512
ROKUPR	6	10	26													119

Table 11 cont. DAILY LIGHTNING COUNTS December 1963 - January 1964, days 17 - 31

FEB. 1964	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
FREETOWN							1				8	8	5	13	8	
YENGEMA		T		3 T			1 T	T		17 T	7 T	11 T				
BO	44	26	1	3	21	237	2	7	26	21	7	55	48	15	4	42
LAKKA	NIL RECORD RECEIVED															
ROKUPR		1				1	20	5	2	1	1			2	2	6
MAKENI	COUNTER INSTALLED 17th.FEB.															
DARU	COUNTER INSTALLED 19th.FEB.															
KENEMA	COUNTER INSTALLED 20th.FEB.															
MAR. 1964																
FREETOWN	13	65	40	49 T	4 T		11	29	3	9						23 T
YENGEMA		339 T	255 T	19 T	392 T	2 T	160 T		1 T	218 T			9 T	26 T		305 T
BO	200 T	149 T	107 T	135 T	62 T	65 T	199	4 T	5	11	33	33	65 T	1	36	10 T
LAKKA									5		39		4			159
ROKUPR	1	4	2	1	1		1	3		2					1	2
MAKENI	5	5	531 T									6				
DARU	49	296 T	859 T	258 T	46 T	25	1715 T		14	1249 T	11 T	10	546 T	21 T	87	77
KENEMA	T	11	105	8	124	13 T	9	10	10 T	10	9	10	8	10	9	10

Table 11 cont. DAILY LIGHTNING COUNTS February - March 1964, days 1 - 16

FEB. 1964	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTAL
FREETOWN			4	3	8								21			79
YENGEMA	13 T				3 T			115 T	13 T	12 T	408 T	158 T	100 T			861
BO	15	12	18	3	37	13	18	142	31	148 T	290 T	169 T	30 T			1485
LAKKA	NIL RECORD RECEIVED															0
ROKUPR			1		3			7	2	7	3	12	3			79
MAKENI			78	47	5		3	22	15			5				175
DARU				6	40	273 T	196 T	78 T	93 T	50	162 T	183	191 T			1272
KENEMA					9	23	53 T	T	16 T	27 T	12 T	4 T	6 T			150
MAR. 1964																
FREETOWN	13	11	40 T	37	25	T										372
YENGEMA	1 T		2 T	3 T	97 T				2 T	1088 T					809 T	3728
BO	24	15 T	49	59	40 T	374 T	39	43	78	1	150 T	87 T	118	34	48 T	2274
LAKKA			121		30	156		160	27	5	8	8		78	52	871
ROKUPR			9	2	8 T	24 T	6 T	6			1		3	4	2	83
MAKENI			33		T	10 T										590
DARU	51	854 T	105	77 T	1781 T	122 T	68	66	274 T	169 T		304 T		38 T	126 T	9298
KENEMA	5	7 T	10	8 T	9	9 T	10	7	10	10	10	8 T	8	10 T	10 T	487

Table 11 cont. DAILY LIGHTNING COUNTS February - March 1964, days 17 - 31

APR. 1964	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
FREETOWN	NIL RECORD RECEIVED															
BO	33 T	42	18	563	62 T	24	21	11	37 T	11	8	12 T		245		82
LAKKA	46		1	267		47		202		86	41	252	2	327	6	163
ROKUPR	2	6	2	55	2	7			4	1	1	15	5			T
MAKENI	14 T															
DARU	189 T	87	31	177 T	333 T	37	46	18	38	48	17	223	104		174	220
KENEMA	10 T	9	8	8 T	10 T	10	9	10	10 T	9	10	8	9	10	10	8
MAY 1964																
FREETOWN	NIL RECORD RECEIVED															
YENGEMA	1 T	5 T		T	8	210	T	2 T	T		1 T	684 T	1028 T	33 T	4 T	2 T
BO	166	179	43	71 T	348	148 T	192 T	134 T	87 T	753 T	234 T	1285 T	120 T	75 T	78 T	179 T
LAKKA					1										4	
MAKENI	T					T	7		77 T			T	357 T	20 T		2 T
DARU	397 T	154 T	131 T	843 T	1172 T	26 T	29	267	1940 T	143 T	321 T	626 T	1424 T	217 T	100	311 T
KENEMA	9 T	10 T	10 T	10 T	10	10	10 T	9 T	10 T	9 T	9 T	7 T	10 T	8 T	8 T	9 T

Table 11 cont. DAILY LIGHTNING COUNTS April - May 1964, days 1 - 16

APL. 1964	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTAL
FREETOWN						T										0
BO	155	46 T		120	894 T	89 T	125 T	743 T	306 T	297 T	85 T	37 T	512 T	96 T		4674
LAKKA	149	10	16													1615
ROKUPR		1 T	T	T			T	1 T			T	T	T	T		102
MAKENI				T						16 T			229 T	T		259
DARU	232	242	804 T	162 T	8	635 T	94 T	181	33	389 T	350 T	240 T	1692 T	322 T		7126
KENEMA	6	10 T	10 T	10 T	10 T	7 T	9 T	10	10 T	10 T	6 T	10 T	10 T	8 T		274
MAY 1964																
FREETOWN	2		18 T	321				T	107 T	T	498 T	T	8 T	T		955
YENGEMA		83	T	1 T	60	4	4		101 T	813 T	1 T	5 T	2 T			3052
BO	196 T	3 T	13 T	236	574 T	573 T	749 T	871 T	421	179	376 T	477 T	488 T	1057 T	840 T	11145
LAKKA	112		4			98		2			2			1		224
MAKENI		1 T						2 T	T	8 T		T	T	177 T	T	651
DARU	1042 T	240 T	499 T	733 T	826 T	81 T	47	1455 T	874 T	163 T	566 T	2540 T	228 T	1374 T	657 T	19426
KENEMA	10 T	14 T	9 T	10 T	6 T	4 T	19 T	1 T	11 T	616 T	15 T	74 T	30 T	28 T	237 T	1232

Table 11 cont. DAILY LIGHTNING COUNTS April - May 1964, days 17 - 31

JUN. 1964	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
FREETOWN	14 T	61 T	T	4 T	T	T	7 T	T		T	T	T	T	T	T	T
YENGEMA	1587 T	905 T	139 T	16 T	644 T	8 T		17 T	2 T	2 T	367 T	64 T	665 T		3 T	16 T
BO	777 T	1593 T	16 T	365 T	788 T	1420 T	41 T	73 T	742 T	630 T	1116 T	859 T	583 T	882 T	255 T	86 T
ROKUPR	T	1 T	T	T	T	T	15 T	1 T	T	44 T	2 T	6 T	5 T	93 T	T	T
MAKENI		T		T			75 T		T			T	3 T	369 T	T	
DARU	414 T	1852 T	467 T	268 T	2181 T	1181 T		31	175	551	959 T	552 T	1855 T	1303 T	189 T	174 T
KENEMA	136 T	196 T	570 T	118 T	46 T	415 T	32 T	230 T	3 T	13 T	189 T	311 T	212 T	972 T	301 T	48 T
JUL. 1964																
FREETOWN				27 T	1 T	T	T			12	1 —	OUT OF ACTION	—	—	—	—
YENGEMA	1 T	9	2 T	1		8 T	5 T							T		
ROKUPR	22 T	2 T			2 T	140 T	1 T			7		3			T	
MAKENI						1 T										
DARU	926 T	20	27	295 T		519 T	46 T	17		80	65	2	7	258	355 T	70 T
KENEMA	300	650	10	151	25	29	415	30	2			73			119	187

Table 11 cont. DAILY LIGHTNING COUNTS June - July 1964, days 1 - 16

JUN. 1964	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTAL
FREETOWN	T		1 T	33 T		T	237 T	4 T	2 T		T	T		T		363
YENGEMA	10 T	24 T		4 T		103 T	56 T	3 T			25 T		T	52 T		4712
BO	94	71 T	175 T	250 T	480 T	346 T	1338 T	1131 T	32 T	404 T	37 T	64 T	340 T	118 T		15106
ROKUPR	T	T	7 T	67 T	56 T	T	T	T	58 T	1 T	27 T	18 T	T	56 T		457
MAKENI	T			14 T	T		T				2 T		T			490
DARU	100 T	101 T	588	818 T	41	108 T	790 T	743 T	1106 T	92	338 T	251 T	59 T	358 T		17645
KENEMA	58	9 T	34	224 T	414	12	46 T	346 T	580 T	270	24	94 T	98 T	8 T		6009
JUL. 1964																
FREETOWN	OUT OF ACTION															
YENGEMA	4 T			10			4 T	43 T								87
ROKUPR		13 T											67 T			257
MAKENI								T								1
DARU	118	16 T	25		27	8	113 T	19	4	16	229 T		268 T			3530
KENEMA	15	12	63	5	5	1		65	8			1	5	15	5	2211

Table 11 cont. DAILY LIGHTNING COUNTS June - July 1964, days 17 - 31

AUG. 1964	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
FREETOWN				26	8	3		1	3	26			1	1	1	7
YENGEMA	30 T (days 1–2)			4		4 T	T	T			T	9				
DARU					61 T	46 T	1	2	17	12	7	17	14	5	3	13
KENEMA	6	27 (days 2–8)								16		1	1			1
SEPT. 1964																
FREETOWN	8	51	8	19		82 T	800 T	22	7	82		246	16	6	4	2
DARU		89 T		7 T	364 T (days 5–6)		365 T	94 T	2	150	195	354 T			13	2
KENEMA		22 T		8 T	46 T	26 T	3	22 T	24 T	OUT OF ACTION						
OCT. 1964																
FREETOWN	OUT OF ACTION															
YENGEMA	OUT OF ACTION															
DARU	1349 T (days 1–4)				107 T	144 T	60 T (days 7–8)		346 T	1178 T (days 10–11)		687 T	24 T	36 T	202 T	394 T

Table 11 cont. DAILY LIGHTNING COUNTS August - October 1964, days 1 - 16

AUG. 1964	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTAL
FREETOWN	23	1	11	13		1	8	38	85 T	19		5	1			282
YENGEMA	6 T			5 T			6 T			20 T	. T	20		46 T	1 T	151
DARU		124 T	18		12		43	90	114		40 T	36		9 T	1	685
KENEMA				9		6	15	8	3	8	4					105
SEPT. 1964																
FREETOWN	25	———	———	———	———	———	OUT OF ACTION	———	———	———	———	———	———	———	———	1378
DARU	111	275		372 T	72	229 T	113	563 T	465 T	T	951 T	104 T	175 T	335 T		5400
KENEMA		———	———	———	———	———	OUT OF ACTION	———	———	———	———	———	———	———	———	151
OCT. 1964																
FREETOWN	———	OUT OF ACTION	———	———	———		21 T	255 T	10	78	293 T	T	T	T	2 T	659
YENGEMA	– OUT OF ACTION	———				29 T	35		45	25 T	7	42 T	194 T	8	T	385
DARU		594 T	773 T	215	149 T	868 T	77 T	147 T	115 T		1048 T	1496 T	588 T			10597

Table 11 cont. DAILY LIGHTNING COUNTS August – October 1964, days 17 – 31

NOV. 1964	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
FREETOWN	— OUT OF ACTION —				277 T	424	271 T	T	1 T	32 T	38 T	2	7 T	4 T	16 T	
ROKUPR	— OUT OF ACTION —									20 T	125 T	57 T	207 T	24 T	1	8 T
DEC. 1964																
FREETOWN	8 T		T	169	8	33	1	1	1 T	344	231 T	542 T	326 T	136	14	8
ROKUPR	36 T	25 T	20 T	20 T					170 T			16 T	5			

Table 11 cont. DAILY LIGHTNING COUNTS November - December 1964, days 1 - 16

NOV. 1964	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTAL
FREETOWN	25 T	62 T		T	4 T	996				81 T	T			1		2241
ROKUPR	8 T	16 T	3	139 T	10 T	4 T	1	6 T	57 T	7 T	28 T	2 T	38 T	20 T		781
DEC. 1964																
FREETOWN	6	9 T	4 T	11	14	238 T	49 T	4	2			1		2	92	2254
ROKUPR		12 T		29 T	3	38 T	21 T		3				1	1	3	403

Table 11 cont. DAILY LIGHTNING COUNTS November - December 1964, days 17 - 31

		J	F	M	A	M	J	J	A	S
FREETOWN	1963					21 18 17 16 23	27 23 20 19 26	26 24 21 12 27	29 27 27 10 16	30 30 30 17 23
	1964		10 7 2 0 0	15 13 12 5 6	0 0 0 1 6	6 5 4 9 22		4 2 2 4 7		
YENGEMA	1963					10 9 9 12 12	15 14 12 20 24	17 14 14 17 24	20 20 17 17 21	24 23 22 23 25
	1964	14 9 5 15 15				21 11 8 19 25		10 5 2 8 13	12 9 5 13 17	
BO	1963						21 20 20 15 18	21 14 13 26 29	9 9 8 13 13	20 17 15 22 25
	1964	26 23 17 2 2	29 24 22 4 7	31 26 26 15 18	27 27 26 15 15	31 30 30 24 29	30 30 30 29 30			
LAKKA	1963									
	1964	7 6 5 0 3	0 0 0 0 0							
ROKUPR	1963									
	1964				13 5 2 10 15					
MAKENI	1963									
	1964		7 6 4 0 3	6 6 3 3 18		9 6 4 15 25	5 3 3 14 20	1 0 0 2 7		
DARU	1963									
	1964		10 10 9 6 8	28 28 28 18 25	29 29 28 12 14	31 31 31 27 28	29 29 29 23 26	25 23 21 11 23	22 18 15 5 8	23 21 20 15 24
KENEMA	1963									
	1964			30 30 17 9 26		31 29 19 29 30	30 29 27 24 25			7 6 5 6 7

Table 12. COUNT DAYS AND THUNDERSTORM DAYS - January to September 1963-1964

		O	N	D
FREETOWN	1963	17 17 16 17 21	21 20 19 17 23	4 4 4 2 3
	1964		16 11 10 15 22	26 18 3 13 10
YENGEMA	1963	25 24 23 25 26	25 22 20 25 25	27 14 11 21 21
	1964	8 8 6 5 9		
BO	1963	26 26 24 24 27	11 10 8 17 18	7 7 7 1 4
	1964			
LAKKA	1963	14 13 12 5 17	30 27 27 4 27	
	1964			
ROKUPR	1963		7 4 2 1 1	17 14 7 3 3
	1964			
MAKENI	1963			
	1964			
DARU	1963			
	1964	22 22 22 21 24		
KENEMA	1963			
	1964			

KEY

COUNT DAYS		
Total	5	10
T.S.D.		
Local	Over estimated range (20 mls.)	

Table 12 cont. COUNT DAYS AND THUNDERSTORM DAYS (cont.) - October to December 1963-1964

	(1) Total T.D. at station	(2) Total T.D. within range	(3) Total C.D.	(4) Total C.D. > 5	(5) Total C.D. > 10	(6) Total C.D. / Total T.D.	(7) C.D. > 5 / T.D. in range	(8) C.D. > 10 / T.D. in range	(9) Total C.D. / T.D. in range
FREETOWN	144	238	242	219	197	1.7	0.92	0.83	1.02
YENGEMA	220	257	222	182	154	1.01	0.70	0.60	0.86
BO	207	235	289	263	246	1.40	1.1	1.05	1.2
LAKKA	9	47	51	46	44	5.7	0.98	0.94	1.08
ROKUPR	14	19	37	23	11	2.64	1.20	0.58	1.9
MAKENI	34	73	28	21	14	0.82	0.29	0.19	0.38
DARU	138	180	219	212	203	1.6	1.2	1.1	1.2
KENEMA	68	88	98	94	68	1.4	1.1	0.77	1.1

Table 13. RATIO BETWEEN C.D. / T.S.D. UNDER VARIOUS CONDITIONS Totals 1963 - 1964

NOTES

1. The most general agreement between count days and thunderstorm days is obtained by ignoring any count day with a count less than 5 and by including any thunderstorm day reported within the apparent range of the counters. (Column 7 above). This is taken as being 20 miles. (See Appendix 2 page 69.)

   This procedure is adopted in formulating Table 14 page 68.

2. YENGEMA seems to be the exception to this and in Table 14 the T.S.D. figures for this station are the local figures.

NOTES ON TABLE 13 cont.

3. The T.S.D. figures for LAKKA are unreliable. This is indicated by the large increase in T.S.D. reported within range of the counter (columns 1 and 2 above).

4. The figures for MAKENI show little agreement between C.D. and T.S.D. This is most certainly because the counter at this station was incorrectly calibrated. MAKENI is therefore excluded from Table 12.

	J	F	M	A	M	J	J	A	S	O	N	D
FREETOWN	377 3	71 0	365 6	0 6	1945 22.5	7132 26	1406 17	4639 16	12864 23	1950 21	3509 22.5	1283 8
BO	2414 2	1472 7	2268 18	4674 15	11142 29	5445 18	1834 29	365 13	1309 25	5129 27	2334 18	1345 4
LAKKA	1151 3	0 0	867 8	1612 10	210 22					6517 17	9013 27	
ROKUPR	110 0	57 2	53 9	88 15		452 30	249 12				438 9.5	281 7
DARU		1272 8	9298 25	7126 14	19426 28	17645 26	3524 23	678 8	5396 24	10597 24		
KENEMA		146 9	487 26		1232 30	6006 25	2207 (14)	95 (14)	148 7			
* YENGEMA	610 15	854 15	3717 18		3275 17	4355 21	670 12.5	1029 15	4997 23	5344 25	4612 25	314 21
MEAN	203	97	155	225	256	282	92	103	242	259	195	81

KEY

Lightning Count (excluding days with count < 5)
T.S.D. - taken over range of 20 mls.

NOTES

1. Two T.S.D. figures for KENEMA ( ) taken from Dodo.
2. T.S.D. figures for YENGEMA are local station figures.

Table 14. TOTAL MONTHLY LIGHTNING COUNT - Average 1963-1964

APPENDIX 2

ESTIMATED RANGE OF E.R.A. LIGHTNING STROKE COUNTER

It was apparent from the beginning of the survey that the counters were operating over a greater distance than that for which thunder could be heard. On one occasion, a storm immediately east of the Colony Hills was being registered by the Freetown counter, but was not heard at the counter site.

Whilst the counters are known to have recorded some very distant storms (see page 5), it is felt that if the number of days during which thunder is reported at stations 20, 25 and 30 miles distance from each counter is correlated with the monthly number of count days for each counter, some assessment of the mean range of the counters can be made.

Although the number of additional T.S.D. stations situated within each distance is small (see Table 15 below), the highest correlation between count days and thunderstorm days is obtained at a distance of 20 mls. (Table 16 , pages 71 &72).

The readings for some stations have been omitted from Table 16 . This is because there is insufficient data from stations within the different distances from the counters.

ADDITIONAL STATIONS

	d = 20 mls.	d = 25 mls.	d = 30 mls.
FREETOWN	Lungi, Pepel, Guma, Kissi, Lakka.	Newton	Maswari
YENGEMA	Wordu, Koidu	-	Bandajuma Sandaru
BO	Tikonko, Bumpe Kpetema	Serabu	Njala

APPENDIX 2 (continued)

LAKKA	Lungi, Guma, Freetown, Kissi, Newton, Hastings, Pepel.	Maswari	-
ROKUPR	Kambia, Mamge Bureh, Port Loko.	-	Pepel
MAKENI	Magburaka, Teko.	Bumbuna	Batkanu
KENEMA	Hangha, Segbwema.	Dodo	Daru, Jojoima, Kpuwabu.
DARU	Segbwema, Jojoima, Pendembu.	Bandajuma, Hangha.	Dodo, Kenema, Kailahun.

Table 15. ADDITIONAL T.S.D. STATIONS IN RANGE OF LIGHTNING COUNTERS

MONTH	STATION	COUNT DAYS	THUNDERSTORM DAYS			
			Local	20 mls.	25 mls.	30 mls.
1963 MAY	FREETOWN	21	16	23	24	24
	YENGEMA	10	12	12	12	12
JUN.	FREETOWN	27	19	26	28	28
	YENGEMA	15	20	24	24	24
	BO	21	9	18	18	18
JUL.	FREETOWN	26	12	27	27	28
	YENGEMA	17	17	24	24	24
	BO	21	26	29	29	30
AUG.	FREETOWN	29	10	16	21	21
	YENGEMA	20	17	21	21	21
	BO	9	13	13	14	16
SEP.	FREETOWN	30	17	23	25	25
	YENGEMA	24	23	25	25	25
	BO	20	22	25	27	27
OCT.	FREETOWN	17	15	21	21	21
	YENGEMA	25	25	26	26	26
	BO	25	23	27	27	27
	LAKKA	14	5	17	17	17
NOV.	FREETOWN	21	17	23	27	27
	YENGEMA	25	25	25	25	25
	BO	11	17	18	18	19
	LAKKA	30	4	27	27	27
	BOKUPR	7	1	1	1	1
DEC.	FREETOWN	8	2	3	3	3
	YENGEMA	21	21	21	21	21
	BO	7	4	4	4	4
	BOKUPR	17	3	3	3	3
1964 JAN.	FREETOWN	9	2	3	3	3
	YENGEMA	14	15	15	15	15
	BO	26	2	2	2	15
	LAKKA	7	0	3	3	3
FEB.	FREETOWN	10	0	0	0	2
	BO	29	4	7	7	7
	LAKKA	0	0	0	2	2
	MAKENI	7	0	3	3	3
	DARU	10	6	8	9	9
MAR.	FREETOWN	15	5	6	8	8
	BO	31	15	18	20	20

Table 16. CORRELATION BETWEEN COUNT DAYS AND T.S.D. AT DIFFERENT DISTANCES

MONTH	STATION	COUNT DAYS	THUNDERSTORM DAYS			
			Local	20 mls.	25 mls.	30 mls.
MAR.	MAKENI	6	3	18	18	18
	DARU	28	18	25	27	27
	KENEMA	30	9	26	26	29
APL.	FREETOWN	0	1	6	10	13
	BO	27	15	15	15	16
	ROKUPR	13	10	15	15	15
	DARU	29	12	14	17	18
MAY	FREETOWN	6	9	22	22	23
	YENGEMA	21	22	25	25	26
	BO	31	28	29	29	29
	MAKENI	9	14	25	30	30
	DARU	31	27	28	31	31
	KENEMA	31	29	30	30	31
JUN.	FREETOWN	9	25	29	29	29
	BO	30	29	30	30	30
	MAKENI	5	14	20	23	26
	DARU	29	23	26	27	27
	KENEMA	30	24	25	25	27
JUL.	FREETOWN	4	4	7	7	7
	YENGEMA	10	8	13	13	16
	MAKENI	1	2	7	11	18
	DARU	25	10	23	23	24
AUG.	YENGEMA	11	13	17	17	19
	DARU	22	5	8	8	16
SEP.	DARU	23	15	24	24	26
	KENEMA	7	6	7	7	8
OCT.	YENGEMA	8	5	9	9	9
	DARU	22	21	24	24	24
NOV.	FREETOWN	16	15	22	22	22
DEC.	FREETOWN	26	10	13	14	14
		CORRELATION COEFFICIENT r	0.6	0.62	0.59	0.6

Table 16 cont. CORRELATION BETWEEN COUNT DAYS AND T.S.D. AT DIFFERENT DISTANCES

APPENDIX 3

THE EFFECT OF TEMPERATURE VARIATION ON THE CALIBRATION OF THE E.R.A. LIGHTNING STROKE COUNTER

1. From the time of the installation of the first counter, it was apparent that the diurnal variation of temperature in Sierra Leone was sufficient to seriously affect the calibration of the counter. On two occasions the newly erected instrument was correctly calibrated during the late afternoon. Severe local thunderstorms occurred during the following night but the counter failed to register. On testing the instrument on the following morning, it was found to be grossly under calibrated.

2. To investigate the effect of temperature on the calibration of the counter, an instrument was installed in the normal way, but without the aerial array. A thermocouple was fixed to the side of the valve and valve voltmeters connected so as to measure the test voltage applied to the valve when the test button was pressed, and also the calibration voltage supplied to the valve from the potentiometer P_1. (See Fig. 9).

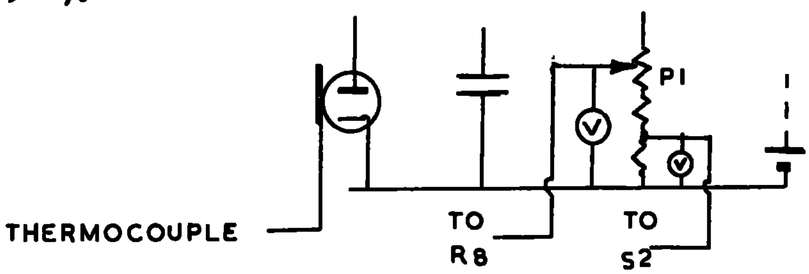


Fig. 9. CONNECTIONS OF THERMOCOUPLE AND VOLTMETERS FOR TEST ON COUNTER

3. Experience had already shown that it was most difficult to obtain a setting of the sensitivity control which would give alternate counts on pressing the test knob at five second intervals. The procedure

suggested by the Federal Committee for Lightning Investigation, Southern Rhodesia (9) was therefore used. This was to press the test knob ten times, at five second intervals, and record the number of counts registered by the counter. Ten tests, each consisting of ten presses of the test knob at five second intervals, followed by fifteen seconds rest, were given for each temperature recorded on the thermocouple. The results are shown in Table 17, pages 77 & 78.

4. Following a number of such tests it was found that only a very small movement of the sensitivity control knob, about 1° arc of movement, was sufficient to throw the counter completely off its setting. The counter calibration unit was then changed to the one shown in Fig. 10. Subsequently it was found that the counters being used in Southern Rhodesia were being modified in a similar way (9). The results given in Table 17 were obtained from the counter modified in this way.

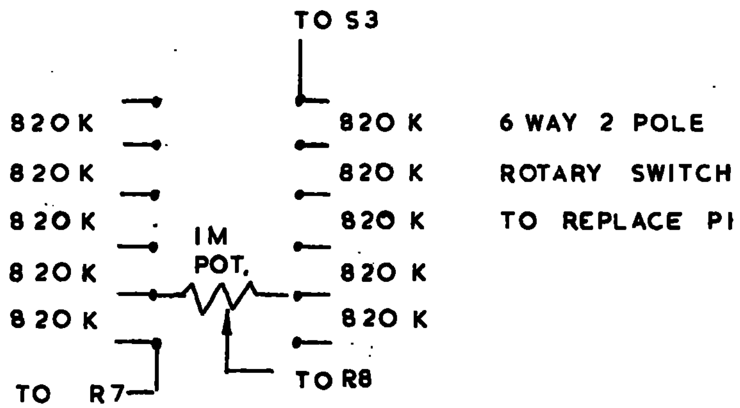


Fig. 10. MODIFIED CALIBRATION CIRCUIT FOR COUNTER

5. Further study of Table 17 shows the wide variation in the number of counts obtained from successive tests on an apparently correctly calibrated instrument. An average standard deviation (σ_m) of 2.2 suggests that any count of between three or seven out of ten should be accepted as a correct count.

In an attempt to reduce this variation in the number of counts recorded during each test, a small neon lamp was placed in contact with the valve so as to strengthen the ionization taking place in the valve [5]. The effect of this was to reduce σ_m to 0.5 and make uniform calibration much easier to obtain. The last five records in Table 17 were obtained in this way.

6. The graph of temperature of the valve plotted against the sum of the test voltage and the potentiometer voltage is shown in Fig. 11 , page 79 . The graph appears to consist of two straight lines which intersect at the point T = 26°C. On three occasions when tests were carried out at this temperature, it was impossible to obtain a correct setting of the sensitivity control. Either the counter counted ten out of ten tests or none out of ten tests.

7. <u>CONCLUSIONS</u>

a. The counter must be calibrated when the temperature is low. This will mean that it will be over-sensitive during the warmer parts of the day, but that it will record lightning during storms in the night when temperatures are lower.

The temperatures measured inside the counter housing during December 1963 and January 1964 were:-

MAXIMUM	Mean 34°C	Highest 39°C	Lowest 30°C
MINIMUM	Mean 20°C	Highest 23°C	Lowest 17°C

Mean diurnal range 14°C

b. The inclusion of a neon lamp, placed close to the valve, enables a more accurate calibration to be achieved. It is then possible to register alternate test impulses. However, because of the drain on the batteries resulting from the inclusion of the neon lamp in the circuit, this procedure was not adopted for the operational counters.

T VOLTS.	5.8	5.8	5.78	5.8	5.8	5.8	5.8	5.8	5.7	5.7	5.62	5.62
. VOLTS.	35.6	35.2	36.0	36.2	35.8	35.3	36.0	36.0	35.9	35.1	36.1	35.2
TEMP.	24.0	32.9	26.0	26.0	25.0	25.0	29.0	24.3	25.0	25.0	25.2	27.0
A	5	6	6	5	6	7	7	7	6	5	6	4
B	0	5	0	0	3	4	7	7	5	6	9	5
C	5	6	0	0	8	8	7	6	7	5	9	8
D	9	7	0	0	9	8	8	8	5	0	8	6
E	9	8	0	0	9	8	9	10	5	0	8	7
F	9	1	0	0	9	10	10	7	8	3	7	6
G	8	9	0	0	10	4	10	7	8	0	6	8
H	9	7	0	0	10	9	10	10	7	2	8	7
I	4	9	0	0	10	6	9	7	8	3	9	4
J	8	10	0	0	10	6	5	9	1	5	7	6
COUNT	6.6	6.8	0.6	0.5	8.4	7.0	8.2	7.8	6.0	2.9	7.7	6.3
σ	2.9	2.5	X	X	2.2	1.9	1.6	1.3	2.0	2.2	1.1	1.4
. TEMP.	24.8	32.1	26.0	26.0	25.0	25.1	29.0	25.0	25.0	25.0	26.0	28.0
N TEMP.	24.4	32.5	26.0	26.0	25.0	25.0	29.0	24.6	25.0	25.0	25.6	27.5
AL VOLTS	41.4	41.0	41.8	42.0	41.6	41.1	41.8	41.8	41.6	40.8	41.7	40.8
			X	X	X		X	X		X	X	

T VOLTS.	5.6	5.7	5.7	5.6	5.6	5.6	5.7	5.6	5.7	5.7	5.6	5.6
. VOLTS.	35.0	35.1	36.0	35.0	34.9	35.2	36.1	35.1	35.1	35.1	34.5	35.0
T. TEMP.	34.0	29.0	23.9	31.1	32.0	29.8	23.8	32.6	29.1	33.8	28.5	28.1
A	5	7	6	6	3	3	5	6	4	5	5	7
B	1	3	7	4	8	9	8	5	8	7	8	4
C	7	9	8	8	6	7	2	3	3	4	1	8
D	3	0	4	4	7	8	4	6	0	0	7	8
E	5	2	6	8	7	9	6	9	3	5	7	8
F	1	1	8	8	4	6	7	8	3	6	6	6
G	2	4	1	8	1	5	9	7	2	3	1	9
H	8	2	7	6	5	8	9	3	8	6	7	8
I	0	9	3	6	2	6	9	4	4	4	1	0
J	2	0	8	8	6	5	8	7	7	3	4	0
N COUNT	3.4	3.7	5.8	6.6	4.9	6.6	6.7	5.8	4.2	4.6	4.7	5.8
σ	2.6	3.3	2.3	1.6	2.2	1.9	2.3	1.9	2.5	1.9	2.6	3.2
. TEMP.	34.0	29.0	24.0	31.7	32.0	29.8	24.0	33.0	29.0	33.8	28.9	28.1
N TEMP.	34.0	29.0	23.9	31.4	32.0	29.8	23.9	32.8	29.0	33.8	28.7	28.1
AL VOLTS.	40.6	40.8	41.7	40.6	40.5	40.8	41.8	40.7	40.8	40.8	40.1	40.7

Table 17. SENSITIVITY CONTROL AND TEMPERATURE VARIATION

ST VOLTS.	5.7	5.7		5.5	5.4	5.3	5.3	5.3	
T. VOLTS.	35.0	35.9		36.2	36.1	35.5	36.0	36.0	
IT. TEMP.	30.0	26.0		23.1	24.3	35.0	26.4	31.0	
A	3	4		6	5	5	5	5	
B	4	0		7	5	4	5	5	
C	4	1		6	5	5	5	5	
D	3	0		5	5	5	5	4	
E	8	0		5	5	5	5	5	
F	4	0	NEON	6	4	4	4	5	
G	1	0		6	3	5	4	5	
H	3	0	LAMP	6	3	5	4	5	
I	7	0		5	3	5	3	5	
J	8	0	IN	5	3	5	2	5	
AN COUNT	4.5	0.5	POSITION.	5.7	4.1	4.8	4.2	4.9	
σ	2.2	X		0.6	0.9	0.4	0.3	0.3	
I. TEMP.	30.0			23.9	24.9	34.2	27.4	31.0	
AN TEMP.	30.0		$\sigma_R = 2.2$	23.5	24.6	34.6	26.9	31.0	$\sigma_D = 0.5$
TAL VOLTS.	40.7			41.7	41.4	40.8	41.3	41.3	
		X							

Table 17 cont. SENSITIVITY CONTROL AND TEMPERATURE VARIATION

E

The voltage across the potentiometer is a measure of the setting of the sensitivity control knob. However, since the test voltage did not remain constant throughout tests, the total voltage applied to the grid of the valve is used in plotting the ph shown in Fig.

APPENDIX 3. (continued)

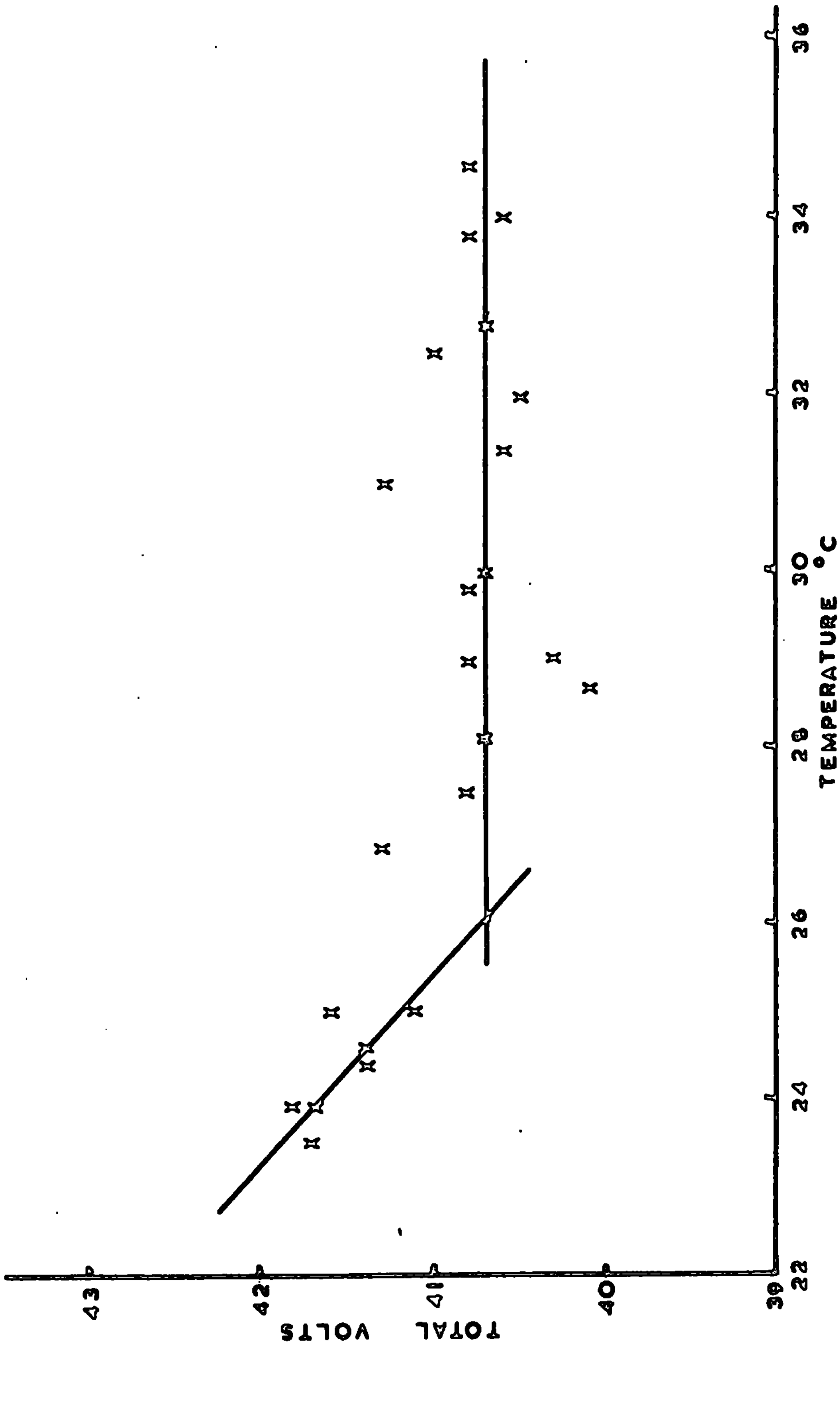


FIG. II SENSITIVITY CONTROL & TEMPERATURE VARIATION

APPENDIX 4

HOURLY LIGHTNING COUNT RATE FOR FREETOWN

1. At the FREETOWN station an event recorder was operated in conjunction with the lightning counter for part of the period under review. With this instrument the recording of each lightning count was registered on a rotating strip of paper. Although this was functioning only during the period November 1963 to March 1964, the hourly count rates shown in Table 18 , pages 82 & 83 , can be used to describe the pattern of storms in this season of the year.

2. Table 19 shows the mean hourly count rates for the period and the graphs (Fig. 12 , page 85) underline the presence of heavy storms in the late hours of the day and the early hours of the morning. Whilst the Freetown counter was registering some counts fairly regularly during the hours 1600 - 0800 hrs. (Fig. 12c), the magnitude of the counts was highest during the period 0200 - 0300 hrs. (Fig. 12b). This illustrates the presence of the 'bush-washing' storms experienced at this time of the year. When a graph of Total count / count hour is drawn (Fig. 12d) this becomes even more apparent.

3. An analysis of seven heavy storms which occurred at Freetown during November 1963 is given in Table 20 , page 87 .

a. Storms A, B, C and D are of a similar pattern with the counter beginning to register six or seven hours before the peak of the storm reaches the counter and continuing to register for a similar period after the storm centre has passed over. In each case over 35% of the lightning strokes counted are registered in the peak hour and the preceding hour.

b. Storms E, F and G are of a different type - but one which is often experienced in Sierra Leone. The storm reaches a sudden very high peak and then ceases abruptly. In storm E almost 60% of the count was in one hour, between 0200 and 0300 hrs. and the counter ceased to register after the next thirty minutes. Fig. 13 , page 88 , shows the event recorder chart for the period of this storm.

It is regrettable that this event recorder was not operational for a greater part of the review and that more of these instruments were not available. The reasons for this illustrate the difficulties met in a survey of this nature. Only very limited funds are available for the purchase of equipment and it is very difficult to obtain spare parts. In any future work of this kind it is to be hoped that sufficient stocks of spare parts will be carried so that the recordings can be continued without interruption.

TIME	NOVEMBER 63 1	2	3	4	5	6	7	8	9	10	11	JANUARY 64 25	26	27	28	29	FEBRUARY 64 7	11	12	13	14	15	16
00–01		6		2	6	29	33				1		4		26	1						1	3
01–02		18		3	2	30	65			2	1		3		32				1	3		1	1
02–03		12		8		31	351			2	4		3		9					3			
03–04		11		7	1	22	72			15	41	1	2	2	23				1			1	
04–05		39				12			3	7	50	1	2		20				2			1	
05–06		14		1		14				1	31	1	3		22								
06–07		7		8		1			1		3		1		22					1	1		
07–08		1		2		6						3			9					1		1	4
08–09		1		1		13			1	1										4			
09–10				1		15						1											
10–11						4			1														
11–12						4			2														
12–13						12			1			2											
13–14						4			3														
14–15				2		7			8			3	4			1					1		
15–16				8	1	2	1		2			1	2										
16–17	3		2	1	8	10	4		7			1	1		1								
17–18	8		21	7	35	8	1		4			9					1	1					
18–19	6		42	21	30	1	11		2	3		8		6				3			2		
19–20	13		34	22	38	5	4	10	2	29		4			1						3		
20–21	42		40	57	46	11	5	10		69		9		4							2		
21–22	33		35	79	78	14	32	1	1	53		7		6									
22–23	52		34	44	90	19	38	8				12		19	2								
23–24	19		26	17	61	19	40	2				10		27	1								

Table 18. LIGHTNING COUNT / HOUR – FREETOWN Nov.1963 – Feb.1964

TIME	FEBRUARY 64					MARCH 64																
	19	20	21	22	29	1	2	3	4	5	6	8	9	10	11	16	17	18	19	20	21	22
00–01						2	2	6	9			2			1		3		1	1	4	
01–02						5		2	4	2			3				2		1	5		1
02–03						5	1	2	4			2					2	1	2	2		8
03–04				1		1	1	4				1	1	1			1					1
04–05				2			1	2		3		1			1		3			1		
05–06		1					2	1				1			2		5		2	3		2
06–07		2					3	2						1			3		5	1		1
07–08						2	1	3				1					1					
08–09								1									3		1		3	
09–10							2	2	3			2										
10–11						1		1	1			5					2		1		2	
11–12								2												1		
12–13		1	1					1	2			1							1			
13–14			1			1			1			3								2		
14–15							3		2			2		1			1		2			
15–16							2		4										3			
16–17			1				1	1	3			1					1		1		2	
17–18							4		4	1		2	1	3					3			
18–19	1	1	2				1		3	1		1							2		1	
19–20							9	1	3	1						2	1		2	1	1	
20–21							1	1	9	1		3		1		1	2		3	1	3	
21–22					4		6	3	6		3	1					2		5	3		
22–23		1			1		6	8	3			1							1	2		
23–24					1		8	2				2							2	2		

Table 18 cont. LIGHTNING COUNT / HOUR – FREETOWN Feb.1964 – Mar.1964

TIME	TOTAL COUNT NOV 63	JAN 64	FEB 64	MAR 64	MEAN %	T.S.D. HEARD NOV 63	JAN 64	FEB 64	MAR 64	MEAN %	COUNT HOURS NOV 63	JAN 64	FEB 64	MAR 64	MEAN %	MEAN COUNT PER COUNT HOUR %
00-01	77	31	4	31	4.4	14	1	2	4	3.4	6	3	2	10	5.6	3.7
01-02	121	35	6	25	5.7	10	1	2	5	2.9	7	2	4	9	5.9	4.7
02-03	408	12	3	19	13.8	13	1	1	3	2.9	6	2	1	10	5.1	13.1
03-04	169	28	3	11	6.4	13	2	1	1	2.7	7	4	3	8	5.9	5.3
04-05	111	23	5	12	4.6	7	0	3	1	1.8	5	3	3	7	4.8	4.6
05-06	61	26	1	18	3.2	9	0	1	2	1.9	5	3	1	8	4.6	3.4
06-07	20	23	4	16	1.9	4	0	2	0	1.0	5	2	3	7	4.6	2.0
07-08	9	12	6	8	1.1	4	0	1	0	0.8	3	3	3	5	3.8	1.4
08-09	17	0	4	8	0.9	1	0	0	0	0.2	5	0	1	4	2.7	1.6
09-10	16	1	0	9	0.8	2	0	0	1	0.5	2	1	0	4	1.9	2.0
10-11	5	0	0	13	0.5	2	0	0	0	0.3	2	0	0	7	2.4	1.1
11-12	6	0	0	3	0.3	0	0	0	0	0	2	0	0	2	1.1	1.3
12-13	13	2	2	5	0.7	0	0	0	1	0.2	2	1	2	4	2.4	1.3
13-14	7	0	1	7	0.5	8	1	0	0	1.5	2	0	1	4	1.9	1.2
14-15	17	7	1	11	1.1	12	0	1	0	2.1	3	2	1	6	3.2	1.6
15-16	14	3	0	9	0.8	14	1	2	2	3.1	5	2	0	3	2.7	1.4
16-17	35	3	1	10	1.5	31	0	5	8	7.1	7	3	1	7	4.8	1.5
17-18	84	9	2	18	3.4	47	0	2	8	9.2	7	1	2	7	4.6	3.6
18-19	116	14	9	9	4.5	56	1	3	10	11.3	8	2	5	6	5.6	3.8
19-20	157	5	3	21	5.7	63	2	6	14	13.7	9	3	1	9	5.9	4.7
20-21	280	13	2	26	9.8	36	0	4	17	9.2	8	2	1	11	5.9	8.0
21-22	327	13	4	29	11.4	28	3	5	16	8.4	9	2	1	8	5.4	10.0
22-23	285	33	2	21	10.4	26	1	2	13	6.8	7	3	2	6	4.8	10.1
23-24	183	38	1	16	7.3	24	2	3	7	5.8	7	3	1	5	4.3	8.2

Table 19. HOURLY COUNT RATES - FREETOWN Nov.1963 - Mar.1964

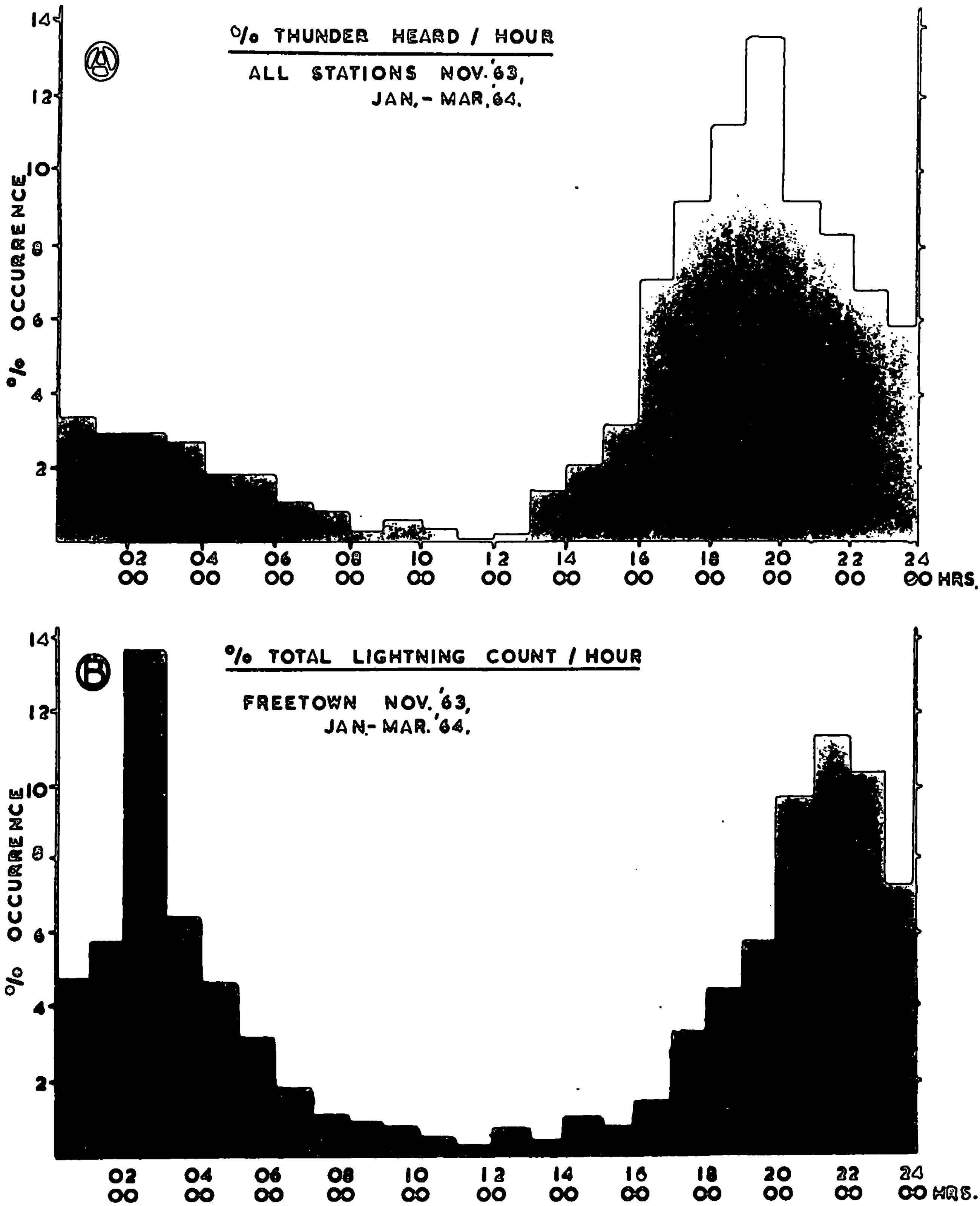
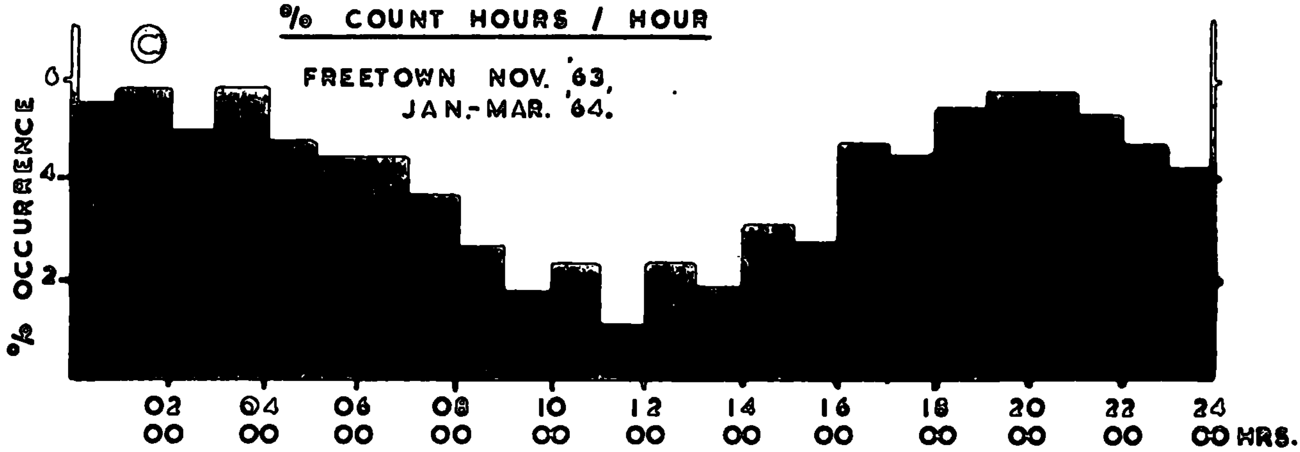


FIG.12 DIURNAL VARIATION OF LIGHTNING COUNTS - FREETOWN



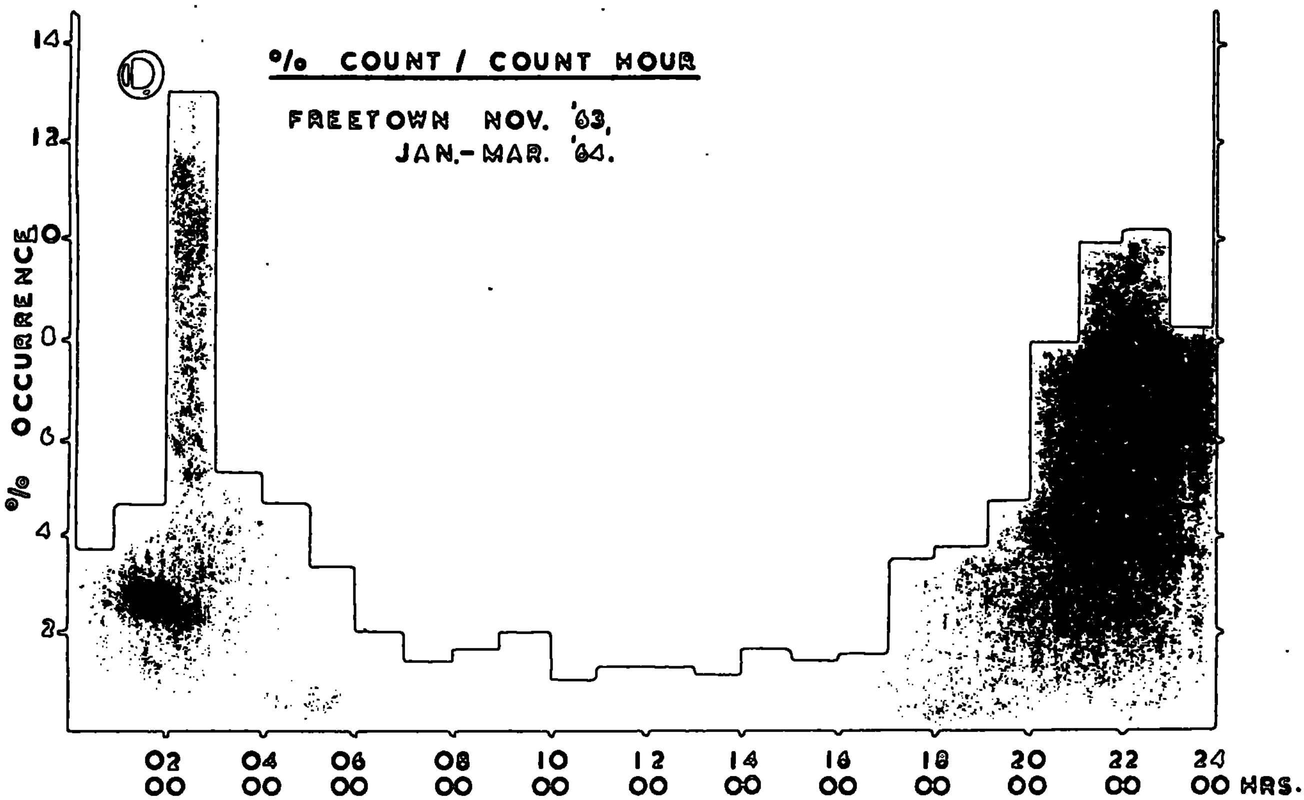
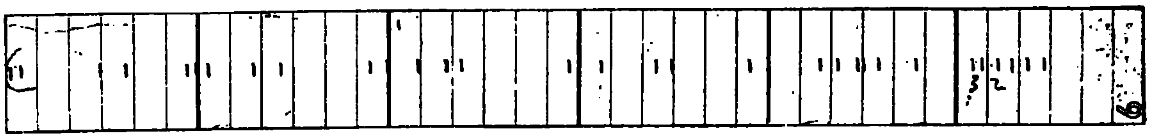


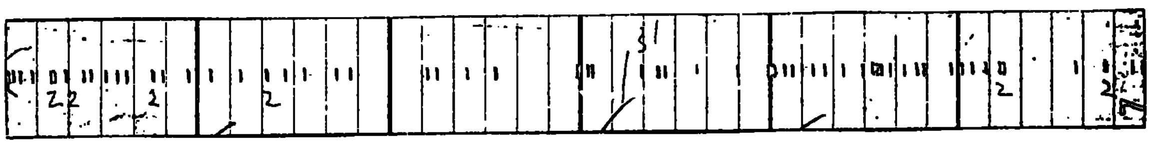
FIG.12 CONT. DIURNAL VARIATION OF LIGHTNING COUNTS - FREETOWN

DATE NOV.		HOURS BEFORE AND AFTER PEAK																	
		P-8	P-7	P-6	P-5	P-4	P-3	P-2	P-1	PEAK	P+1	P+2	P+3	P+4	P+5	P+6	P+7	P+8	P+9
A	1/2			1.1	2.8	2.1	4.6	14.8	12.0	18.3	6.7	2.1	6.3	4.2	3.9	13.7	4.9	2.6	0.4
B	3/4				0.8	8.3	16.5	0	13.4	15.8	13.8	13.4	10.0	0.8	1.2	3.2	2.8		
C	4/5		0.8	3.0	0.4	2.6	7.9	8.2	21.4	29.6	16.5	6.4	2.2	0.8	0	0.4			
D	5/6		0.2	1.5	6.6	5.7	7.2	8.7	14.8	17.1	11.6	5.5	5.7	5.9	4.2	2.3	2.7	0.2	
E	6/7	0.2	0.8	1.9	2.4	3.2	3.2	5.6	11.0	59.5	12.2								
F	10/11							1.9	18.8	44.8	34.4								
G	10/11					0.8	0.8	3.1	31.3	38.2	24.6	2.3							

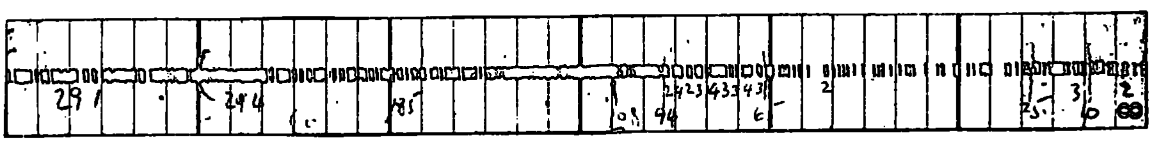
Table 20. PERCENTAGE LIGHTNING COUNT FOR INDIVIDUAL STORMS - FREETOWN Nov.1963



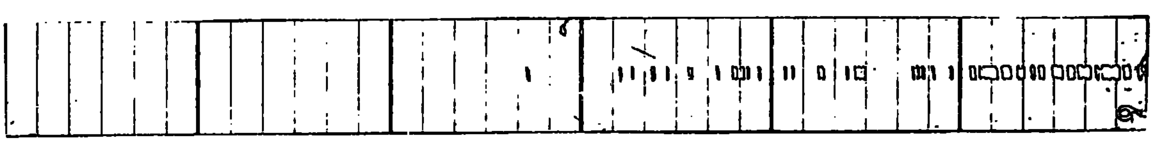
0100 hrs. count in hour = 33 2400 hrs.



0200 hrs. count in hour = 65 0100 hrs.



0300 hrs. count in hour = 351 0200 hrs.



0400 hrs. count in hour = 72 0300 hrs.

SPEED OF CHART = 6" / hour.

Fig. 13. EVENT RECORDER CHART FOR 2400 - 0400 hrs. Freetown, 7th. Nov. 1963

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