

Report to Cigré WG 33-01
for discussion in Dublin, June 1977.

Parameters of upward lightning flashes

Statistical evaluation of all upward lightning flashes from Mount San Salvatore within the observation period 1963...1973 is given in this report.

The analog evaluation of downward flash parameters was published in Electra 1975, Nr. 41 by K. Berger, R.B. Anderson and H. Kröniger for the period 1963...1971.

Before entering into details a remark is necessary regarding definition of upward and downward flashes. This definition is based on progression of the leader which is proved by lightning photography and lightning current oscillograms. Figure 1 shows the 4 types of flashes resulting from polarity and leader progression (Bull. SEV 57, 1966, Nr. 14) as used also in Electra Nr. 41, 1975 for downward flashes. An exception was made there from the above definition for the extremely heavy discharges from positive clouds, initiated by long leaders of 4...25 ms duration and lowering a multiple of the leader charge from cloud to ground. We then decided to count these very heavy discharges as downward flashes, though they had upward leaders. These about 26 heavy flashes were represented in Electra Nr. 41 as curves 3 in the figures 1...9.

Coming now to the evaluation of upward flashes, we have to include this small but important group according to the strong definition based on leader progression. Therefore it becomes necessary now to distinguish positive flashes without and with heavy following impulses. This means split up the former type 4 of figure 1 into the new types 4a and 4b as shown in the new figure 2. Type 4a are flashes without, type 4b flashes with following impulses. These impulses behave exactly like "return strokes" from the cloud to ground.

K.Berger
23.May.1977.

WG 33-01

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Another remark relates to the numbers of figures. Types 2 and 3 of the old figure 1 were interchanged to types 3 and 2 of the new figure 2. This means that distinction is made now basically on polarity, not on leader direction. Types 1 and 2 now represent all negative flashes, types 3 and 4 all positive flashes.

Types 1, 2 and the very rare type 3 probably are not limited to mountainous regions but will happen also in the flat or open country. Schonland in South Africa made observations exclusively on type 1, McEachron and al. (Hagenguth) in New York on type 2. Only one photograph has been published of a flash to Campione on the lake of Lugano by a camera with moving film. Type 4 on the contrary is the specific type on mount San Salvatore, designated as "mountaintip flash" by M.A. Uman et al. (Journal of Geophysics Research 80, 1975, p.373...376).

Some of the most interesting parameters of the statistic of all types of upward flashes are given on the annexed tables I...IV. Types 2a, 2b and 4a have been evaluated by computer by Mr. M. Hwang of the High Voltage Dep. of the Swiss Institute of Technology, Prof. W. Zaengl in Zürich. The values of type 4b correspond to curves 3 in the figures in Electra 1975, Nr. 41, referred to as "positive downward" flashes, as explained before.

Some examples of distribution curves of the parameters, as listed in the tables, are annexed to this report; some other ones will be shown in Dublin.

Annexes:

Figures 1 and 2,
Tables I...IV,
Curves Nr. 1, 4, 12, 13,
17, 19, 21, 31.

K. Berger

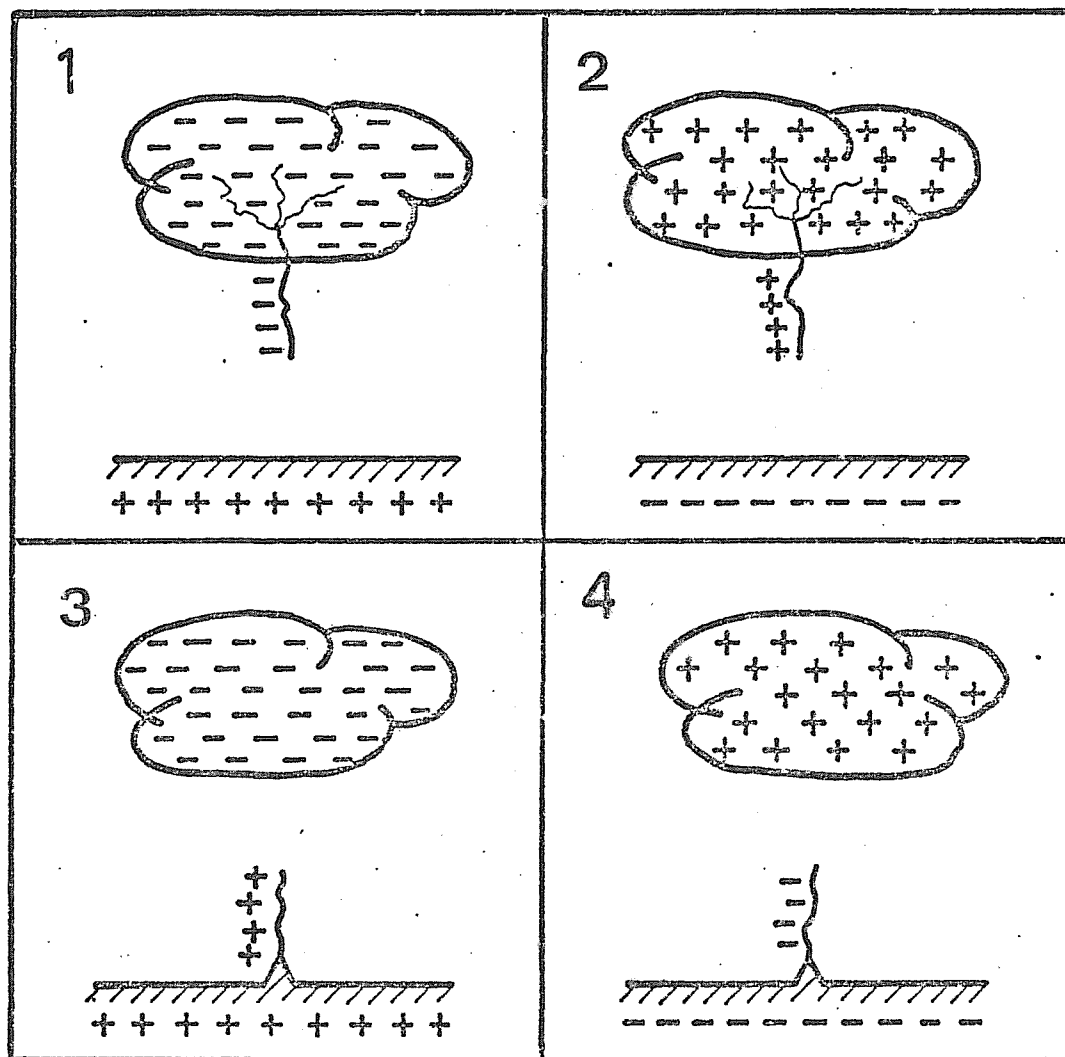


Figure 1

The four types of leaders

(Bull. SEV 57, 1966, Nr.14, fig. 11)

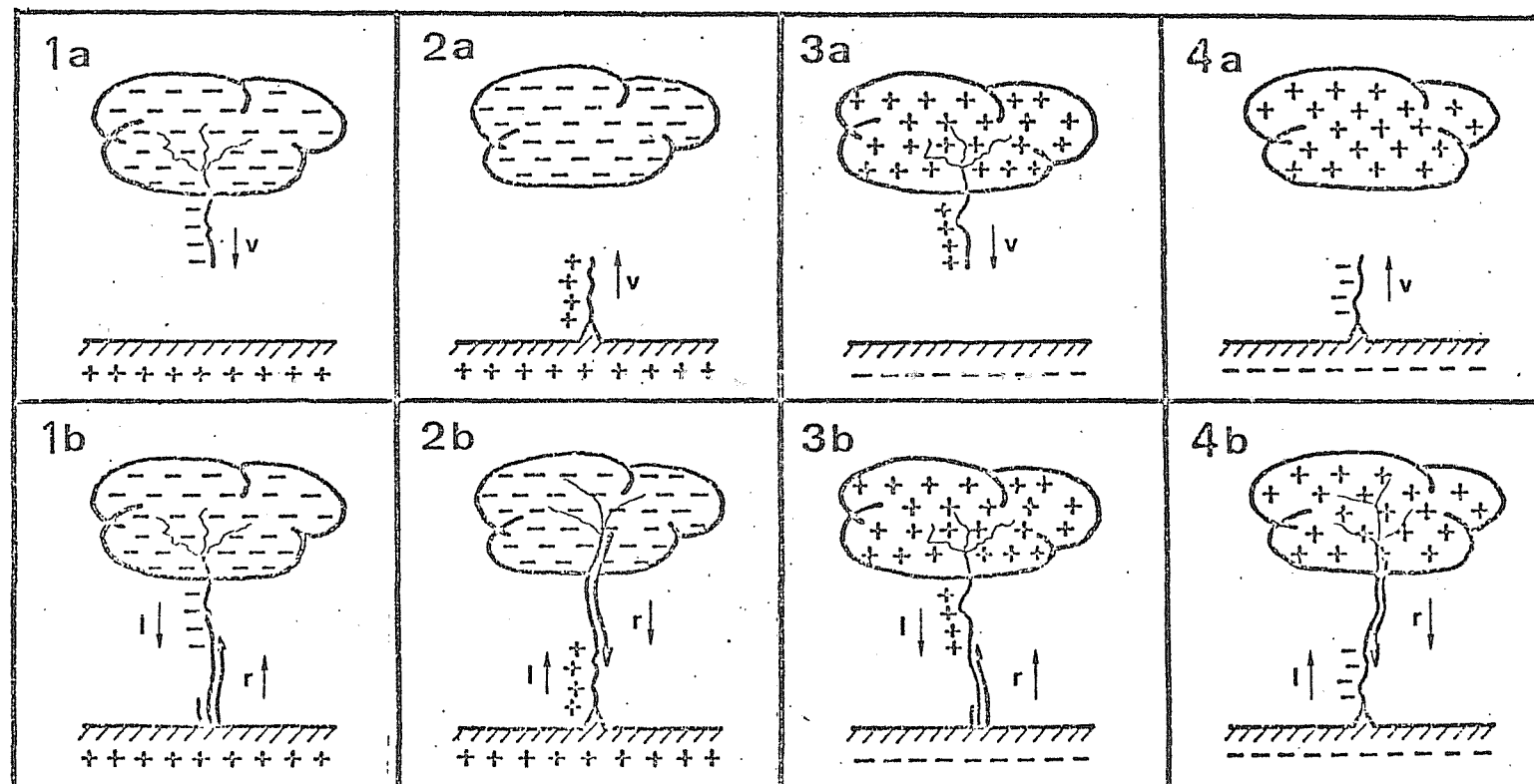


Figure 2

The eight types of flashes

Types 1a and 3a are cloud flashes only

Parameters of upward Lightning strokes from Mt. San Salvatore
Observation period 1963...1973.

Table I

Nr.	Parameter	Type of Flash (Fig.2)	Single or Multiple	Polarity of current	Kind of statistics	Number of oscill.	10%	50%	90%	σ
							A	A	A	
1 ⊗	$\hat{i}$	2a & 4a	S	+ & -	Single str.flash	777	2040	290	41	4,5
2		2a	S	-	" " "	639	1030	203	40	3,5
3		4a	S	+	" " "	138	11'000	1510	206	4,4
-		4b	S	+	" " "	26	250'900 x)	35'000	4'600 x)	-
4 ⊗	$\hat{i}$	2b	M	+ & -	Strokes in multiple flashes	399	1640	266	43	4,0
5		2b	M	+ & -	First strokes	219	1650	276	46	3,7
6		2b	M	-	" "	195	1310	248	47	3,3
9		2b	M	+ & -	Following strokes	180	1730	255	38	4,3
10		2b	M	-	" "	151	923	183	36	3,4
10a		2a & 2b	M	bipolar	-	13	5830	1670	478	2,2
7		2a & 2b & 4a	S & M	+ & -	Single strokes & first strokes	996	1910	287	43	4,3
8		2a & 2b	S & M	-	" "	834	1070	213	42	3,5
⊗ copy of curve annexed						x)	5% and 95% -values			

Parameters of upward lightning strokes from Mt. San Salvatore
Observation period 1963...1973.

Table II

Nr.	Parameter	Type of Flash (Fig.2)	Single or Multiple	Polarity of current	Kind of Statistics	Number of oscill.	10%	50%	90%	σ
							Cb	Cb	Cb	
11	Q	2b	M	+ & -	All strokes in flashes	824	26,9	2,0	0,15	7
12		2a	S	-	Single stroke flashes	638	69	11,6	1,94	4
13		4a	S	+	" "	137	187	26,4	3,72	4,3
-		4b	S	+	" "	26	350 x)	80	20 x)	-
14		2b	M	+ & -	Following strokes	609	7,2	0,93	0,12	4,38
15		2b	M	-	" "	579	4,1	0,77	0,14	3,42
16	Q Imp.	2b	M	+ & -	" "	547	1,5	0,52	0,18	2,2
							kA / μ s	kA / μ s		
17	di / dt	2b	M	+ & -	Following strokes	725	124	26	5,3	3,3
18		2b	M	-	" "	710	123	26,4	5,6	3,2
-		4b	S	+	Single stroke flashes	21	32 x)	2,4	0,2 x)	-

Ø copy of curve annexed

x) 5% and 95% -values

Parameters of upward lightning strokes from Mt. San Salvatore
Observations period 1963...1973.

Table III

Nr.	Parameter	Type of Flash (Fig.2)	Single or Multiple	Polarity of current	Kind of Statistics	Number of oscill.	10%	50%	90%	σ
							$\text{kA}^2 \cdot \text{s}$	$\text{kA}^2 \cdot \text{s}$	$\text{kA}^2 \cdot \text{s}$	
19	$\int i^2 \cdot dt$	2b	M	+ & -	Following strokes	420	$1,8 \cdot 10^4$	$2,7 \cdot 10^3$	$4,1 \cdot 10^2$	4,1
20		2b	M	-	" "	398	$1,0 \cdot 10^4$	$2,3 \cdot 10^3$	$5,0 \cdot 10^2$	3,2
-		4b	S	+	Single stroke	26	$1,5 \cdot 10^7$	$6,5 \cdot 10^5$	$2,5 \cdot 10^4$	-x)
							μs	μs	μs	
21	T Front	2b	M	+ & -	Following strokes	711	4,2	1,0	0,3	2,6
22		2b	M	-	" "	696	4	2	0,3	2,6
-		4b	S	+	Single stroke	19	200 x)	22	3,5 x)	-
							ms	ms	ms	
23	T Flash	2b	M	+ & -	Complete flash	236	800	331	137	1,94
24		2b	M	-	" "	212	791	338	144	1,9
-		4b	S	+	Single stroke	24	500 x)	85	14 x)	-

A copy of curve annexed

x) 5% and 95% -values

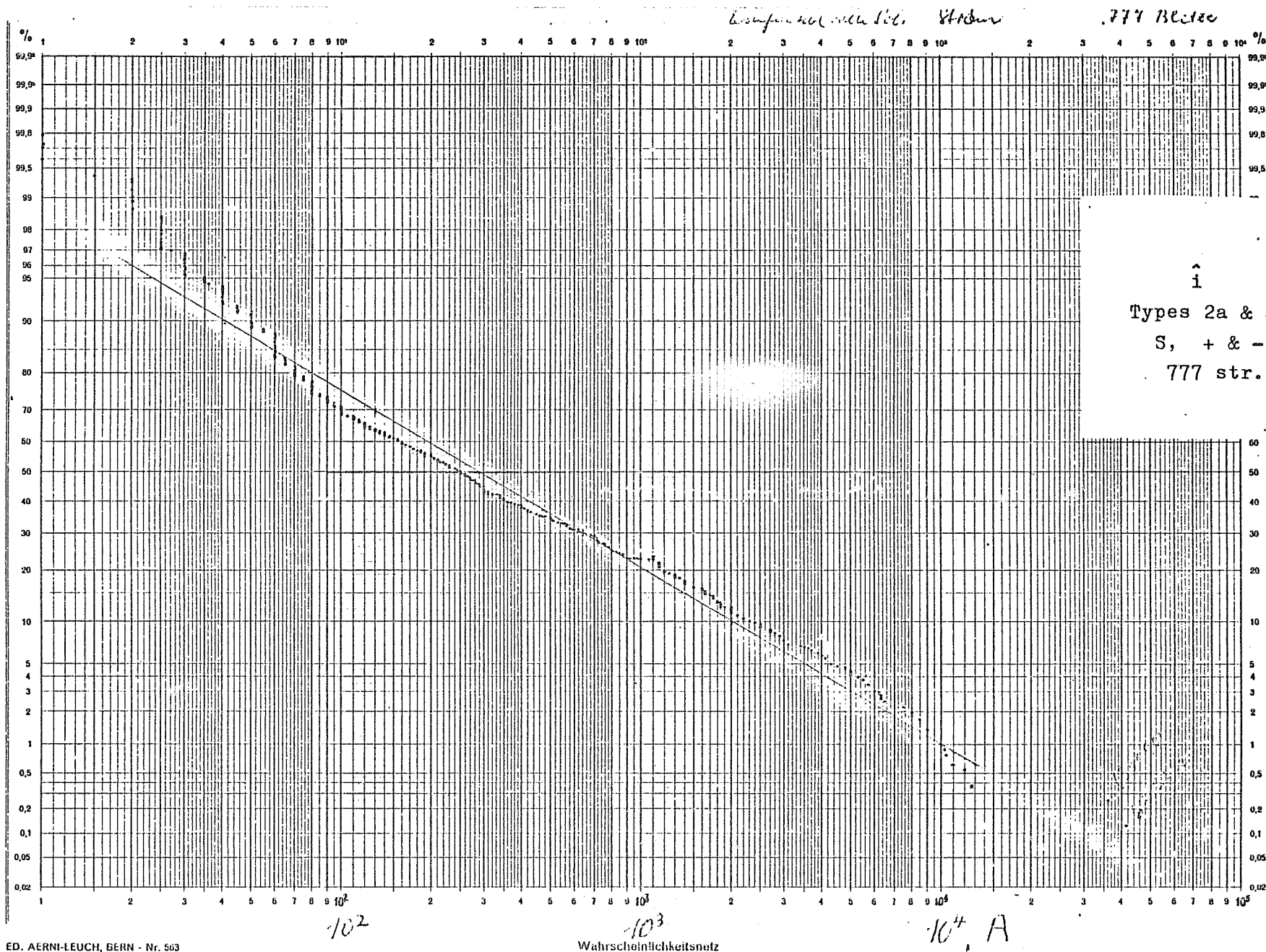
Parameters of upward lightning strokes from Mt. San Salvatore
Observation period 1963...1973.

Table IV

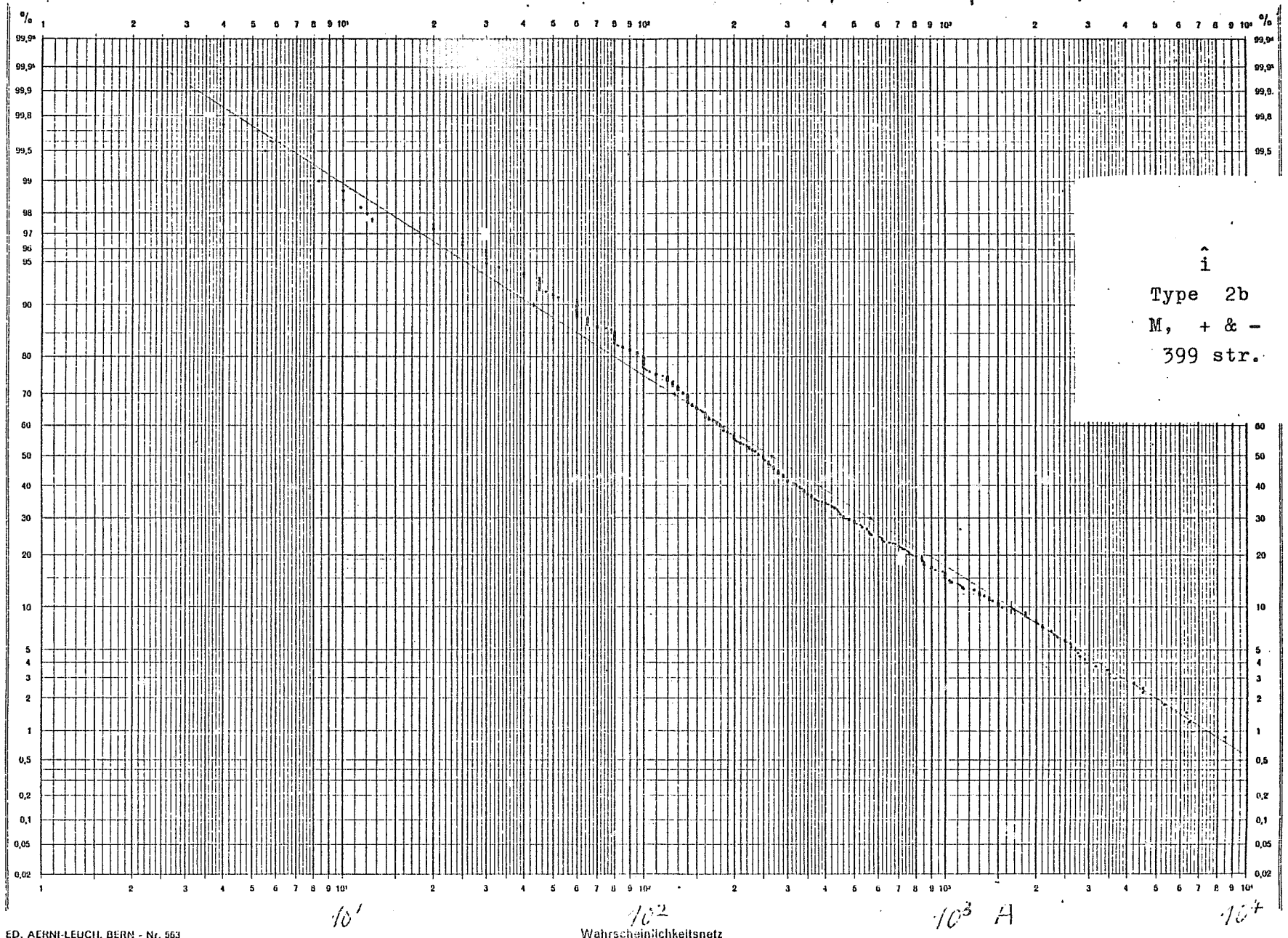
Nr.	Parameter	Type of Flash	Single or Multiple	Polarity of current	Kind of Statistics	Number of oscill.	10%	50%	90%	σ
							ms	ms	ms	
25	T Stroke	2b	M	+ & -	Strokes in multiple flashes	1149	131	8,2	0,52	7,4
26		2a	S	-	Single str.flash	639	407	163	65	2,0
27		4a	S	+	" " "	138	215	72	24	2,3
-		4b	S	+	" " "	24	500 x)	85	14 x)	-
28		2b	M	+ & -	Following strokes	919	27,5	3,9	0,56	4,0
29		2b	M	-	" "	888	22,3	3,6	0,57	3,7
30		2b	M	+ & -	Single strokes & first strokes	1007				
31	n number of strokes per flash	2b	M	+ & -	First strokes & following strokes	1236	} No Gaussian distribution See curves !			
32		2b	M	+ & -	Following strokes	998				
33		2b	M	-	" "	966				

copy of curve annexed

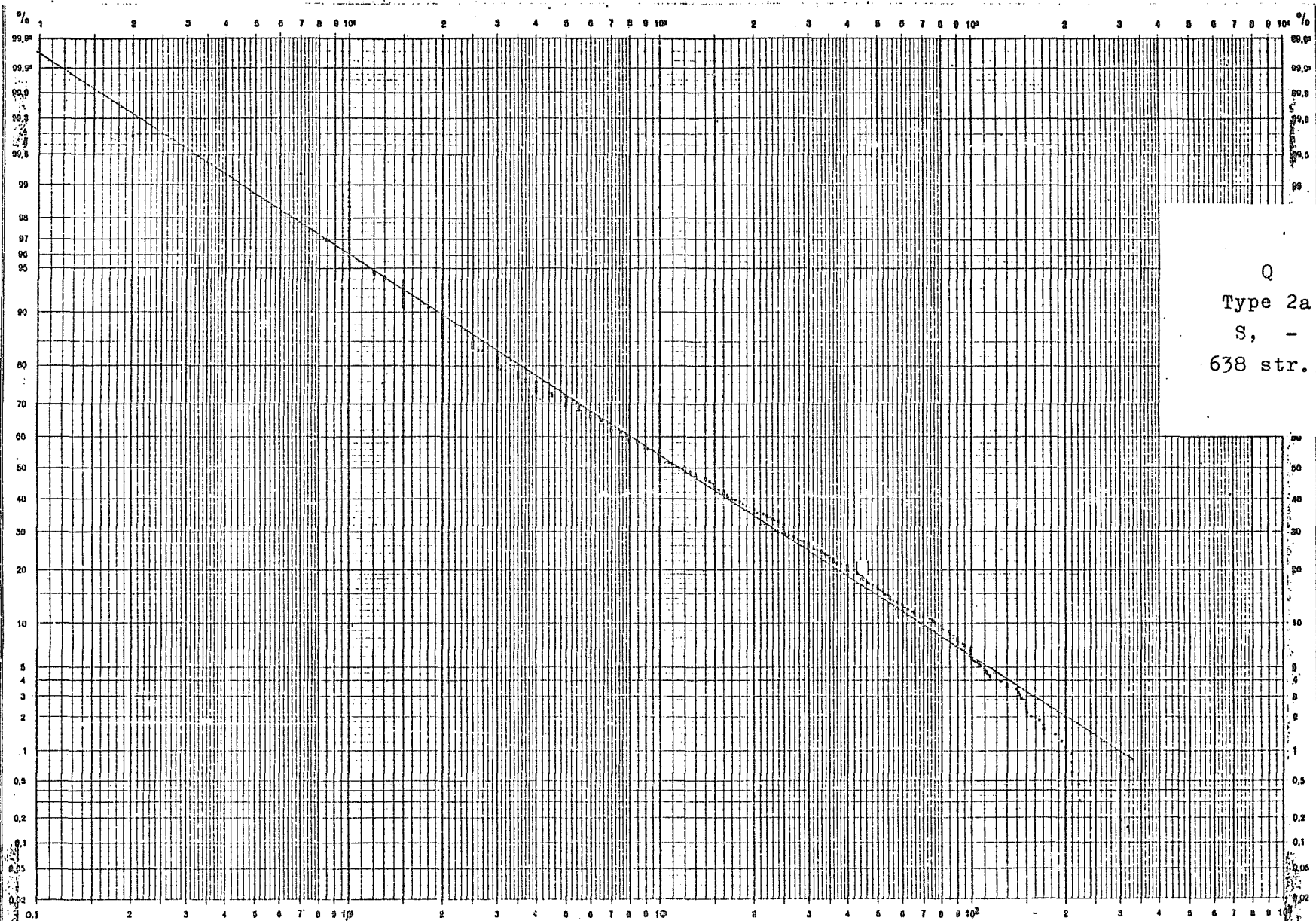
x) 5% and 95% -values



2, wie mehrfachste, 1971



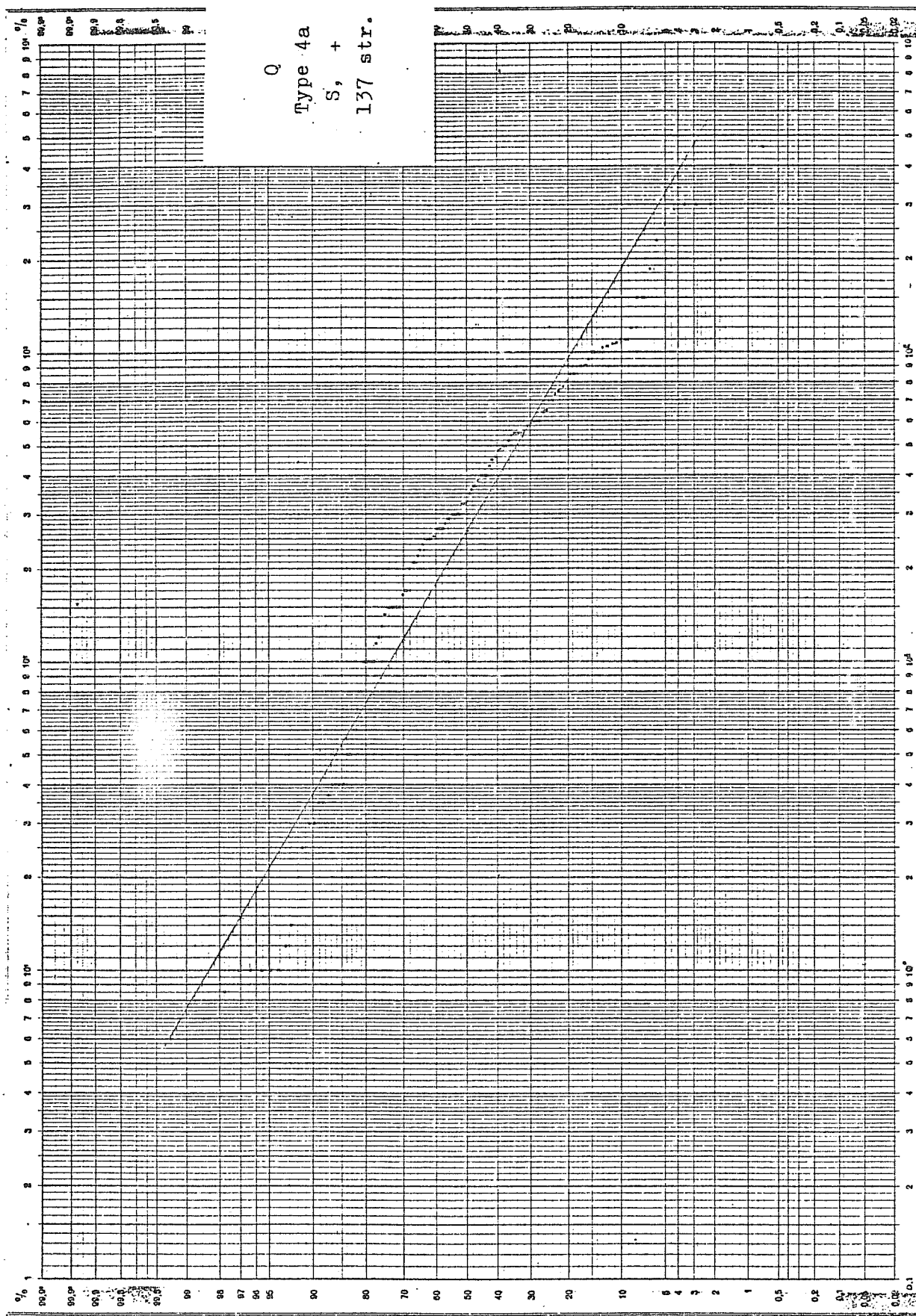
$\hat{i}$
Type 2b
M, + & -
399 str.



Q
Type 2a
S, -
638 str.

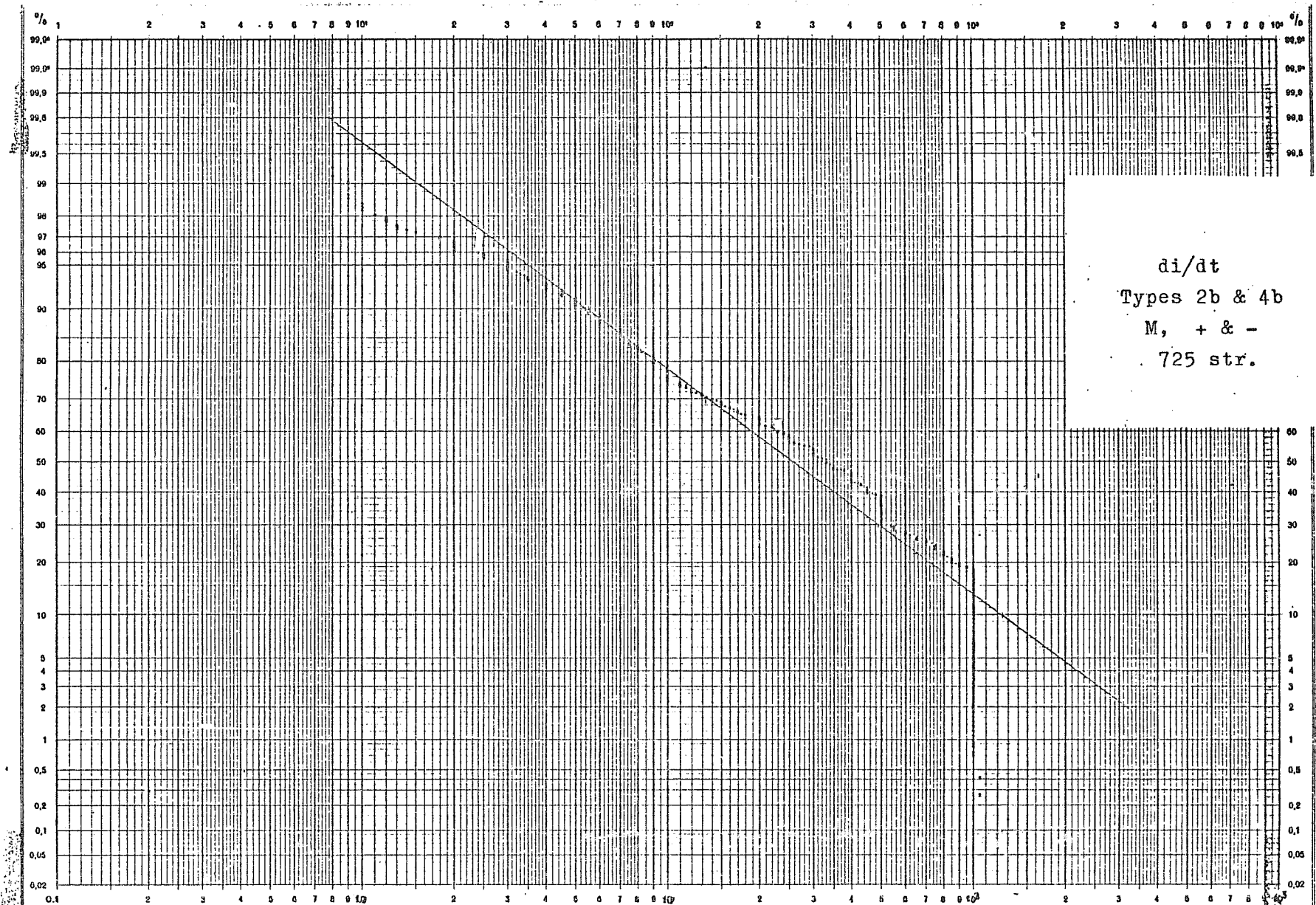
12

Q
Type 4a
S, +
137 str.

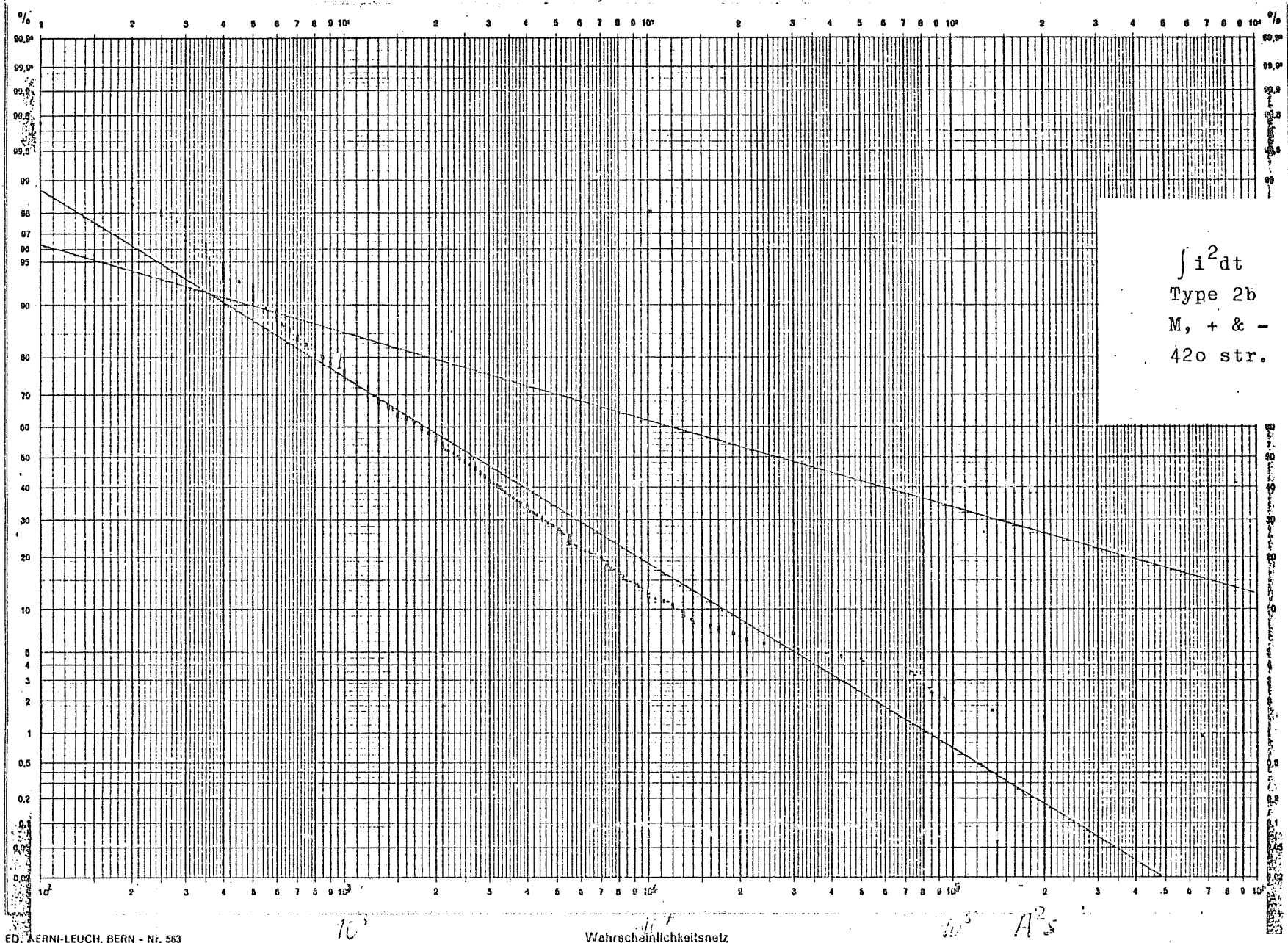


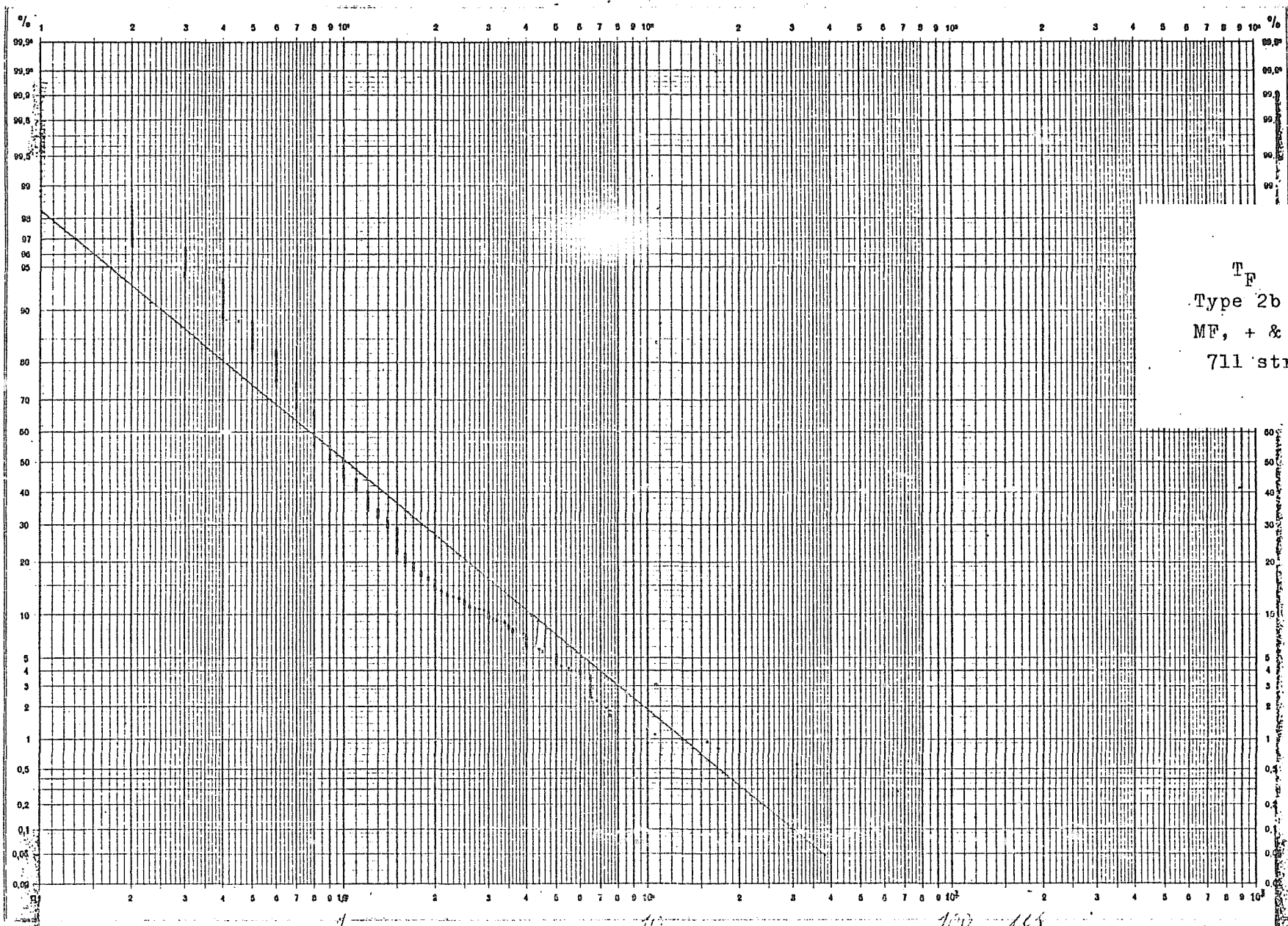
100.00

Wahrscheinlichkeitsnetz



di/dt
 Types 2b & 4b
 M, + & -
 725 str.



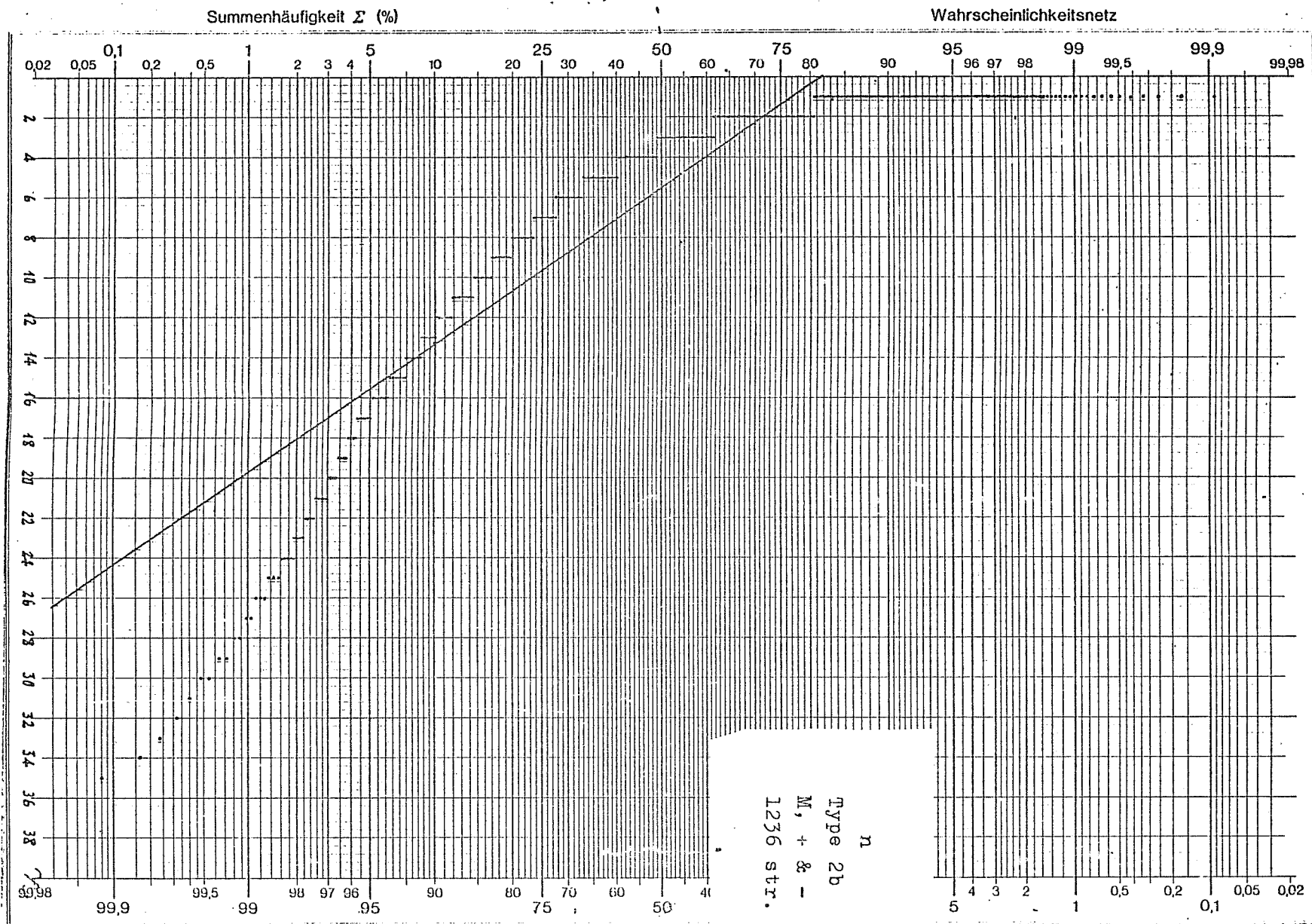


T_F
 Type 2b
 MF, + & -
 711 str.

21

100 ACS

115



K. Berger
6 June 1977

Cigré WG 33-01

Supplement to the report :
Parameters of upward lightning flashes.
June 1977.

1) Tables I...IV have been completed by an evaluation of lightning flash types 4b and (4a & 4b) for the 11-years period 1963...1973, completing the lines without numbers and marked with a cross x) in the report. The values for type 4b and indicated in the report are concerned with the 9-year period 1963...1973 and gave 5 % and 95 % values, instead of 10 % and 90 % in the report for Dublin. For the 5 % and 95 % values see Electra Nr.41, 1975.

The expanded values are for type 4b :

Table	Nr.	Parameter	Strokes	10 %	50 %	90 %	$\bar{\sigma}$
I	3a	$\hat{i}$	35	127	36,3	10,4	2,45
II	13a	Q	35	348	84,2	20,4	2,73
II	18a	di/dt	31	12,2	1,85	0,28	3,77
III	20a	$\int i^2 dt$	35	$8,6 \cdot 10^6$	$6,6 \cdot 10^5$	$5,0 \cdot 10^4$	6,5
III	22a	T(Front) μs	23	340	39	4,5	4,4
III	24a	T(Flash) ms	34	240	67,6	19,1	2,5
IV	27a	T(Stroke) "	"	"	"	"	"

2) Curves Nr.31...33 have been completed by the "group-frequency" G joined to the summation frequency Σ .

3) The report to Dublin provides stroke parameters, not parameters of the whole flashes. This is of special interest for the electric charge Q of complete flashes, which are not mentioned in the report. To compensate this lack, an evaluation of the total charge, transported by positive and negative up- and downward flashes in the whole period 1963...1973 is given here :

Q in negative flashes	Q in positive flashes
↓ 1'469 Cb or 5 %	↓ 3'456 Cb or 24,4 %
↑ 27'244 " " 95 %	↑ 10'691 " " 75,6 %
28'713 Cb or 100%	14'147 Cb or 100 %

The total charge in all + and -, ↓ and ↑ flashes = 42'860 Cb.
The percentage of the total charge is therefore :

Negative flashes	Positive flashes
↓ 1469 / 42860 = 3,4 %	↓ 3456 / 42860 = 8,1 %
↑ 27244 / " = 63,6 %	↑ 10691 / " = 24,9 %
<u>All neg.flashes = 67 %</u>	<u>All pos.flashes = 33 %</u>

The mean electric charge per flash is in the 11 year period :

↓ Negative flashes = 11,1 Cb/flash, ↓ positive fl.= 91 Cb/fl.
↑ Negative flashes = 32,5 " ↑ positive fl.= 54 "

These figures are the result of 1222 flashes, 1963...1973.
In the 9-years-period 1963...1971 the corresponding number of oscillograms (flashes) was 1026, and the relative numbers of flashes of types 1...4 are reproduced here below (see Bull.SEV 63, 1972, Nr.24, p.1402...1423), table V.
A typical example of a 4b-type-flash is annexed to this supplement (Fig.3).

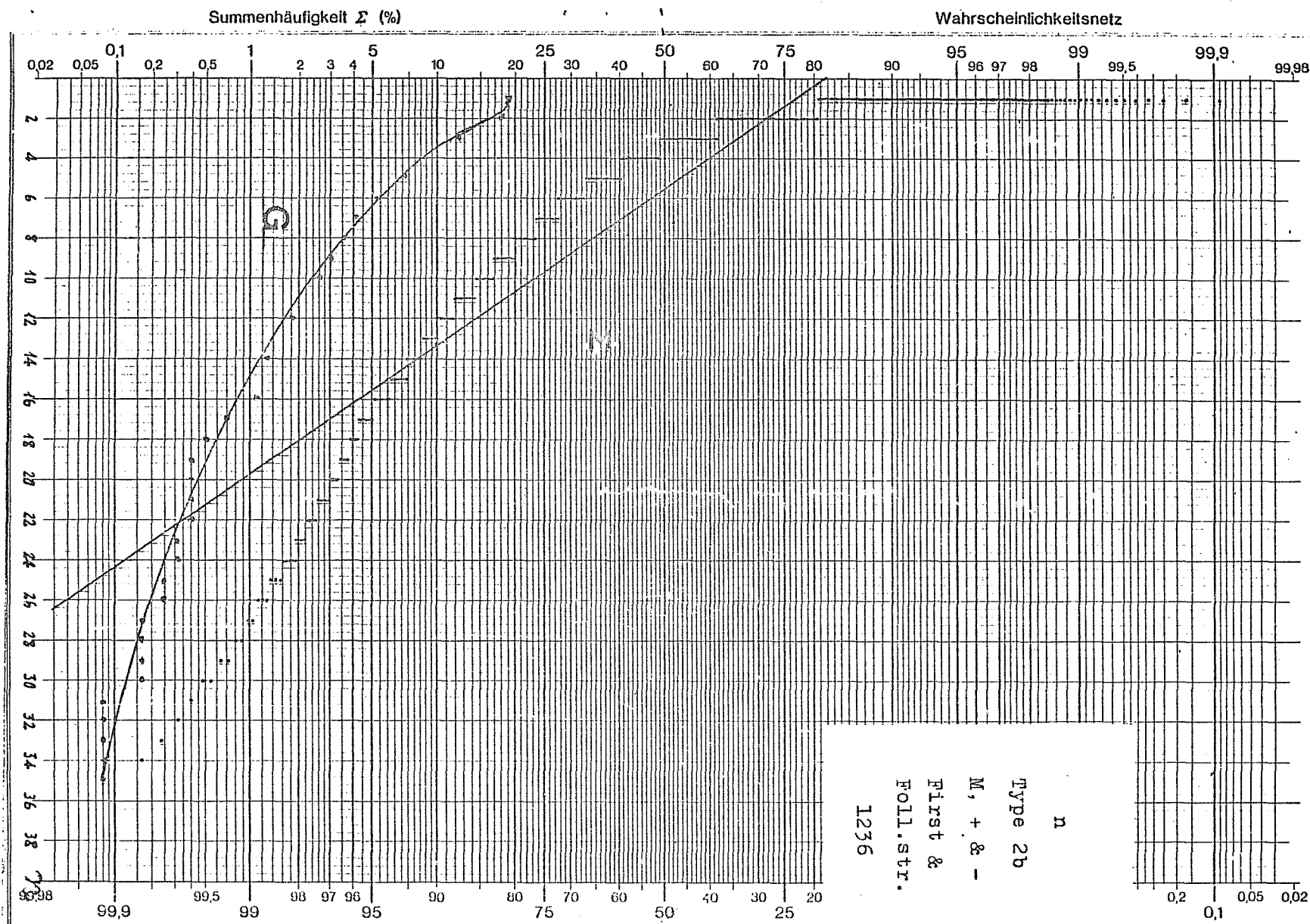
Table V.

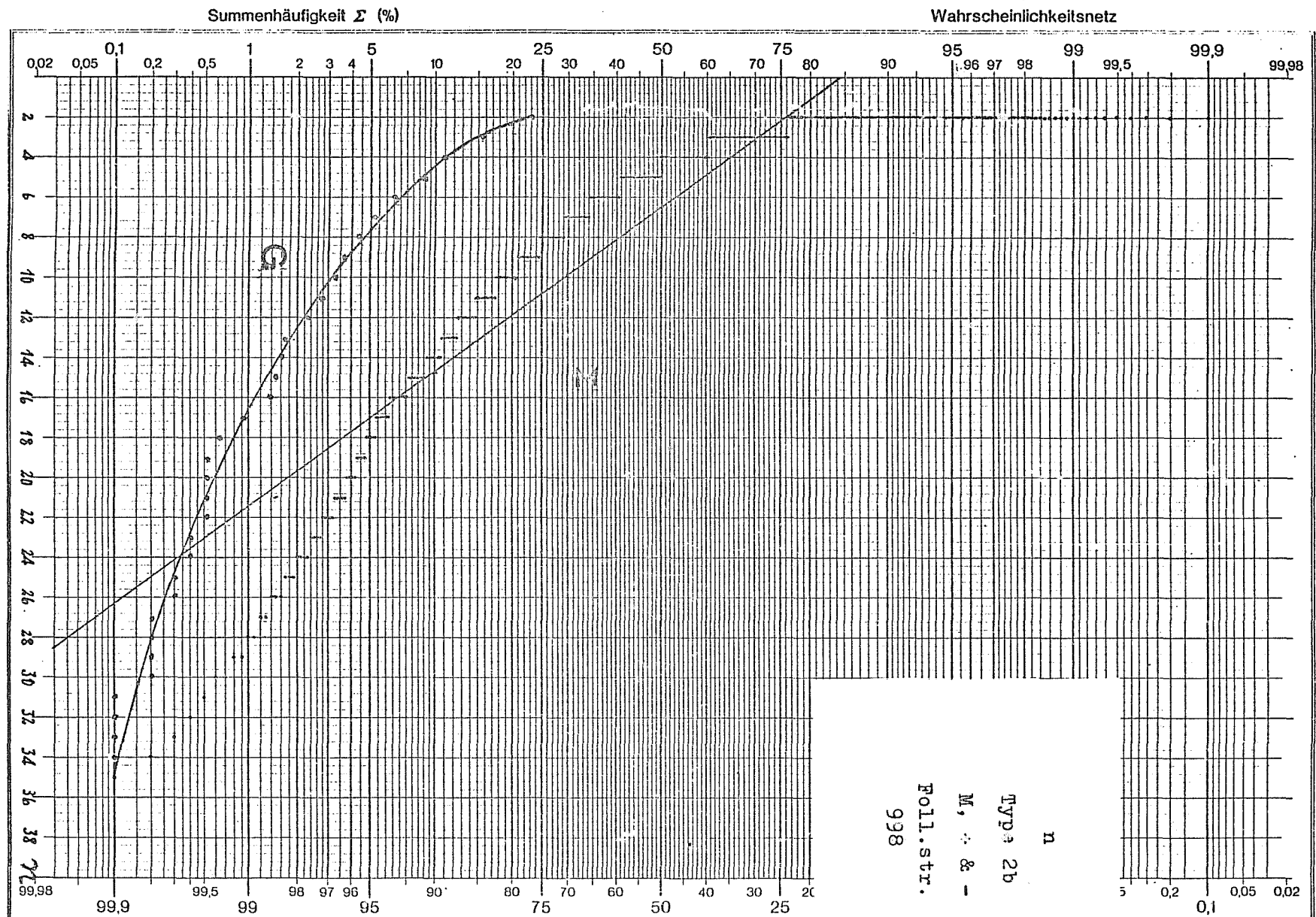
Jahr	↓ -	↑ -	↓ +	↑ +	Bipolar		Total
					↓	↑	
1963	22	83	3	5	1	4	118
1964	6	37	1	6	0	6	56
1965	3	91	1	15	0	8	118
1966	6	120	5	19	3	7	160
1967	12	90	9	26	0	13	150
1968	2	85	4	5	0	3	99
1969	3	38	2	6	1	2	52
1970	32	68	0	2	0	6	108
1971	20	120	2	18	0	5	165
1963 bis 1971	106	732	27	102	5	54	1026

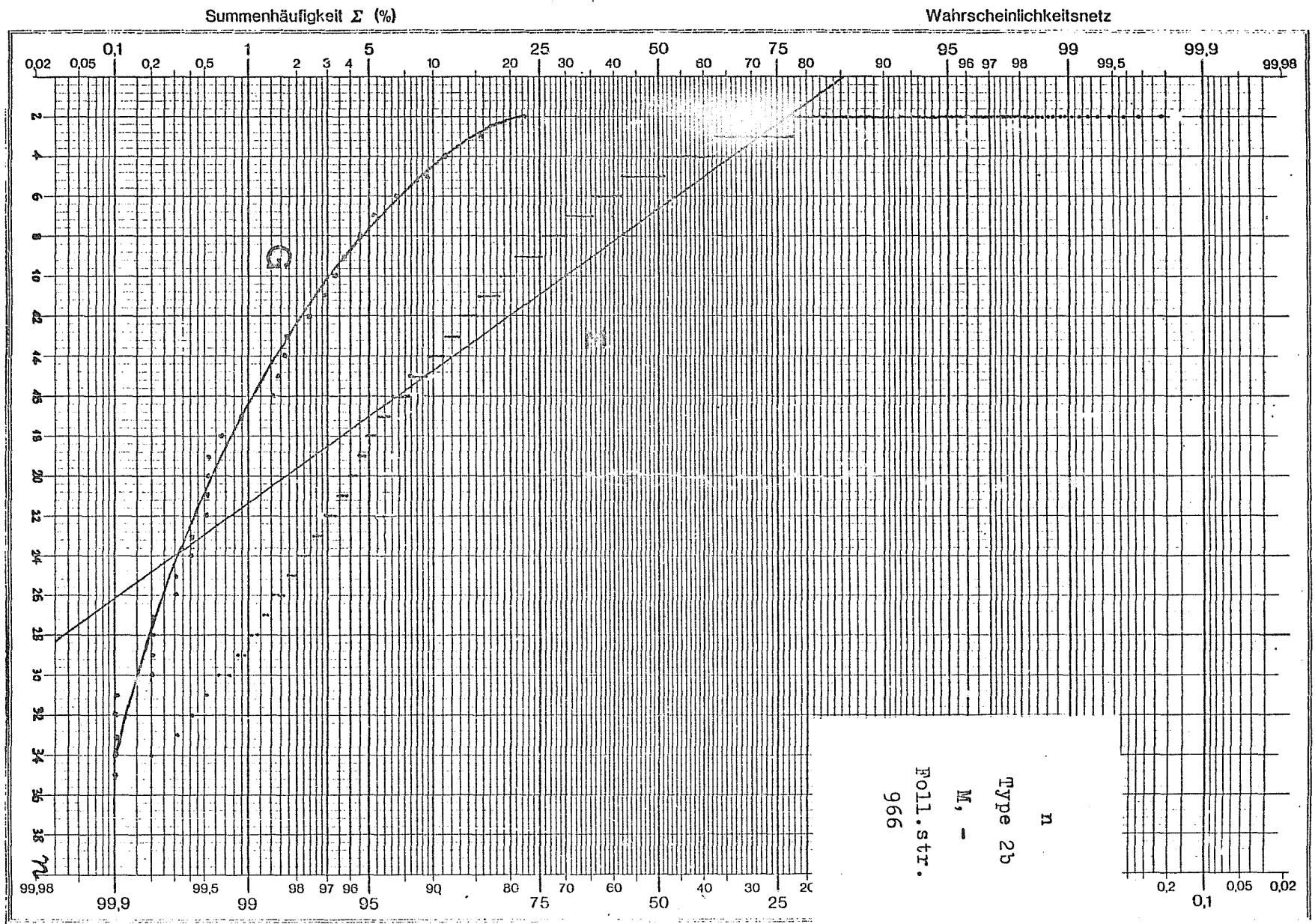
Annexes:

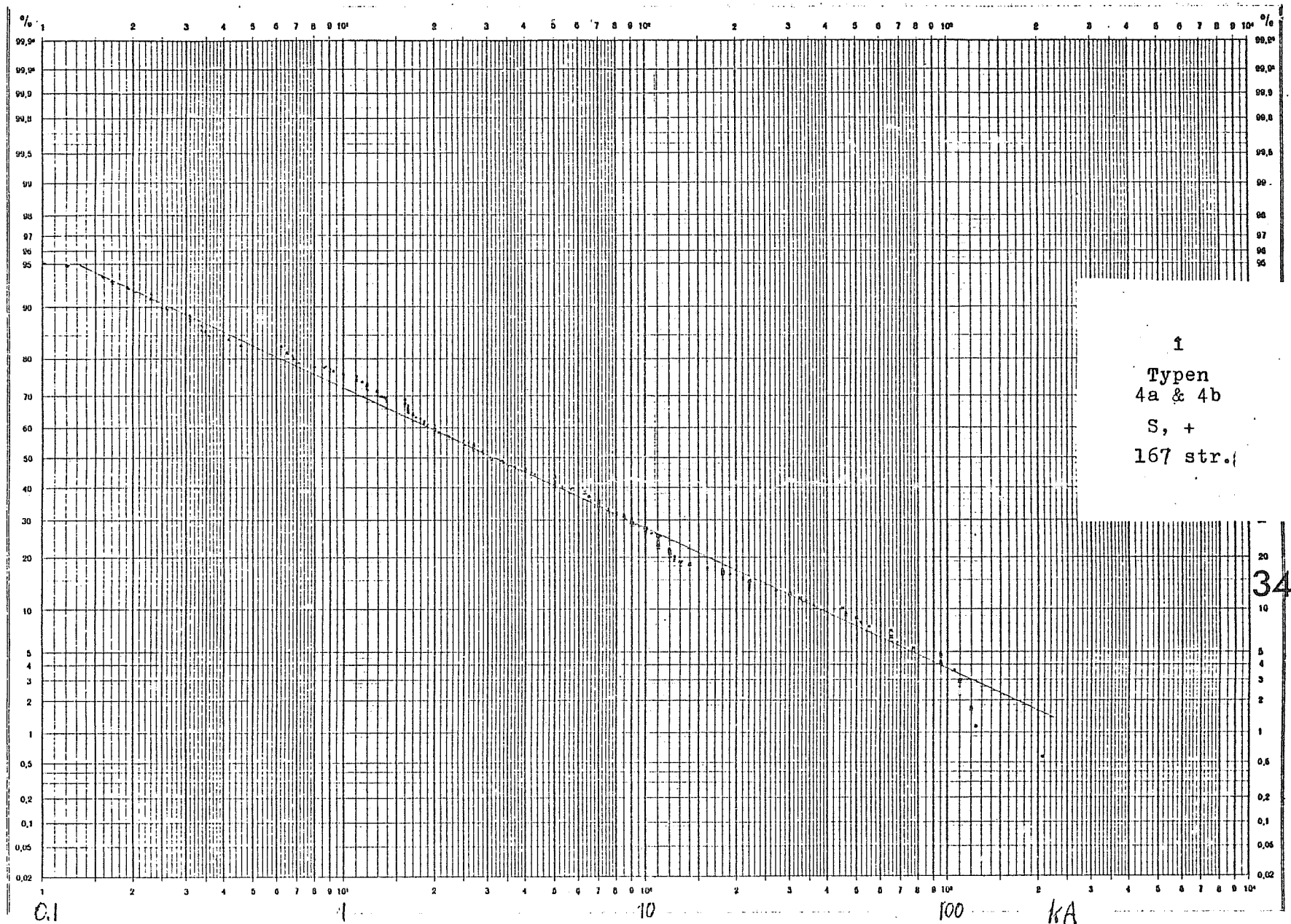
Curves 31, 32, 33, 34

Osc. Fig. 3.









i
 Typen
 4a & 4b
 S, +
 167 str.

34

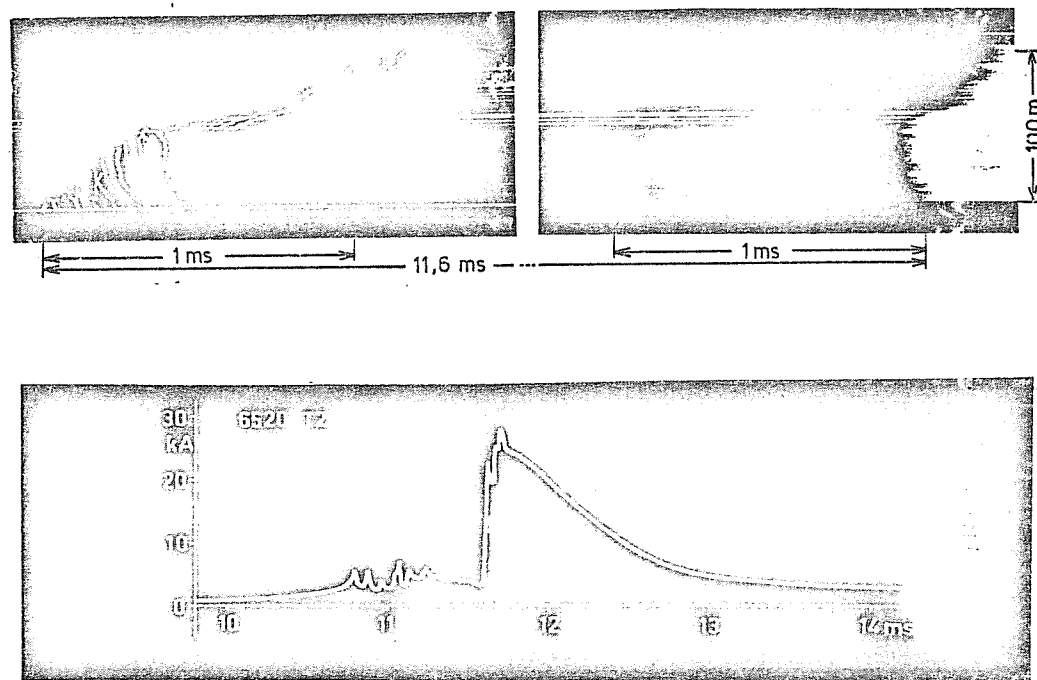


Figure 3 Positive flash to the tower on mount San Salvatore : Upward leader/downward return stroke

Above : Streak camera foto

Below : Current oscillogram