PRECIPITATION RATE ANALYSIS ON HIGH VOLTAGE WET TESTS

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Abstract : This paper analyzes the precipitation distribution in the test zone, on high voltage wet tests. The horizontal and vertical components of the precipitation produced by one nozzle , were measured and 2 matrixes obtained with this information. The precipitation distribution on the test zone was analyzed by means of a computer program. This program superposes the rain produced by a certain number of nozzles by means of adding their precipitation intensity matrixes.

This study concludes that large rain non uniformities may appear although the apparatus is adjusted according to present standards.

These large non uniformities are proposed as one of the causes of great dispersions in flashover voltages on wet tests.

INTRODUCTION

The great dispersion in flashover voltages on wet tests is well known. It becomes a problem when the same object is tested at different laboratories , as mentioned in several papers [1] , [2]. Many other papers [3 to 7] establish the influence of different factors on flashover voltages. Some of these factors are the water resistivity , the prewetting time , the precipitation rate , the influence of previous flashovers , etc. On papers referenced in [2] and [9] , the influence of precipitation non uniformity and the measurement procedures are analyzed. They conclude that the lack of rain uniformity along a vertical axis over the test object, generates large variations on the flashover voltages.

Our paper focuses on these two last factors. Therefore a computer program to simulate rain apparatus adjustments was developed.

Knowing the precipitation distribution produced by one nozzle , and entering the directions at which sprays are aimed, the rain distribution at the test area is obtained.

With this method , different adjustments can be simulated in few minutes. The precipitation non uniformities and their influence on the flashover voltages were analyzed in this way, for different rain apparatus adjustments.

MEASUREMENT OF THE PRECIPITATION RATE OF ONE NOZZLE

The apparatus used on this paper possesses nozzles according to IEC standard [8] , type I of 0.5 mm in diameter , and its general construction coincides with the description contained in reference [10] . Our rain equipment was originally conceived to produce precipitations of 3 mm/min . Notwithstanding our work was carried out using average precipitations in the 1.0-1.5 mm/min range , and extreme precipitations of 0.5 mm/min and 2.0 mm/min , according to the revised procedure of the standard previously mentioned.

General conditions of the tests were :

water overpresure	: 2.0 kgf/cm
flow rate	: 186 cm /min
nozzle position	: horizontal
distance between nozzle and test plane	: 4.4 m

Measurements were taken with several collecting vessels, set simultaneously side by side on a horizontal row. Their openings were 10 cm high and 5 cm wide. Changing openings directions , both vertical and horizontal rain components were measured with this same setting . While taking each series of measurements over the test zone , the entire row of vessels was kept steady , covering each time a measuring zone of 10 cm high. Measurements were taken this way at different hights covering the entire test plane in short time.

A suitable nozzle had to be chosen for this test . Several nozzles were discarded because they produced unstable or irregular sprays. It was found that small irregularities on the capillary conduct were cause of sudden deviations of as large as 3 degrees , on water jet trajectories. These deviations are big enough as to overlap two adjacent sprays over the test zone , leaving there some dry areas.

It was stated that optically smooth conducts produce fairly stable regular sprays.

Tables I and II present resulting precipitation intensity matrixes. It should be noticed that both matrixes are exactly symmetrical in respect to a central vertical axis . This was achieved by substituting slightly different values symmetrically positioned , for their average value. Each matrix value corresponds to the precipitation intensity on a rectangle of 5 cm wide and 10 cm high on the test plane. It is worth noting that maximum values of both matrixes do no coincide spatially.

Maximum of vertical component matrix values (1.80 mm/min) lies 20 cm under maximum of horizontal component matrix (2.73 mm/min).

Figures 1 and 2 show the diagrams of precipitation intensity along the horizontal and vertical axes, along the maximum value of each matrix . Figure 1 corresponds to horizontal precipitation intensity, and figure 2 to the vertical one.

It should also be noted that values, along the vertical central axis over the maximum of the horizontal matrix (fig. 1a), are meaningful to as far as 1.1 m of the maximum. Meanwhile, for the vertical matrix (figure 2a) values are meaningful still further , until 2.4 m of the maximum . This is true, although the average rain angle observed remains 45 degrees because while loosing horizontal speed the water jet is accelerated downwards , resulting in a kind of accumulation of vertical component of the precipitation , as noted on previous papers [11].

Thereafter it results apparent how difficult it is to propose an adequate precipitation measuring method , and a spray apparatus setting method when numerous nozzles are used. When using a multiple nozzle equipment, the 45 degrees-visual-setting method is inappropriate and inaccurate, because of the one-nozzle precipitation distribution previously described.

Present widely used setting method , of adjusting vertical and horizontal rain components individually, although more objective is neither perfect . Using this last adjustment method one can achieve both , a rain which falls visually in 45 degrees over the test object , and a rain composed of strong horizontal and vertical components with no 45 degrees falling drops . With such both rain

0.05	0.08	0.15	0.08	0.05
0.09	0.39	1.41	0.39	0.09
0.12	0.67	2.73	0.67	0.12
0.14	0.96	2.30	0.96	0.14
0.16	1.08	1.44	1.08	0.16
0.17	0.65	0.93	0.65	0.17
0.17	0.49	0.61	0.49	0.17
0.16	0.37	0.47	0.37	0.16
0.14	0.31	0.37	0.31	0.14
0.13	0.27	0.33	0.27	0.13
0.11	0.20	0.24	0.20	0.11
0.08	0.17	0.19	0.17	0.08
0.07	0.14	0.15	0.14	0.07
0.05	0.10	0.13	0.10	0.05

Table I

Horizontal precipitation-intensity matrix produced by 1 nozzle.

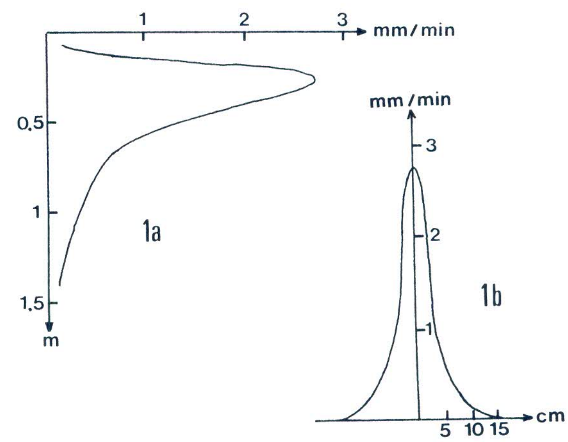


Figure 1

Horizontal precipitation-intensity distribution, produced by 1 nozzle.

0.00	0.00	0.16	0.00	0.00
0.00	0.07	0.26	0.07	0.00
0.04	0.15	0.39	0.15	0.04
0.07	0.34	1.27	0.34	0.07
0.12	0.78	1.80	0.78	0.12
0.20	0.76	1.17	0.76	0.20
0.28	0.68	1.00	0.68	0.28
0.30	0.68	0.93	0.68	0.30
0.33	0.58	0.77	0.58	0.33
0.30	0.52	0.73	0.52	0.30
0.23	0.53	0.72	0.53	0.23
0.23	0.50	0.64	0.50	0.23
0.25	0.48	0.63	0.48	0.25
0.22	0.44	0.57	0.44	0.22
0.18	0.40	0.50	0.40	0.18
0.17	0.38	0.49	0.38	0.17
0.16	0.36	0.48	0.36	0.16
0.18	0.34	0.46	0.34	0.18
0.20	0.33	0.43	0.33	0.20
0.18	0.31	0.41	0.31	0.18
0.17	0.30	0.39	0.30	0.17
0.15	0.25	0.32	0.25	0.15
0.12	0.21	0.25	0.21	0.12
0.11	0.21	0.25	0.21	0.11
0.11	0.22	0.26	0.22	0.11
0.10	0.22	0.25	0.22	0.10
0.10	0.22	0.25	0.22	0.10
0.08	0.17	0.21	0.17	0.08
0.06	0.12	0.16	0.12	0.06

Table II

Vertical precipitation-intensity matrix produced by 1 nozzle.

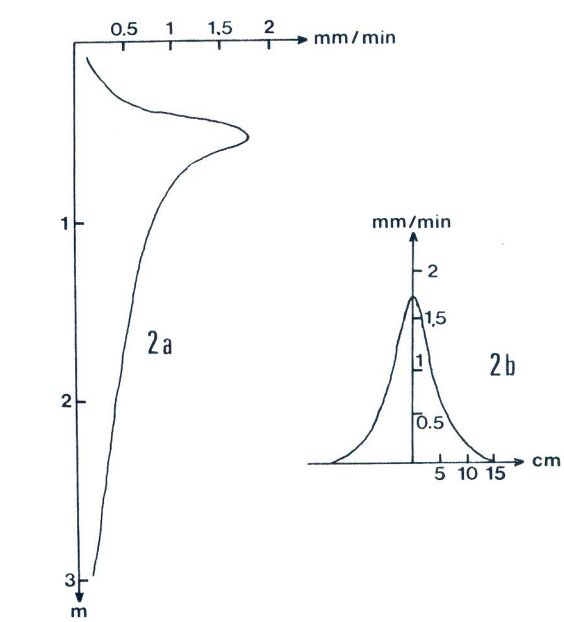


Figure 2

Vertical precipitation-intensity distribution, produced by 1 nozzle.

distributions , and depending on the geometry of the test object , different zones of the object will be wetted with different intensities , although both rains may comply with present standards. Our present work deals not with this last point , which certainly needs further study to determine its incidence on wet tests results.

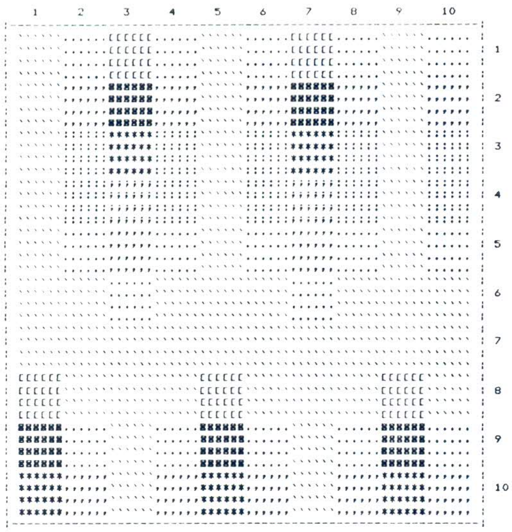
COMPUTER ASSISTED SPRAY APPARATUS SETTING

Knowing the precipitation matrixes of one nozzle , the computer program simulates the superposition of the sprays of several nozzles over the test area. Entering the positions of the precipitation maxima of each spray, on the test zone , the program calculates horizontal and vertical precipitation matrixes of total rain, by adding precipitation matrixes of each spray . At the same time, it prints shaded diagrams representing precipitation intensities, for quickly visualizing rain homogeneity and verifying that certain limits are not passed. In this paper, limits proposed on IEC already mentioned standard were assumed.

Table III and figure 3 show a well homogeneous rain complying with the standards. On the figure , dark areas represent zones of maximum precipitation of total rain, and the adjacent table shows positions of maximum precipitation of each individual spray.

Table III shows the corresponding precipitation matrix values . It should be remembered that each matrix value corresponds to an area of 5 cm x 10 cm , so if standards measuring criteria are to be met (minimum collecting vessels appertures of 100 cm2 allowed) then each adjacent pair of matrix values should be averaged. This could have been avoided by recalculating the precipitation intensity matrixes of the nozzle used, for 10 cm x 10 cm areas. Nevertheless this was not done just in order to do a better study of rain non uniformities. Thereafter , the test zone was restricted to a rectangle of just 50 cm wide and 1 m high , although our rain equipment was conceived for much larger areas.

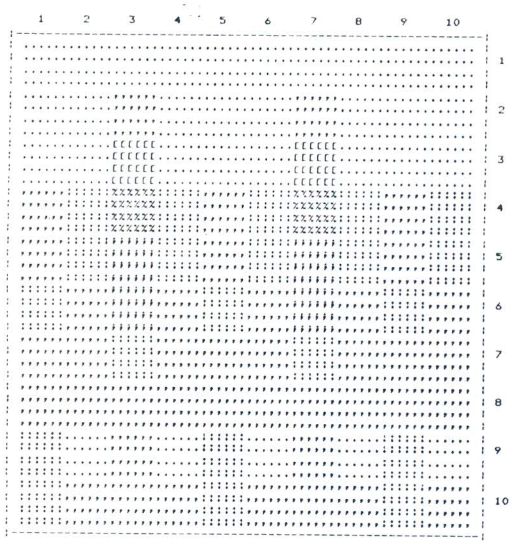
Computing time for a spray apparatus setting simulation is very short because program iterations run very fast . This allowed us to study several settings. Table IV and figure 4 show one of this settings , which in spite of its obvious non uniformities , results to be according to IEC standards if vessels with appertures of 30 cm x 25 cm are used for measuring purposes as permitted .
This particular apparatus setting , produces a precipitation with high lateral intensities and poor central one . If we assume a central rain zone of 20 cm wide then its average precipitation intensity results of 0.6 mm/min.



MAXIMA POSITIONS

row	column
-4	1
-4	5
-4	9
2	-1
2	3
2	7
2	11
9	1
9	5
9	9

3a. Horizontal component.



MAXIMA POSITIONS

row	column
-2	1
-2	5
-2	9
4	-1
4	3
4	7
4	11
13	1
13	5
13	9

3b. Vertical component.

Figure 3
Well uniform rain distribution on the test area, produced by 10 nozzles.

0.65	0.76	1.73	0.76	0.65	0.76	1.73	0.76	0.65	0.76
0.61	0.98	3.01	0.98	0.61	0.98	3.01	0.98	0.61	0.98
0.61	1.23	2.56	1.23	0.61	1.23	2.56	1.23	0.61	1.23
0.56	1.28	1.66	1.28	0.56	1.28	1.66	1.28	0.56	1.28
0.53	0.82	1.09	0.82	0.53	0.82	1.09	0.82	0.53	0.82
0.49	0.63	0.75	0.63	0.49	0.63	0.75	0.63	0.49	0.63
0.60	0.55	0.67	0.55	0.60	0.55	0.67	0.55	0.60	0.55
1.69	0.70	0.55	0.70	1.69	0.70	0.55	0.70	1.69	0.70
2.99	0.94	0.57	0.94	2.99	0.94	0.57	0.94	2.99	0.94
2.52	1.16	0.52	1.16	2.52	1.16	0.52	1.16	2.52	1.16

IIIa. Horizontal matrix.

0.93	0.75	0.86	0.75	0.93	0.75	0.86	0.75	0.93	0.75
0.85	0.73	1.05	0.73	0.85	0.73	1.05	0.73	0.85	0.73
0.87	0.86	1.87	0.86	0.87	0.86	1.87	0.86	0.87	0.86
0.96	1.31	2.26	1.31	0.96	1.31	2.26	1.31	0.96	1.31
1.04	1.26	1.63	1.26	1.04	1.26	1.63	1.26	1.04	1.26
1.19	1.16	1.50	1.16	1.19	1.16	1.50	1.16	1.19	1.16
1.17	1.12	1.37	1.12	1.17	1.12	1.37	1.12	1.17	1.12
1.16	0.98	1.13	0.98	1.16	0.98	1.13	0.98	1.16	0.98
1.25	0.90	1.07	0.90	1.25	0.90	1.07	0.90	1.25	0.90
1.20	0.96	1.04	0.96	1.20	0.96	1.04	0.96	1.20	0.96

IIIb. Vertical matrix.

Table III
Precipitation intensity matrixes, expressed in mm/min, of a well uniform rain on the test zone, produced by 10 nozzles.

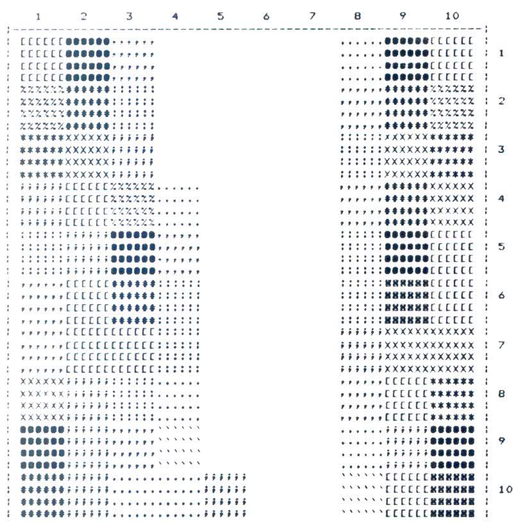
Similarly , for lateral rain zones of 15 cm wide, average intensity is of 1.9 mm/min.

Oppositely , table V and figure 5 show an equally complying setting that has high central intensities and poor lateral ones (1.8 mm/min at the center zone and 0.7 mm/min at laterals).

This spray apparatus settings , although permitted , show great rain non uniformities which can produce large flashover voltage variations , depending primarily on the test object geometry. It should be noted that while using large collecting vessels (appertures of 750 cm2) , great rain non uniformities like those shown on figures 4 and 5 may not be detected. The same will occur, if that common measuring method of moving a small vessel over the test zone is used, averaging precipitation of areas larger than that of the vessel.

According to previous works [1], [5] on the incidence of precipitation rate on flashover voltages , variations as large as 30 % on A.C. flashover voltages should be expected when rain changes from that of figure 4 to that of figure 5 . This is because precipitation intensities vary from 0.6 to 1.9 mm/min , approximately, on corresponding zones when changing from one case to the other.

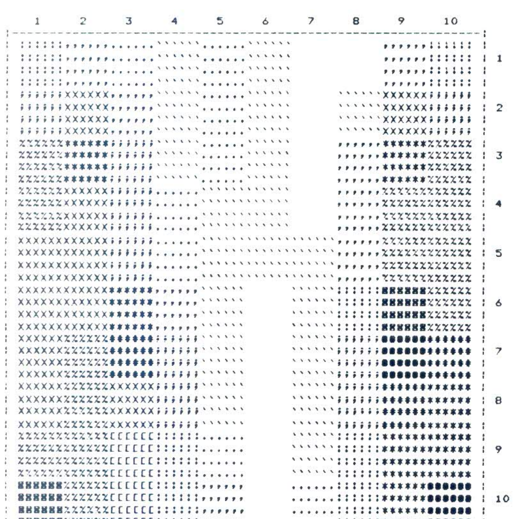
This large predicted variation of flashover voltage is due to the small precipitation intensity recommended by the mentioned standard (1.25 mm/min average) . In the proximity of these values of precipitation , the slope of variation of flashover voltages is steeper than for more intense rains . The last mentioned works lead to the conclusion that with higher rain intensities (near 3 mm/min) , but for similar percentual variations of precipitation in a non uniform rain , flashover voltage variations would be much smaller.



MAXIMA POSITIONS

row	column
-5	5
-4	-2
-4	1
-4	10
-4	13
1	0
1	2
1	9
1	11
5	3
5	9
9	1
9	10
11	5

4a. Horizontal component.

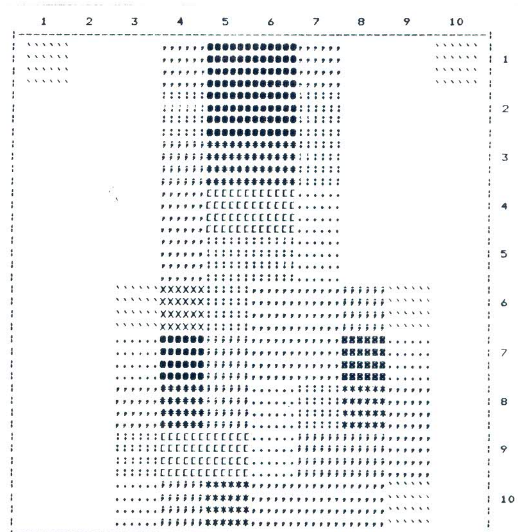


MAXIMA POSITIONS

row	column
-3	5
-2	-2
-2	1
-2	10
-2	13
3	0
3	2
3	9
3	11
7	3
7	9
11	1
11	10
13	5

4b. Vertical component.

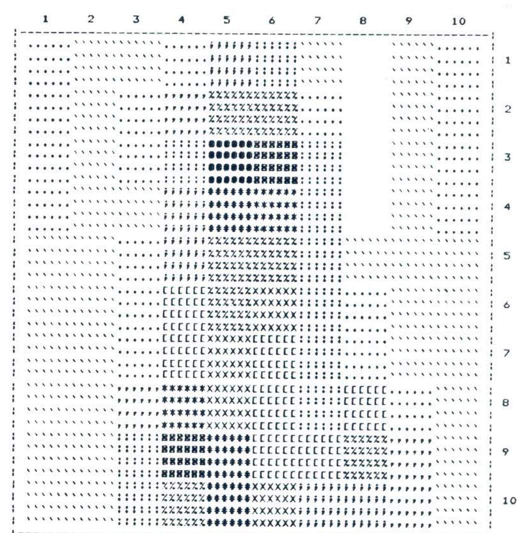
Figure 4
Rain distribution with great lateral intensities on the test area, produced by 14 nozzles.



MAXIMA POSITIONS

row	column
-4	1
-4	5
-4	10
1	5
1	6
7	4
7	8
11	5

5a. Horizontal component.



MAXIMA POSITIONS

row	column
-2	1
-2	5
-2	10
3	5
3	6
9	4
9	8
13	5

5b. Vertical component.

Figure 5
Rain distribution on the test area, with high central intensities.

1.81	3.22	0.97	0.43	0.37	0.31	0.26	0.83	3.22	1.81
2.29	2.75	1.23	0.41	0.33	0.27	0.27	1.10	2.75	2.29
2.54	1.95	1.47	0.44	0.29	0.20	0.32	1.29	2.02	2.57
1.63	1.69	2.25	0.73	0.28	0.17	0.34	1.15	2.71	1.93
1.29	1.62	3.37	0.98	0.27	0.14	0.36	1.24	3.68	1.84
1.03	1.73	2.79	1.22	0.27	0.10	0.35	1.40	3.07	1.85
1.06	1.77	1.85	1.22	0.16	0.00	0.30	1.49	2.13	1.98
2.12	1.50	1.29	0.78	0.17	0.00	0.30	1.01	1.78	2.60
3.30	1.51	0.98	0.68	0.32	0.08	0.33	0.81	1.63	3.62
2.80	1.60	0.87	0.84	1.57	0.39	0.33	0.68	1.70	3.01

IVa. Horizontal matrix.

1.23	1.11	0.78	0.62	0.77	0.58	0.37	0.45	1.11	1.23
1.45	1.92	0.97	0.59	0.73	0.52	0.37	0.67	1.92	1.45
2.29	2.44	1.47	0.65	0.72	0.53	0.35	1.08	2.60	2.29
2.24	1.97	1.48	0.77	0.64	0.50	0.43	1.06	2.16	2.31
2.04	1.93	1.55	0.91	0.67	0.48	0.57	1.06	2.17	2.15
2.06	2.05	2.42	1.08	0.64	0.44	0.59	1.27	2.98	2.33
2.01	2.32	2.78	1.51	0.62	0.40	0.63	1.58	3.34	2.67
2.00	2.26	2.04	1.44	0.69	0.38	0.67	1.46	2.67	2.56
2.22	2.16	1.90	1.27	0.92	0.36	0.67	1.42	2.48	2.62
3.05	2.25	1.84	1.32	1.02	0.41	0.71	1.41	2.50	3.43

IVb. Vertical matrix.

Table IV
Rain matrixes expressed in mm/min, for high-lateral-intensities distribution.

0.47	0.37	0.44	1.16	3.87	3.77	0.95	0.28	0.37	0.47
0.37	0.31	0.42	1.41	3.63	3.57	1.24	0.28	0.31	0.37
0.33	0.27	0.42	1.51	2.85	2.79	1.37	0.29	0.27	0.33
0.24	0.20	0.39	1.02	1.82	1.78	0.93	0.28	0.20	0.24
0.19	0.22	0.41	0.98	1.37	1.37	0.82	0.40	0.25	0.24
0.15	0.23	0.69	2.08	1.38	1.16	0.99	1.64	0.53	0.24
0.13	0.22	0.91	3.28	1.48	1.02	1.17	2.92	0.77	0.25
0.00	0.14	1.09	2.70	1.56	0.88	1.36	2.43	0.96	0.14
0.00	0.16	1.24	1.83	1.67	0.84	1.44	1.55	1.08	0.16
0.00	0.17	0.82	1.57	2.42	1.09	0.99	1.01	0.65	0.17

Va. Horizontal matrix.

0.93	0.68	0.64	0.87	1.47	1.22	0.49	0.34	0.68	0.93
0.77	0.58	0.73	0.99	2.38	2.19	0.74	0.40	0.58	0.77
0.73	0.52	0.72	1.42	3.31	3.10	1.20	0.42	0.52	0.73
0.72	0.53	0.66	1.49	2.65	2.46	1.19	0.43	0.53	0.72
0.64	0.50	0.74	1.62	2.32	2.18	1.19	0.67	0.50	0.64
0.63	0.48	0.87	1.72	2.31	2.09	1.30	0.81	0.55	0.63
0.57	0.48	0.92	1.74	2.07	1.87	1.28	0.94	0.59	0.61
0.50	0.47	1.00	2.49	2.09	1.79	1.34	1.75	0.74	0.57
0.49	0.50	1.35	2.94	2.68	1.87	1.71	2.20	1.16	0.61
0.48	0.56	1.31	2.33	2.64	1.97	1.65	1.56	1.12	0.68

Vb. Vertical matrix.

Table V
Rain matrixes expressed in mm/min for high-central-intensities distribution.

CONCLUSIONS

A computer assisted method for adjusting high voltage wet tests equipments was introduced . With it , several settings of the rain apparatus can quickly be simulated and the possibility of achieving a rain according to the standards can so be evaluated . It also lets the user to visualize the non uniformity of the precipitation and is an aid to the final adjustment of the equipment.

Presented data is valid only for conditions previously expressed . The proposed method works only if while adjusting the rain apparatus the nozzles are kept horizontal , because their rain distribution changes if they are moved vertically.

Using other nozzles than those described or other test conditions , would require the experimental determination of new precipitation matrixes . Anyway , this work is much easier than that of blindly trying various rain apparatus settings until obtaining the desired rain distribution.

It is recommended to use collecting vessels with small appertures of approximately 100 cm2 and to do precipitation measurements with fixed vessels for correct detection of rain non uniformities . These are proposed as one of the causes of great dispersions in high voltage wet tests results.

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