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Measuring and Analysis of the Acid Rain Effect on EPDM Insulators

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Abstract: Experimental results of Ethylene Propylene Diene Monomer (EPDM) class 15 kV type suspension insulators exposed to an acid environment are reported. The tests were carried out at the High Voltage Laboratory which belongs to Instituto Politecnico Nacional that is located at 2240 masl. During the tests an aqueous solution that simulates acid rain registered in the Valley of Mexico was used. The fog clean method developed for non ceramic insulators (IEC-507) was utilized, with some differences. For evaluate the loss of hydrophobicity the technique of contact angle was used. The flashover voltages and the behaviour of accumulated charge are analyzed as a function of the aqueous solution. Four different aqueous solutions levels were employed. The results show hydrophobicity reduction as the aqueous solution is increased.

Keywords: EPDM insulators, acid rain, high altitude

I. INTRODUCTION

Non ceramic insulators aging because principally the combined effect of UV, temperature, humidity and surface discharges; with the aging the good characteristics to support contamination are diminished. If the altitude effect an acid rain are added the problem results more complex. It is known that a decrement on the surface hydrophobicity implies an increment on the leakage current and on the probability of formation of dry bands, decreasing the time of life of the insulators [1]. In this paper experimental results and analysis about the behaviour of EPDM class 15 kV insulators aged previously in acid rain at an altitude of 2240 masl is presented.

This paper is organized as follow: Section I gives an introduction about aging of non ceramic insulators. Section II presents experimental arrangement, results and analysis. Section III presents the conclusions of the present paper and finally the last section IV presents the references

II. BODY

2.1 Experimental arrangement

It was utilized a clean fog chamber 1.5x1.5x1.5 m^3, figure 1. Instead of a velocity of the entrance of fog of 50 g/h/ m^3 as is indicated in IEC-507 Std, it was used a velocity of 118.5 g/h/m^3 because it has reported that for velocities of the entrance of fog greater that 50 g/h/ m^3 the flashover voltages decreases [2]. It was used a resistor of 2.5 Ω in series with the insulator; so that the voltage drop in the resistor is monitoring by one microcontroller which is communicated to a PC, must be noted the presence of the offset circuit and the protection system which is redundant.

The chemical components that were used for obtain the acid rain are shown in table 1; the selection and quantity of the ingredients have been chosen in accordance with a measure of acid rain with pH = 3.3 [3]; this value is the most acid measurement registered in the Valley of Mexico (1987). The contamination for new insulators was made in agreement with [2] because in this case it is not applicable the IEC-507 Std. For aged insulators it was not necessary because this insulator lost hydrophobicity in such manner that the surface contaminated layer was uniform without previous preparation. Table 2 show the contaminants used for new insulators.

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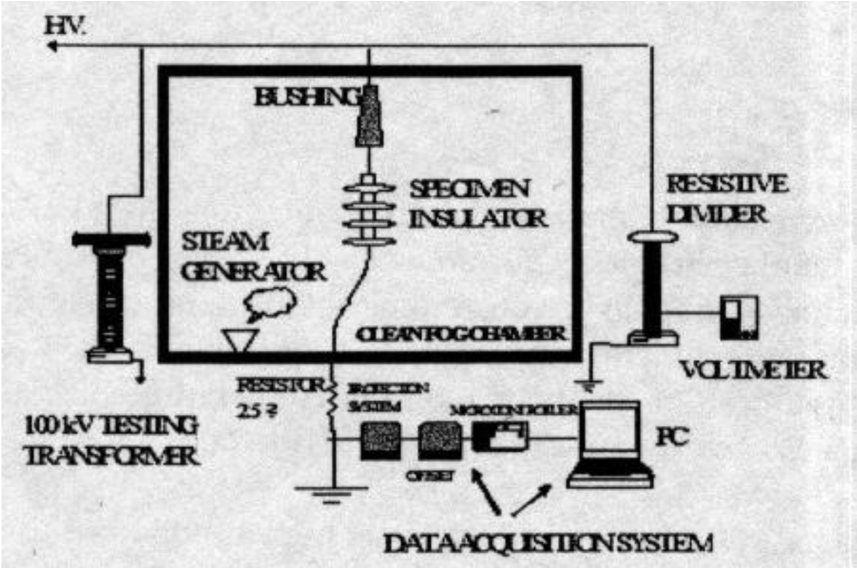

Fig.1. Experimental arrangement

2.2 Results and analysis

In figure 2 are presented the mean values of contact angle in the sheds of insulators versus period of aging. It can be observed that there is a reduction up to 36.4 % in the hydrophobicity for insulator aged 1320 h with relation to new insulator. The insulators were tested 2 times in the clean fog chamber, after test first they were cleaning for removing the contaminants and then evaluated their surface hydrophobicity. New insulators after the test 1 were rested for 168 h, aged with acid rain insulators were rested 312 h before they were exposed to a second test.

TABLE 1. Ingredients of an acid rain with pH = 3.3.

Ingredients	Quantity (mg/l)
NH_4Cl	235.0
NaCl	170.0
KCl	5.9
HNO_3	23.5
$MgSO_4$	35.3
$CaSO_4$	29.4

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Table 2. Mixtures of contaminants used for new insulators.

Mixture Number	Kaolin (g/l)	NaCl (g/l)	ESDD (mg/cm^2)	Pollution Category
1	40	5	0.02085	Very light
2	40	20	0.07501	Light
3	40	80	0.25003	Heavy
4	40	160	0.42500	Very Heavy

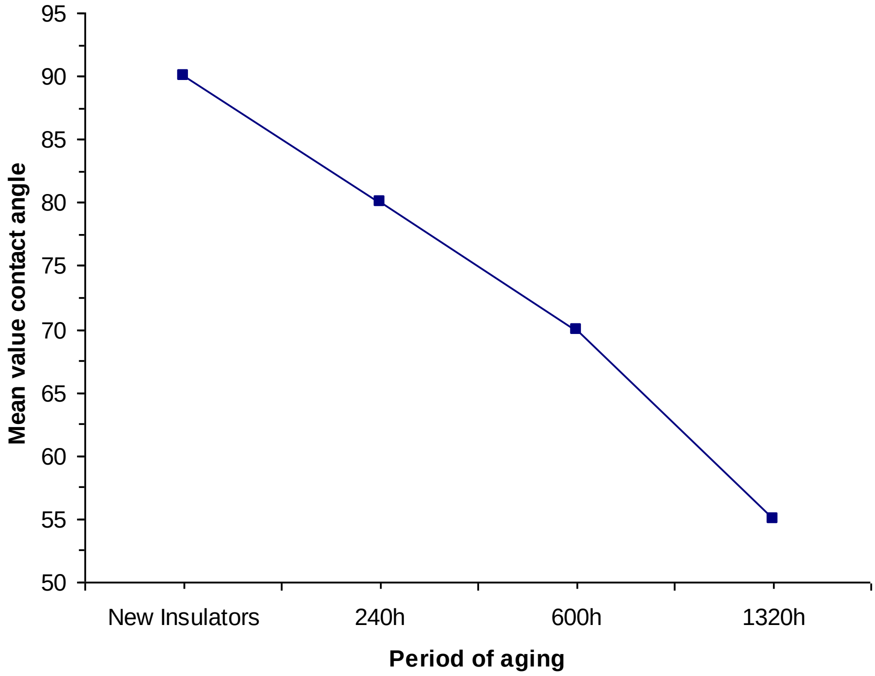

Fig. 2. Relationship between contact angle and period of aging

Figures 3, 4, 5 and 6 show the mean values of contact angle for insulators polluted with ESDD σ = 0.02085 mg/cm^2 and σ= 0.8341 S/cm, with ESDD = 0.075 mg/cm^2 and σ= 3.0 S/cm, ESDD = 0.25 mg/cm^2 and σ= 10.0 S/cm and with ESDD = 0.425 $mg/cm^2$and σ =17.0 S/cm respectively.

As it can be seen the behavior of the hydrophobicity decrease for any value of ESDD. The Insulators have strong surface erosion because the chemical agents of the acid rain, furthermore, they suffer degradation because the surface discharges in presence of humidity, and this is in agreement with [4]. The mean contact angle was reduced 10.8 % for insulators aged with acid rain during 240 h in relation to the contact angle for registered for new EPDM insulators, for the insulators aged for 600 h and 1320 h the mean contact angle was decreased 20.85 % and 36.4 % respectively; this indicates that the acid rain attacks very hard the insulators. Similar tendency was presented for others ESDD values. Figure 7 shows the flashover voltages versus the period of aging.

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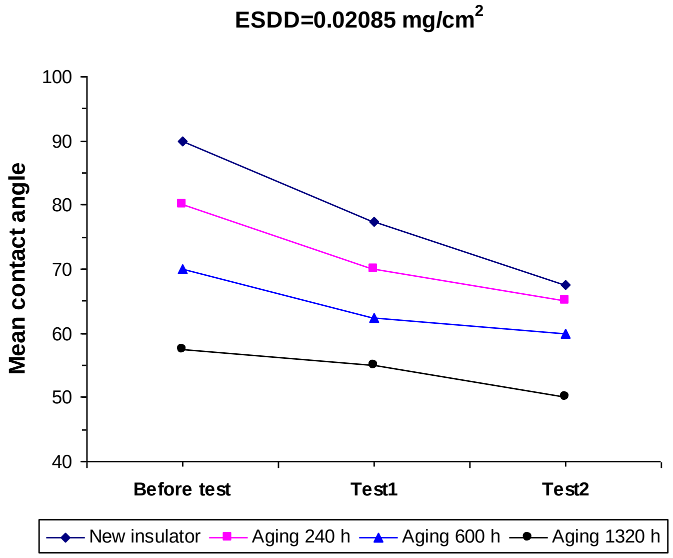

Fig. 3. Mean values of contact angle for insulators polluted with ESDD = 0.02085 mg/cm^2 and σ = 0.8341 S/cm

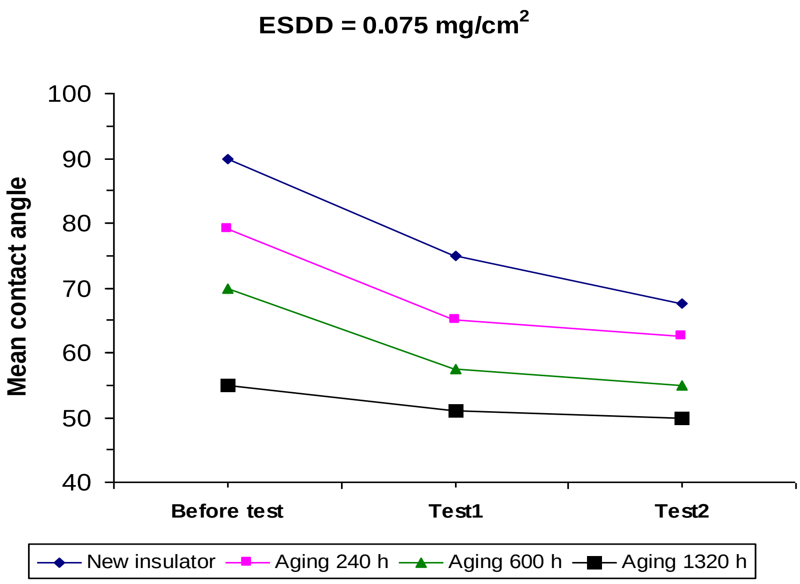

Fig. 4. Values of contact angle for insulators polluted with ESDD = 0.075 mg/cm^2 and σ = 3.0 S/cm

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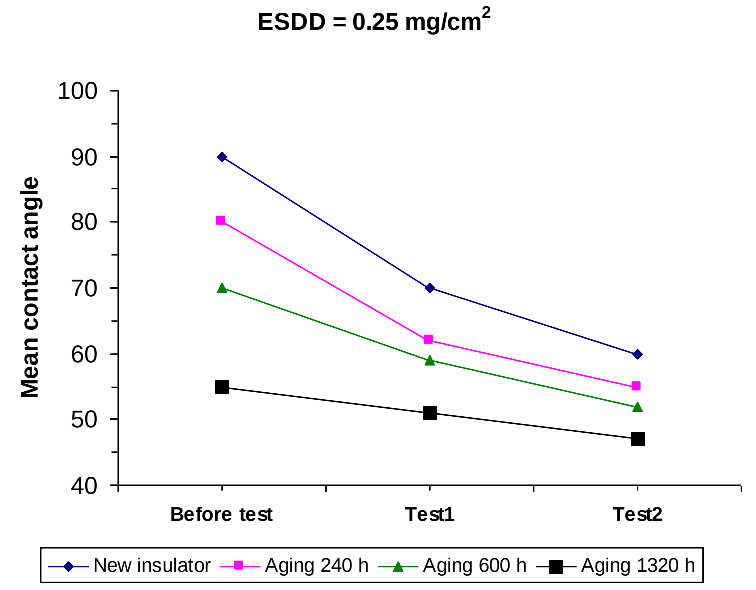

Fig. 5. Values of contact angle for insulators polluted with ESDD = 0.25 mg/cm^2 and σ = 10.0 S/cm.

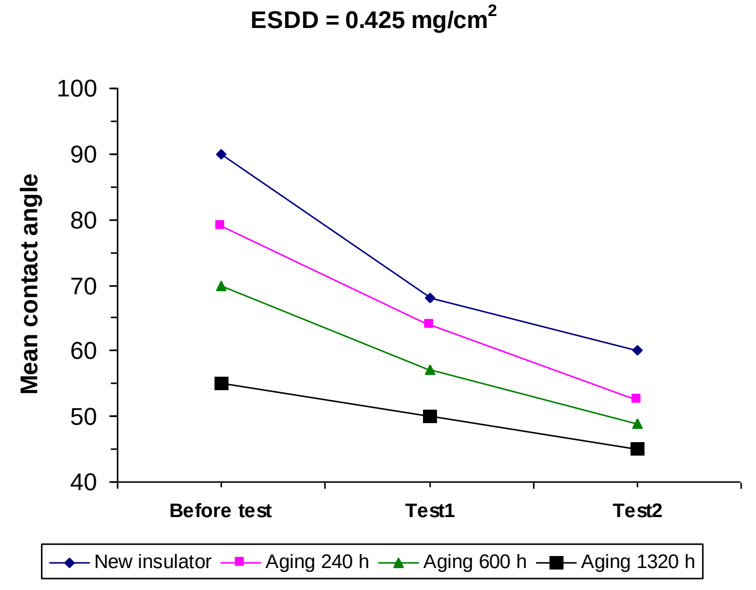

Fig. 6. Values of contact angle for insulators polluted with ESDD = 0.425 mg/cm^2 and σ = 17.0 S/cm

It is possible to see a decrement of the flashover voltages for any ESDD. For example ESDD=0.02085 mg/cm2, the insulator aged 1320 h had a flashover of 23 kV, while in the same conditions the new insulator had a flashover of 28.7 kV, this implies a decrement of 19.9 %, for ESDD=0.075 mg/cm^2 the flashover voltage diminished 31.8 %, for ESDD=0.25 mg/cm^2 the flashover voltage decreased 35 % and finally for ESDD= 0.425 mg/cm^2 the flashover voltage decrease 47.4 %. For test 2 figures 8 shows the respective results.

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The flashover voltages were lower for any case with respect to flashover voltage registered in the test 1, with exception of the new insulator for ESDD = 0.425 mg/cm^2, which had a flashover voltage of 13.3 kV in test 1, while for test 2 the value is 17 kV, the combination of high humidity and high conductivity because a very heavy pollution generate irregular flashover voltages, nevertheless, we can affirm that insulators had not good recovery of the hydrophobicity [5].

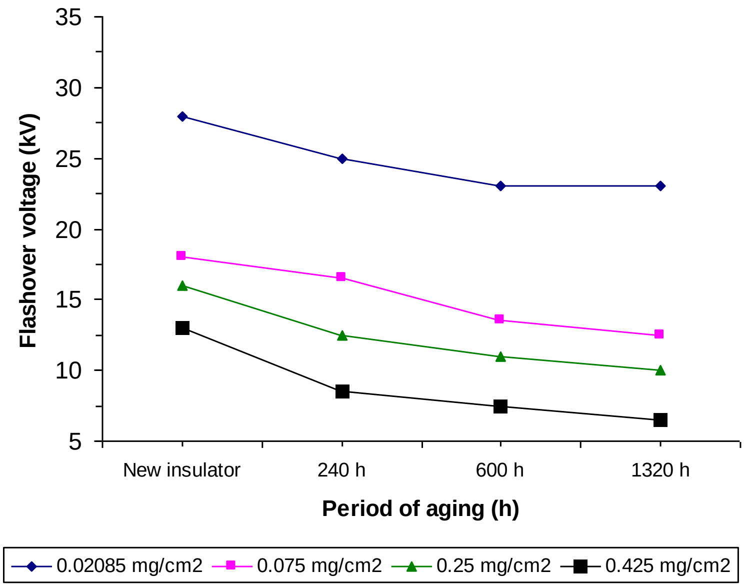

Fig. 7. Flashover voltages versus different period of aging and different ESDD. Test1

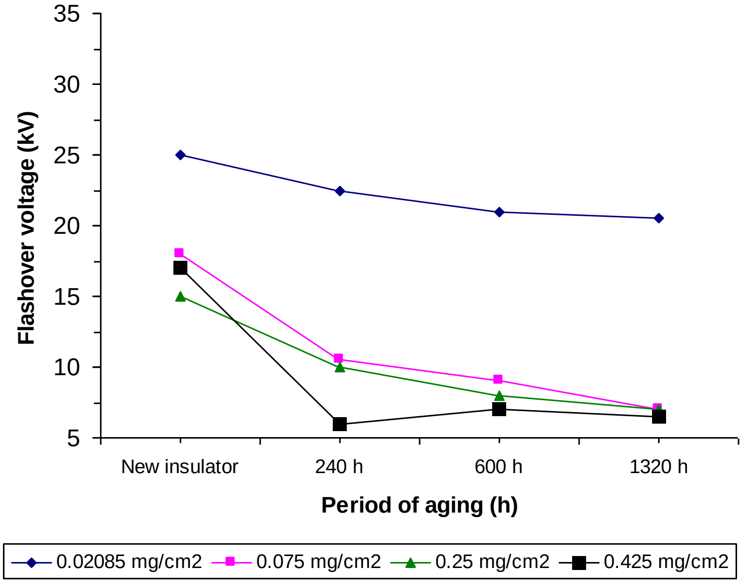

Fig. 8. Flashover voltages versus different period of aging and different ESDD. Test2

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Table 3 shows the flashover voltage V_b, the critical leakage currentI_c, accumulated charge Q and velocity of growth of the accumulated charge m. In general the tendency of growth velocity of the accumulated charge is increasing in relation to the aging time increments. The flashover voltage diminished if the accumulated charge is increased.

III. CONCLUSIONS

Nevertheless, the clean fog test is more representative of in-service insulator performance than the salt fog test, is not appropriate for the acid rain conditions. In general the velocity of increment of the accumulated charge has ascending value related to the aging time of insulators. EPDM insulators exposed to acid rain and electrical discharges never recovery their original hydrophobicity.

Table 3. Flashover voltage V_b, critical leakage current I_c, accumulated charge Q and velocity of the accumulated charge m.

NEW ISULATORS								
	ESDD = 0.02085 mg/cm2 (very light)		**ESDD = 0.075 mg/cm2 (light)**		**ESDD = 0.25 mg/cm2 (heavy)**		**ESDD = 0.425 mg/cm2 (very heavy)**	
	Test 1	**Test 2**	**Test 1**	**Test 2**	**Test 1**	**Test 2**	**Test 1**	**Test 2**
V_b(kV)	28.7	25.2	18.2	18.0	15.4	17.4	13.3	17.0
I_c(mA)	46.0	210.0	50.0	70.0	50.0	180.0	50.0	250.0
Q(mC)	18.0	38.0	15.0	14.5	23.0	140.0	34.0	20.0
m(mC/s)	16.5	29.0	17.2	12.2	16.2	15.8	13.4	14.6
INSULATORS AGED 240 h								
V_b(kV)	25.4	23.0	16.0	10.6	12.6	10.0	8.6	63.0
I_c(mA)	45.0	25.0	50.0	24.0	50.0	25.0	30.0	25.0
Q(mC)	30.0	17.0	470.0	27.0	85.0	75.0	33.0	140.0
m(mC/s)	16.5	7.1	19.7	10.1	18.5	11.1	11.6	9.2
INSULATORS AGED 600 h								
V_b(kV)	23.0	21.7	13.5	9.6	11.3	8.3	7.8	7.0
I_c(mA)	55.0	60.0	30.0	70.0	30.0	80.0	24.0	23.0
Q(mC)	53.0	160.0	108.0	186.0	150.0	80.0	44.0	121.0
m(mC/s)	20.0	15.1	15.0	13.4	13.8	7.6	12.8	14.5
INSULATORS AGED 1320 h								
V_b(kV)	23.0	20.7	12.4	7.0	10.2	7.4	7.0	6.3
I_c(mA)	70.0	50.0	50.0	24.0	40.0	35.0	32.0	23.0
Q(mC)	50.0	50.0	65.0	80.0	75.0	375.0	85.0	45.0
m(mC/s)	29.4	20.1	24.9	11.5	22.1	13.5	15.8	11.0

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