

# Artificial Accelerated Ageing Test of Silicone Rubber Housing Material for Lightning Arrester

W. Payakcho, J. Grasaesom, S. Thong-om and B. Marungsri\*

**Abstract**— This paper presents the experimental results of silicone rubber housing material for 24kV lightning arrester under artificial accelerated ageing test based on IEC 61109 specifications. Specimens having inclined and alternated shed made of HTV silicone rubber with ATH content and having leakage distance 625 mm were tested continuously 1000 hrs in artificial salt fog chamber. After 1000 hrs of salt fog ageing test, obviously surface erosion was observed on trunk between the upper large shed and the lower small shed near the energized end. Decreasing in hydrophobicity and increasing in hardness were measured on tested specimen comparing with new specimen. Chemical analysis by ATR-FTIR confirmed the observation results.

**Keywords**— Accelerated ageing test, Silicone rubber housing material, salt fog test, Lightning Arrester, Ageing

## I. INTRODUCTION

**L**IGHTNING arrester or surge arrester is generally connected between phases-ground in the substations or transmission system or distribution system in order to protect the insulation system from voltage surge such as lightning surge or switching surge. These voltage surges affect to the insulation performances in the system [1].

Presently, silicone rubber (SiR) is an insulating material widely using for lightning arrester housing. SiR offers for good resistance to extreme temperature, tensile strength, elongation, tear strength and compression.

Sundararajan et al. [2] tested the accelerated ageing test of silicone rubber housing material for lightning arrester in multi-stress test. After tested found that arresters sustained the stresses without any major breakdown, just as any polymeric arrester performing well in the field for several years. No flashover, major surface cracking, or erosion was observed.

Marungsri et al. [3] studied the salt fog ageing test result of silicone rubber for outdoor polymer insulators. This studied found that tracking occurred on the surface of RTV (Room Temperature Vulcanized) SiR rod.

Cho et al. [4] found that the hydrophobicity level of tested specimens is bad after 1000hrs ageing test because of local discharges.

Ageing deterioration is major problem of silicone rubber housing material for lightning arrester due to it is polymeric

material. Physical changes (such as erosion tracking), chemical change (depolymerization) or changes in the physicochemical (such as hydrophobic) affect to ageing of polymeric housing materials [5] - [8].

This paper reports the experimental results on salt fog testing of silicone rubber housing material for lightning arrester. Details of the experimental and the results are explained and discussed in the follow sections.

## II. TEST ARRANGEMENT

### A. Specimen

Insulation housing made of silicone rubber with ATH (Alumina trihydrate) content for 24kV system lightning arrester was used in this experimental. Alternated and inclined shed is configuration of tested specimen. Dimensions of tested specimen are illustrated in Fig. 1.

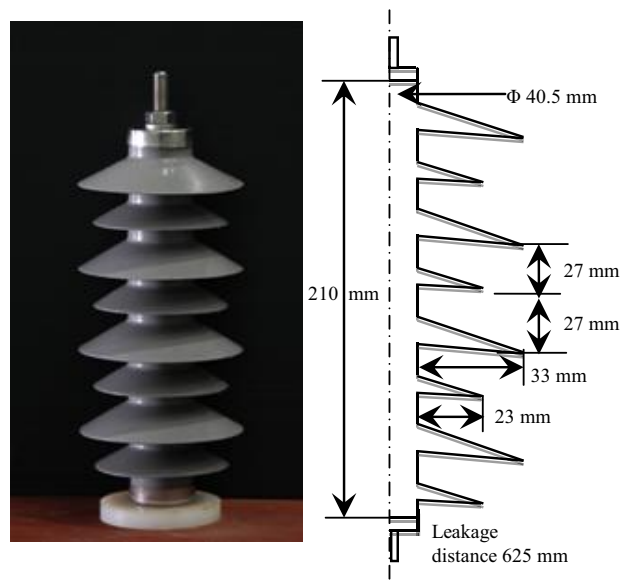


Fig. 1 Configuration and dimensions of specimen.

### B. Test Method

All specimens were placed in the test chamber having volume 9.6 m<sup>3</sup> (2×2×2.4 m<sup>3</sup>). Test chamber made from stainless steel sheet in order to prevent corrosion from salt fog. Salt fog was generated by using ultrasonic humidifier. Test arrangements are shown in Fig. 2 and test chamber is shown in Fig. 3, respectively.

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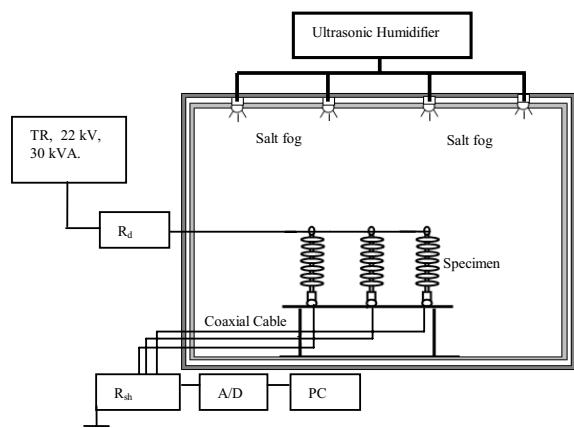


Fig.2 Test arrangement.

TABLE I  
TEST CONDITIONS.

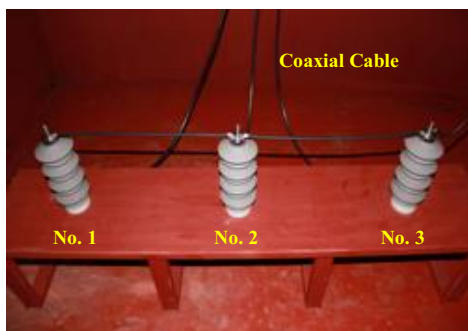
Test Chamber	9.6 m <sup>3</sup>
Test Voltage	AC 18 kV Continuously Applied
Voltage Stress	34.6 mm/kV.
Salt fog Generation	Ultrasonic Humidifier
Salt fog Injection Rate	0.5 l/hr/m <sup>3</sup>
Salt fog Salinity	10 kg/m <sup>3</sup> (16000 $\mu$ S/cm)
Test sequence in 24 hours.	Salt fog injected for 8 hours and stopped for 16 hours.

TABLE II  
TEST CYCLE.

Aging period (hr)	0-8	8-24
Voltage		
Salt fog		



(a) Test chamber



(b) Specimen installation

Fig. 3 Illustration of test chamber.

### C. Test Conditions

Test was conducted continuously for 1000 hrs based on IEC 61109 [9]. The cyclic salt fog ageing test was conducted by injecting salt fog for 8 hours and stopping it for 16 hours every day under AC 18 kV, tested together under the conditions show in Table I and test cycle shown in Table II, respectively.

## III. TEST RESULTS AND DISCUSSIONS

Silicone rubber housing material for lightning arrester was tested base on IEC 61109 in order to elucidate degree of surface ageing. The analyzing by physical method and chemical method such as visual observation, surface contamination degree, loss of hydrophobicity, hardness measurement and ATR-FTIR analysis were conducted on tested specimen after 1000 hrs salt fog test.

### A. Visual Observation

During artificial salt fog ageing test, discharge activities as shown in Fig. 4 were observed. As shown in Fig. 4, yellow light for dry band arcing was observed. Such discharge indicated that large dry band arc discharge occurred on the specimen surface near the energized end. Low power discharge or corona discharge was also observed.

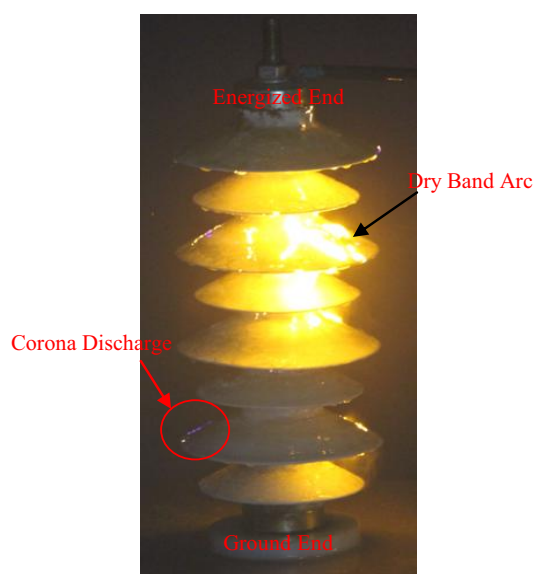


Fig. 4 Discharge Activities

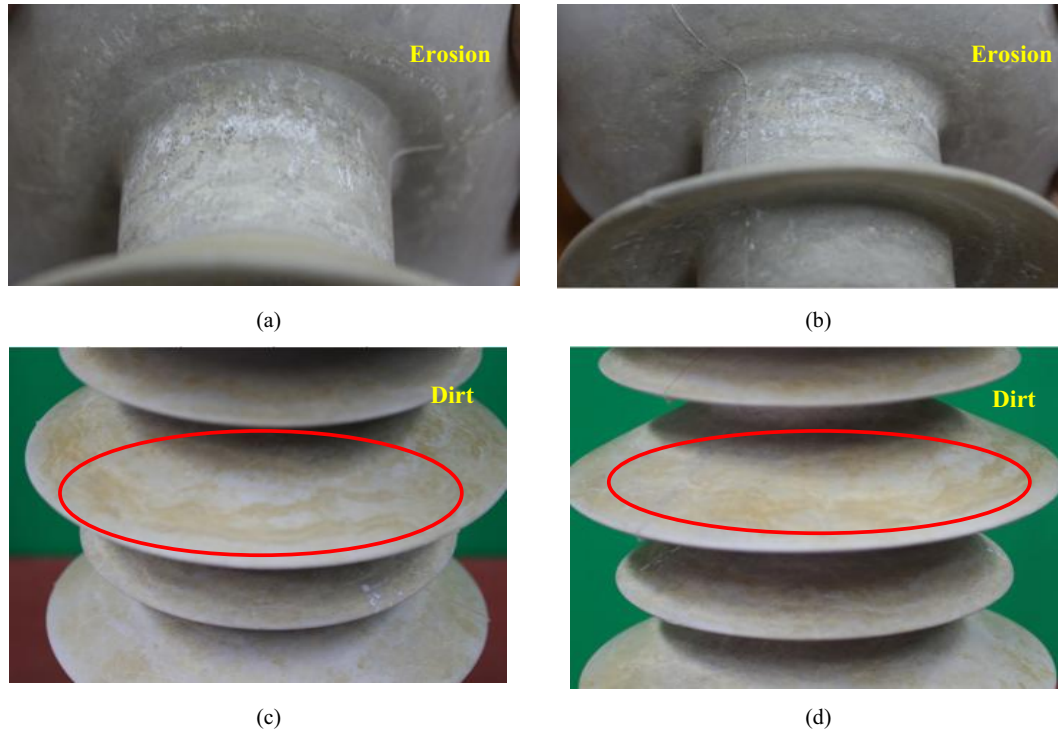


Fig. 5 Visual observation on the surface for lightning arrester.

After 1000 hrs salt fog ageing test, obviously surface erosion was observed on the trunk surface between small and large shed near the energized end of all specimen, as shown in Figure 5 (a) and (b). Slightly surface erosion was also observed on the other trunk portion along the specimen surface. Also, slightly erosion was observed on all shed surface. As shown in Fig. 5 (a), erosion zone on trunk surface occurred close to shed surface and erosion zone on shed surface occurred close to trunk surface. The explanation for such occurring is shown in Fig. 6. In border of wetting zone, dry band arcing easily occurred due to easier formation of dry band than drying and wetting zone. This explanation is supported by no erosion surface on drying and wetting zone.

As shown in Figure 5 (c) and (d), no erosion was observed on the upper shed surface. However, dirt was only observed on such portion.

#### B. Contamination Degree

Surface contamination degree was determined by measuring salt deposit density (SDD). The measurement procedures were based on IEC 60507 [10]. On the tested specimens, more contaminations were observed on the trunk surface than on the shed surface. Contamination degree measurement result on specimen surface after 1000 hrs ageing test is shown in Table III. The formulas for SDD calculation are as follows.

$$SDD = \frac{S_a}{A} \quad (1)$$

$$S_a = (5.7 \times 10^{-4} \sigma_{20})^{1.05} \quad (2)$$

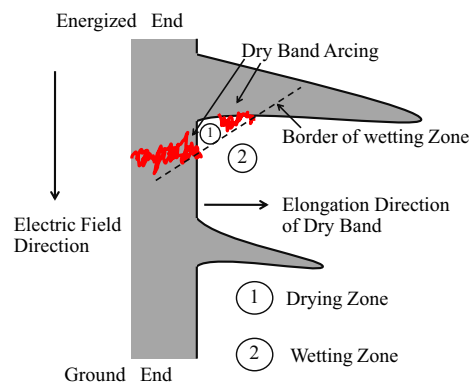


Fig. 6 Explanation of surface erosion

$$\sigma_{20} = \sigma_{\theta} [1 - b(\theta - 20)] \quad (3)$$

where

$\theta$  is solution temperature ( $^{\circ}\text{C}$ ),

$\sigma_{\theta}$  is the volume conductivity at temperature of  $\theta$   $^{\circ}\text{C}$  (S/m),

$\sigma_{20}$  is the volume conductivity at temperature of 20  $^{\circ}\text{C}$  (S/m),

$b$  is the factor depending on temperature of  $\theta$   $^{\circ}\text{C}$ ,

$S_a$  is Salinity ( $\text{mg}/\text{cm}^3$ ),

SDD is salt deposit density ( $\text{mg}/\text{cm}^2$ ),

$V$  is volume of distilled water ( $\text{cm}^3$ ),

$A$  is area of the specimen surface for collecting contaminations ( $\text{cm}^2$ ).

Significant different in contamination degree was not measured.

TABLE III  
CONTAMINATION DEGREE

Specimen No.	Sa (mg/cm <sup>3</sup> )	SDD (mg/cm <sup>2</sup> )
1	2.061	0.2626
2	2.0688	0.2636
3	1.6622	0.2118

*C. Hydrophobicity*

Loss of hydrophobicity on specimen surface after 1000 hrs ageing test was evaluated by STRI guide [11], as show in Fig. 7. Decreasing in hydrophobicity on surface of tested specimen near energized end was obtained from the measuring results. The measurement results are shown in Table IV.

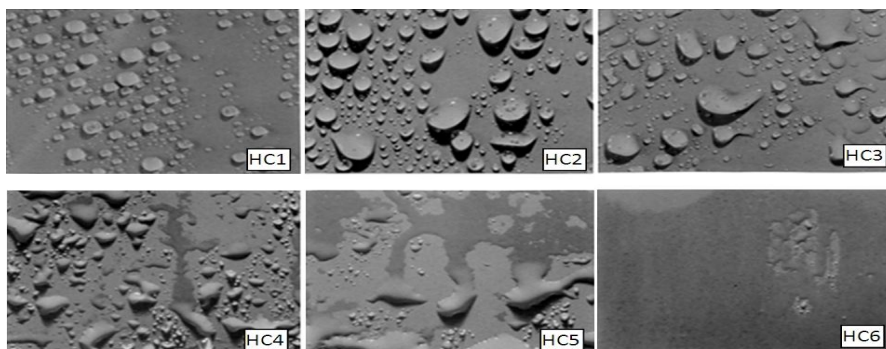


Fig. 7 Characteristics of the sample surface HC1-HC6 [11].

TABLE IV  
HYDROPHOBICITY BY STRI CRITERIA

Position	Specimen			Position
	No. 1	No. 2	No. 3	
1	HC 3	HC 3	HC 4	
2	HC 3	HC 4	HC 4	
3	HC 2	HC 2	HC 2	
4	HC 2	HC 3	HC 3	
5	HC 2	HC 2	HC 3	
6	HC 1	HC 1	HC 2	
7	HC 2	HC 3	HC 2	
8	HC 3	HC 4	HC 4	
9	HC 3	HC 2	HC 3	
10	HC 3	HC 3	HC 3	
11	HC 3	HC 3	HC 3	
12	HC 1	HC 2	HC 1	
13	HC 2	HC 3	HC 2	
14	HC 3	HC 3	HC 3	
15	HC 1	HC 1	HC 2	
16	HC 2	HC 3	HC 2	
17	HC 2	HC 2	HC 2	
18	HC 1	HC 1	HC 1	
19	HC 2	HC 3	HC 3	
20	HC 3	HC 3	HC 3	
21	HC 1	HC 1	HC 2	
22	HC 2	HC 2	HC 3	
23	HC 2	HC 2	HC 3	
24	HC 1	HC 1	HC 2	
25	HC 3	HC 3	HC 3	

*D. Chemical analysis by ATR – FTIR*

In order to confirmed surface ageing, chemical analysis by ATR–FTIR (attenuated total reflection fourier transform infrared spectroscopy) was conducted to evaluate the chemical changed on tested specimen surface. Decreasing in Si – CH<sub>3</sub> bonds (wave number 1260 cm<sup>-1</sup>) indicate that side chains are cleaved. Decreasing of Si – O bonds (wave number 1011 cm<sup>-1</sup>) indicate that back bones are broken or depolymerization.

For comparison ATR–FTIR analysis result of new specimen is defined as 100% and is used to comparing with tested specimen. ATR –FTIR analysis results of position 2 are shown in Fig. 8. ATR – FTIR analysis results for all portion of tested specimen are shown in Table V. Decreasing of side chain and back bonds confirmed surface ageing.

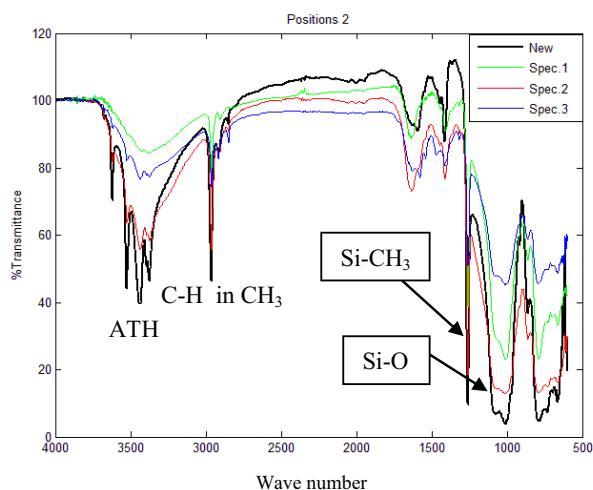


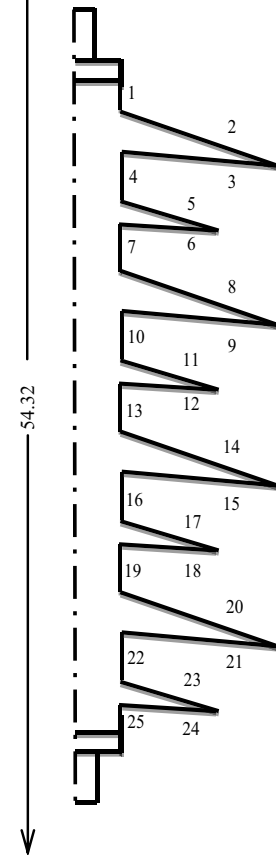
Fig. 8 ATR – FTIR analysis result (Position 2).

TABLE V  
SURFACE ANALYSIS RESULTS BY ATR – FTIR

Position	Specimen							
	%Transmittance (Si-CH <sub>3</sub> )				%Transmittance (Si-O)			
	new	1	2	3	new	1	2	3
1	61.975	55.791	74.207		60.783	79.922	88.545	
2	47.887	63.694	94.543		75.561	83.713	94.922	
3	81.313	64.092	66.27		87.017	89.742	83.644	
4	55.012	56.881	14.185		78.971	61.644	29.272	
5	34.241	12.175	71.043		81.503	27.675	81.317	
6	81.453	60.978	69.988		54.917	89.641	82.551	
7	56.698	60.072	30.238		45.772	78.046	58.207	
8	17.983	25.954	86.879		13.198	55.031	82.6	
9	78.253	78.611	88.923		92.967	78.093	86.818	
10	67.474	76.325	16.091		25.401	82.081	25.09	
11	15.837	13.811	27.71		3.387	23.721	56.696	
12	55.588	23.784	40.774		91.821	53.602	73.817	
13	37.648	34.997	14.866		70.089	69.789	42.156	
14	21.954	81.995	82.753		35.472	39.856	82.002	
15	70.379	71.029	84.49		85.447	77.527	83.611	
16	74.422	27.75	9.6887		74.873	79.049	21.999	
17	23.819	8.316	34.793		68.521	20.799	68.571	
18	76.811	29.864	28.391		25.164	64.829	60.843	
19	87.093	24.369	5.336		92.762	57.523	23.229	
20	6.151	82.55	55.014		95.004	21.961	80.319	
21	70.855	98.516	63.138		106.11	75.936	82.297	
22	84.559	54.193	9.8343		45.045	77.806	28.051	
23	12.316	8.441	51.376		66.021	96.443	79.282	
24	80.502	44.097	43.557		85.114	74.956	75.98	
25	35.936	37.386	37.719		72.118	71.834	69.412	

TABLE VI  
HARDNESS MEASUREMENT RESULTS

Position	Specimen No.				Position
	1	2	3	New	
1	58.32	58.8	59.84		
2	56.32	58.08	57.2		
3	56.64	57.6	56.56		
4	58.32	59.28	59.2		
5	57.52	58.32	58.48		
6	60.4	59.2	58.4		
7	56.64	57.76	59.04		
8	58.96	56.56	57.28		
9	56.64	57.28	55.52		
10	56.8	55.92	60.56		
11	59.28	57.76	58		
12	59.2	58.96	59.12		
13	57.76	53.2	60.24		
14	57.28	58.4	58.8		
15	59.2	59.2	58.48		
16	61.28	59.68	59.84		
17	56.96	58.08	58.32		
18	56.16	56.56	59.44		
19	57.6	53.44	57.92		
20	57.28	57.44	58.16		
21	57.6	58.16	58.08		
22	57.52	58.48	59.12		
23	55.52	59.04	57.12		
24	57.92	58.88	60.24		
25	60.64	60.16	60.56		



#### E. Hardness

After 1000 hrs salt fog test, hardness was measured on tested specimen surface comparing with new specimen surface. Measurement methods were based on the ISO 868 – Shore Hardness [12]. The measurement results are shown in Table VI. Increasing in surface hardness was measured on tested specimen comparing with new specimen. The measurement results showed the oxidation crosslink of silicone rubber or polydimethylsiloxane. However, no significant different in hardness was observed.

#### IV. CONCLUSION

In this study, salt fog ageing based on IEC 61109 is carried out in order to investigate ageing of silicone rubber housing material for distribution type lightning arrester. The following conclusions were given.

(1) Surface erosion was observed on the trunk surface between the upper large shed and the lower small shed more than on the trunk surface between the upper small shed and the lower large shed.

(2) According to STRI Guide, no significant decreasing in hydrophobicity was measured.

(3) Chemical analysis by ATR – FTIR also confirmed surface deterioration of silicone rubber housing material for lightning arrester in the salt fog ageing test.

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