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

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***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

LIGHTNING 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.

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## 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.

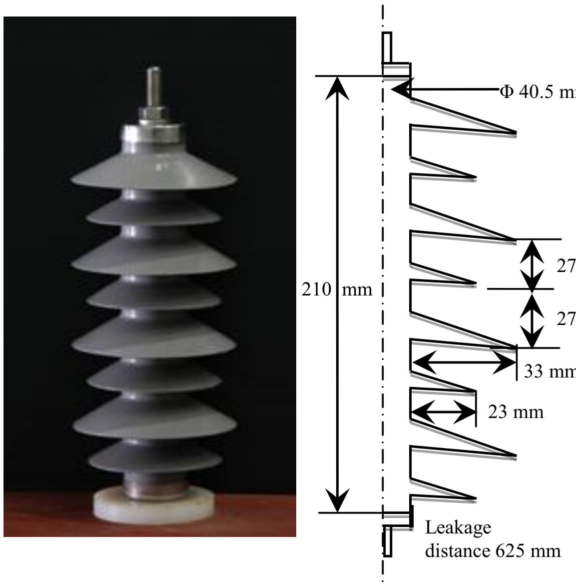



Fig. 1 Configuration and dimensions of specimen.

### B. Test Method

All specimens were placed in the test chamber having volume 9.6 m$^3$ ($2\times2\times2.4$ m$^3$). 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.

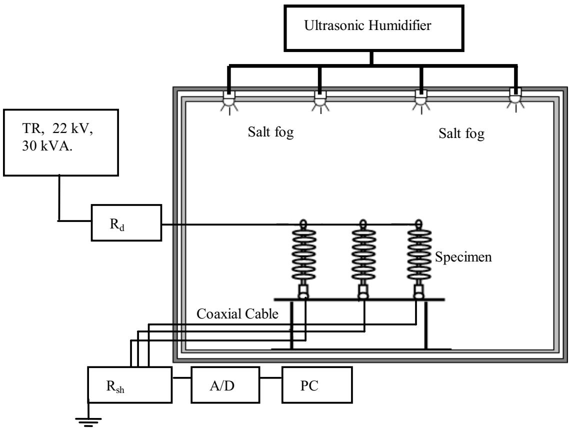
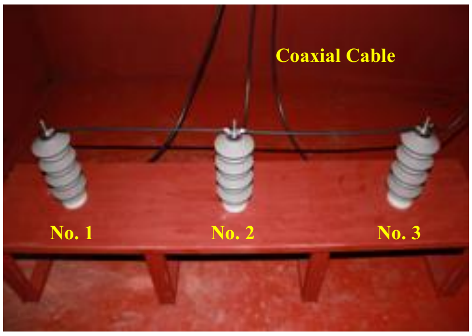



Fig.2 Test arrangement.

(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.

TABLE I
TEST CONDITIONS.

| | |
|---|---|
| Test Chamber | 9.6 $m^3$ |
| Test Voltage | AC 18 kV Continuously Applied |
| Voltage Stress | 34.6 mm/kV. |
| Salt fog Generation | Ultrasonic Humidifier |
| Salt fog Injection Rate | 0.5 $l/hr/m^3$ |
| Salt fog Salinity | 10 $kg/m^3$ (16000 μS/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 | | |

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.

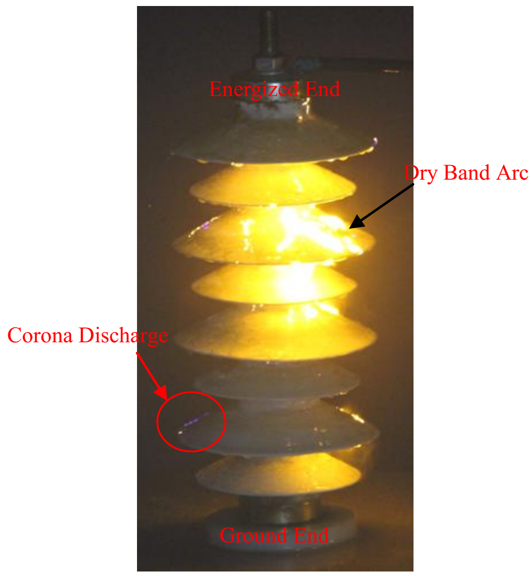
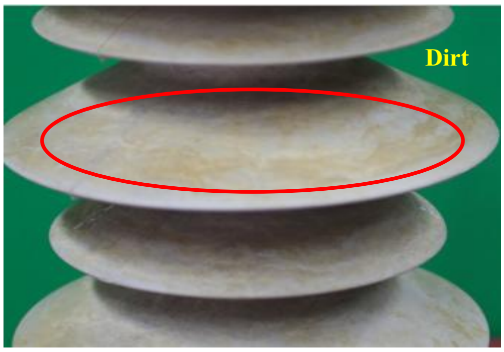



Fig. 4 Discharge Activities


(a)


(b)


(c)




(d)

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.

$$SDD = \frac{S_a}{A} \tag{1}$$

$$S_a = (5.7 \times 10^{-4} \sigma_{20})^{1.03} \tag{2}$$

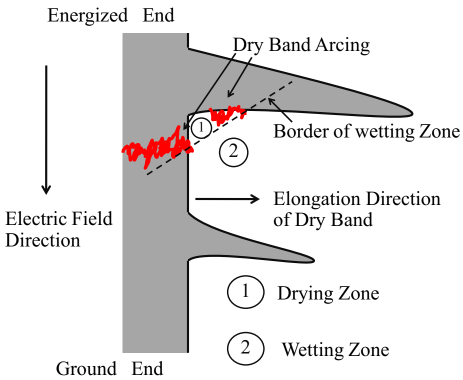



Fig. 6 Explanation of surface erosion

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

where

$\theta$ is solution temperature ($^0$C),

$\sigma_\theta$ is the volume conductivity at temperature of $\theta$ $^0$C (S/m),

$\sigma_{20}$ is the volume conductivity at temperature of 20 $^0$C (S/m),

$b$ is the factor depending on temperature of $\theta$ $^0$C,

Sa is Salinity (mg/cm$^3$),

SDD is salt deposit density (mg/cm$^2$),

V is volume of distilled water (cm$^3$),

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

Significant different in contamination degree was not measured.

TABLE III
CONTAMINATION DEGREE

| Specimen No. | Sa (mg/cm$^3$) | SDD (mg/cm$^2$) |
|---|---|---|
| 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.

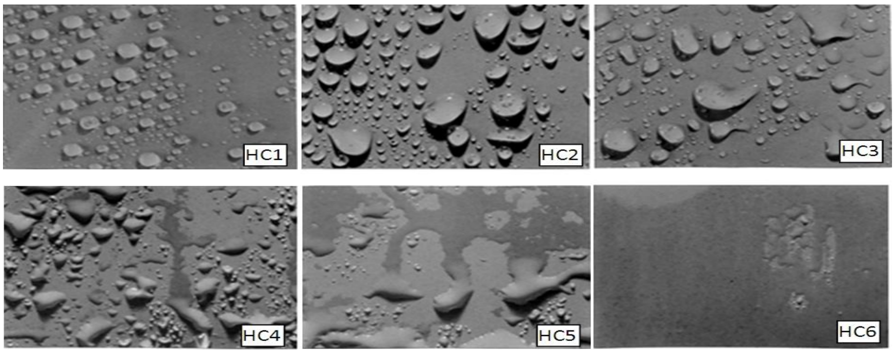
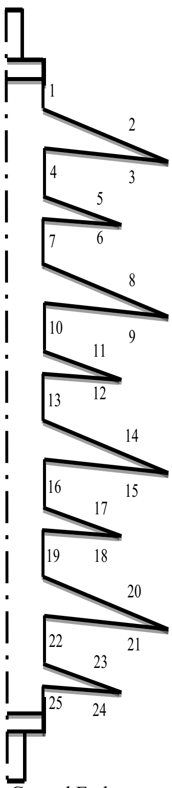



Fig. 7 Characteristics of the sample surface HC1-HC6 [11].

TABLE IV
HYDROPHOBICITY BY STRI CRITERIA

| Position | Specimen No. 1 | No. 2 | No. 3 | Position |
|---|---|---|---|---|
| 1 | HC 3 | HC 3 | HC 4 | Energized End |
| 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 | Ground End |
| 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 conduced to evaluate the chemical changed on tested specimen surface. Decreasing in Si – $CH_3$ bonds (wave number 1260 cm$^{-1}$) indicate that side chains are cleaved. Decreasing of Si – O bonds (wave number 1011 cm$^{-1}$) 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.

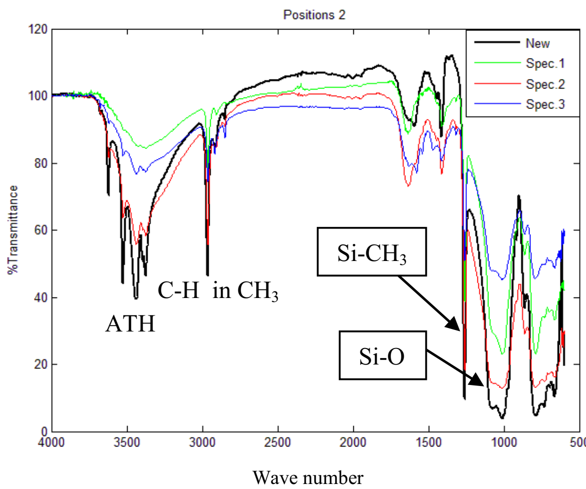


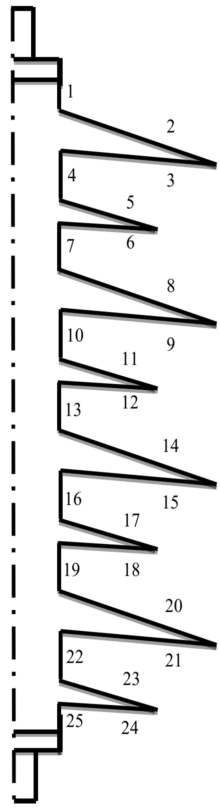

Fig. 8 ATR – FTIR analysis result (Position 2).

TABLE V
SURFACE ANALYSIS RESULTS BY ATR – FTIR

| Position | Specimen | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | %Transmittance (Si-$CH_3$) | | | | %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 | 100 | 37.648 | 34.997 | 14.866 | 100 | 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 | 54.32 | |
| 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.

## ACKNOWLEDGMENT

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