

# INVESTIGATION OF THE AGING CHARACTERISTICS OF CST TERMINATION MADE OF SILICONE RUBBER AT CONTAMINATION AREA



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## ABSTRACT

The CST (Cold Shrink Tube) termination made of silicone rubber has been supplied to practical use in the contamination area since 1996. The accident has not occurred until now. But we think that we should verify the long-term performance of the CST termination. We collect the CST termination used in actual field, and report on the result of the survey of the aging characteristics.

## KEYWORDS

CST Termination, Silicone Rubber, Long-term Performance, Heavy Contamination

## 1. INTRODUCTION

The termination for heavy contamination area made of porcelain that had been used up to now in 6600V distribution line had high reliability. However, because it was very heavy, the workability was bad, and expensive. Therefore, we developed the cable termination that used CST made of silicone rubber. It is light weight, and not expensive. We verified the long-term reliability by the verification of the basic electric performance and the accelerated aging test, and have been using the CST termination since 1996. [1]

The accident has not occurred until today after beginning to use the CST termination. However, we think that we should clarify the tendency of the aged deterioration of this termination, and should estimate an actual long-term performance for stable electric power supplies. In this thesis, we compare and report on the result of the evaluation about the performance of a CST termination used for about nine years in a real field and an initial CST termination. The test items are partial discharge, AC breakdown voltage, lightning impulse breakdown voltage, and chemical composition analysis, etc.

## 2. DESIGN OF THE CST TERMINATION

Design of the CST termination is shown in Figure 1 and Table 1.

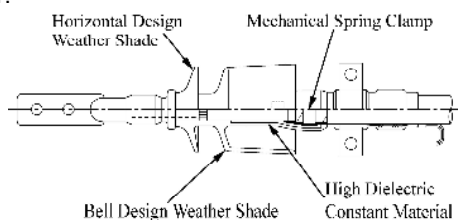


Figure 1: Design of the CST Termination

Table 1: Composition of CST Termination

Item	Description
Insulator material	High tracking resistance silicone rubber
Electrical stress control method	High dielectric constant material stress control
Insulator and weather shade design	Horizontal + Bell design weather shade
Waterproofing concept	Rubber seal stress by CST insulator

## 3. TEST SAMPLE AND CONDITION

### 3.1 Samples

Test terminations were collected from the following area located in Chubu district of Japan.

Table 2: Test Sample

Contamination area	Location	Period used	
General contamination (General)	A	4yr 3mo	9yr 3mo
	B	4yr 2mo	9yr 9mo
	C	4yr 7mo	9yr 7mo
Coarse particulate (Coarse)	D	3yr 11mo	9yr 5mo
	E	3yr 11mo	9yr 6mo
	F	4yr 1mo	9yr 7mo
Calcium chloride spraying(CaCl <sub>2</sub> )	G	4yr 3mo	9yr 8mo
	H	4yr 3mo	9yr 8mo
	I	4yr 6mo	9yr 7mo

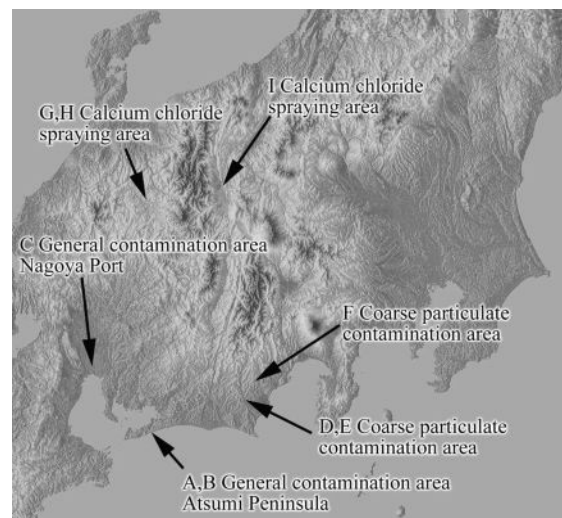
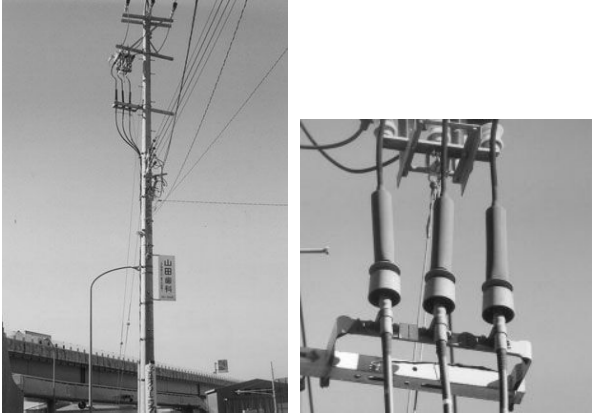


Figure 2: Collecting location



**Figure 3: Location**

**3.2 Test Item**

The collected terminations were evaluated in accordance with the sequence shown in Table 3.

**Table 3: Test Item**

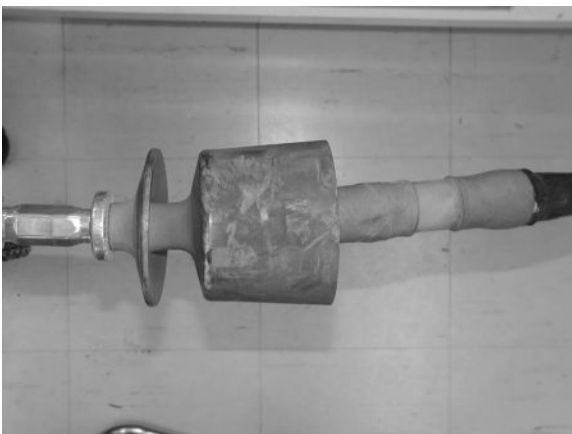
Test Item	Test Sequence			
	1	2	3	4
1 Appearance (outside)	1	1	1	
2 Insulation material analysis	2			
3 Air-tightness	3			
4 Tracking resistance	4			
5 Partial electric discharge		2	2	
6 AC breakdown voltage		3		2
7 Lightning impulse			3	
8 Appearance (inside)		4	4	
9 Accelerated deterioration test				1

As an insulation material analysis, tensile test, elementary analysis, and measurement of the water contact angle, quantitative analysis of low molecular weight siloxane, hardness, and aluminum content measurement are included.

**4. TEST RESULTS**

**4.1 Appearance Test (outside)**

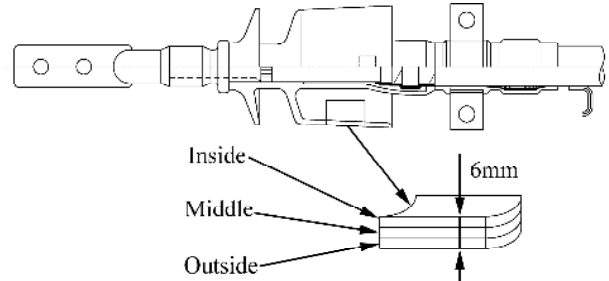
Appearance was observed visually. The surface of the termination was dirty in some degree. However, the defect like the crack or tracking was not observed.



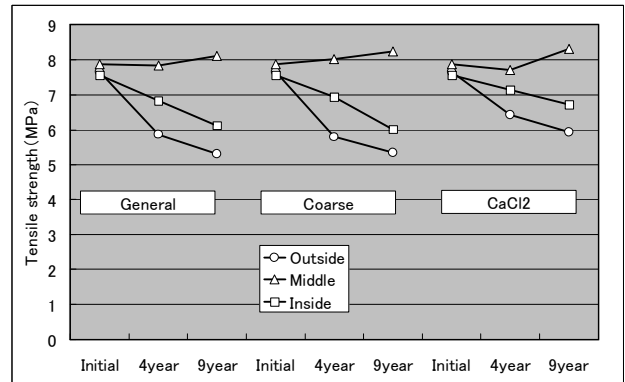
**Figure 4: Appearance of the termination**

**4.2 Tensile test**

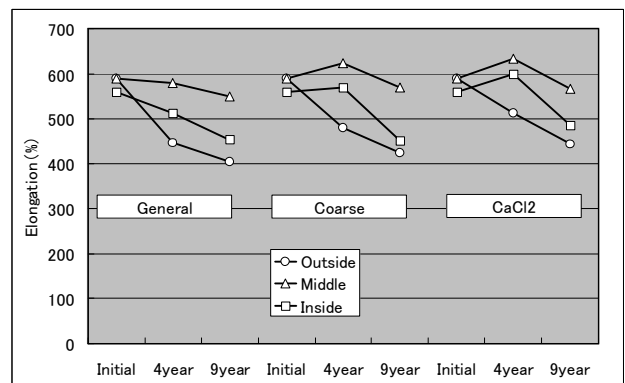
In order to investigate the degradation tendency of physical properties, tensile strength and elongation were measured. The test sheets are prepared from bell shade portion, and divided into three equally at the thickness direction, and cut into dumbbell form.



**Figure 5: Preparation of a sample**



**Figure 6: Tensile strength**



**Figure 7: Elongation**

In the middle portion, there was little degradation. But in outside and inside portions, the degradation tendency of tensile strength and elongation were observed. However, it doesn't become a problem on practical use.

**4.3 Elementary analysis**

A chemical change on the shade surface was observed using EDS analysis. The percentage of O, C, Si and Al-element was investigated.

**Table 4: Test Item**

		Surface Composition (%)			
		O	C	Si	Al
Initial		40	27	24	9
4 Years	General	44	23	24	9
	Coarse particulate	43	25	24	8
	Calcium chloride spraying	43	24	24	9
9 Years	General	44	20	26	10
	Coarse particulate	42	22	26	10
	Calcium chloride spraying	43	28	21	8

Even if time passes, the chemical element of the surface is almost changeless. The difference of the analysis numeric value was in the range of the error of measurement.

**4.4 Contact angle**

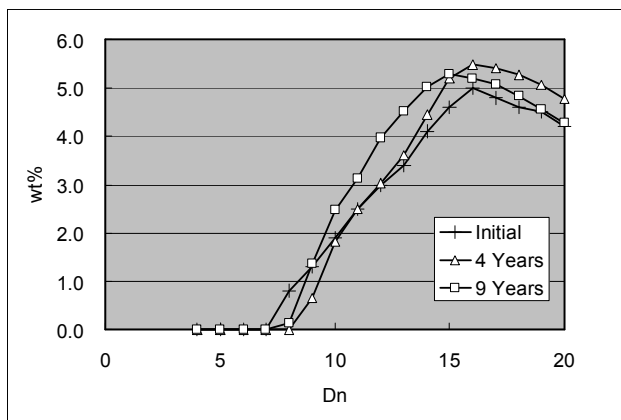
Hydrophobicity is one of the features of silicone rubber. It was confirmed by measuring the water-drop contact angle. Consequently, any change on the hydrophobicity was not observed.



**Figure 8: Contact angle**

**4.5 Quantitative analysis of low molecular weight siloxane**

To investigate the softening degradation of the silicone rubber, the quantitative analysis of low molecular weight siloxane was done by the GC analysis.



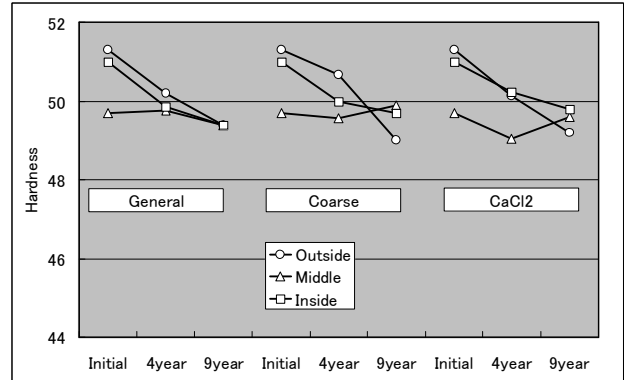
**Figure 9: Low molecular weight siloxane**

Consequently, siloxane increased in number in the range of the degrees 10-20 of polymerization, and it is presumed

that softening degradation is progressing somewhat.

**4.6 Hardness**

As same as the quantitative analysis of low molecular weight siloxane, hardness of the silicone rubber was measured in order to presume the softening degradation during field exposure. As a result, some tendencies to soften were observed.



**Figure 10: Hardness**

**4.7 Aluminum content**

In order to generate a tracking resistance performance for the termination material, aluminum hydroxide is added to the silicone rubber. Change of the aluminum content in the insulator surface was measured by fluorescence X-rays analysis method to verify the residual performance of the tracking resistance.

Consequently, major changes on the aluminum content between the initial insulator and the exposed insulator were not observed.

**Table 5: Alminum content**

		Aluminum content (wt%)
Initial		11.8
4 Years	General	12.4
	Coarse particulate	12.1
	Calcium chloride spraying	13.0
9 Years	General	13.2
	Coarse particulate	12.6
	Calcium chloride spraying	12.7

**4.8 Air-tightness**

Air-tightness of the initial termination and the field exposed termination were measured and met our specification value 49kPa, and showed more values than 120kPa.

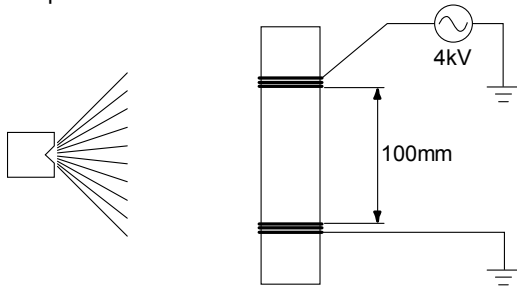
**4.9 Tracking resistance**

Tracking resistance of the field exposed termination was evaluated by JIS C 3005 tracking resistance measurement test method. All samples passed and high tracking resistance performance was verified.

JIS C 3005 anti-tracking test  
Atomization liquid

**Return to Session**

Water 1000ml  
 NaCl 2g  
 Surfactant(7.5mol) 1ml  
 Atomization for ten seconds  
 Stops for 20 seconds  
 This is repeated 101 times.



**Figure 11: JIS C 3005 test method**



**Figure 12: Test sample after tracking resistance test**

**4.10 Partial electric discharge**

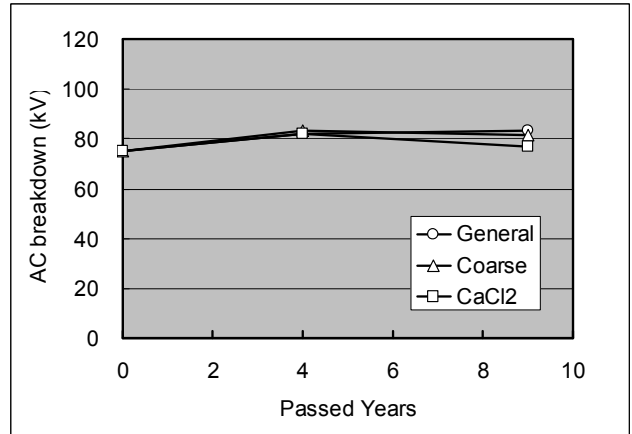
The partial electric discharge of the field exposed termination was measured and compared with initial one. All samples satisfied the specification value enough though a few deterioration tendencies were observed.

**Table 6: Partial electric discharge**

		Partial electric discharge
Initial		>20kV
4 Years	General	>15.8kV
	Coarse particulate	>16.8kV
	Calcium chloride spraying	>12.2kV
9 Years	General	>14.2kV
	Coarse particulate	>18.8kV
	Calcium chloride spraying	>12.5kV

**4.11 AC breakdown voltage**

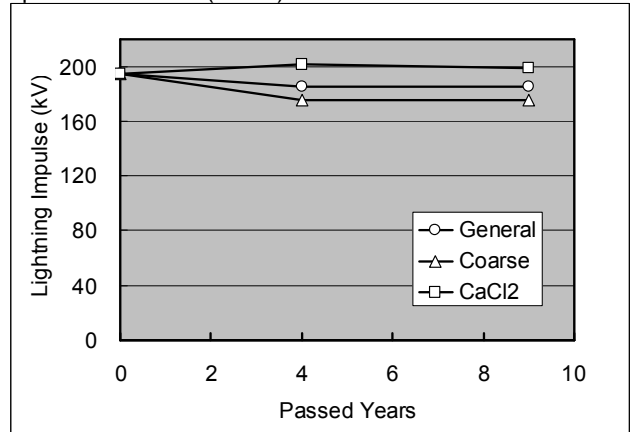
The AC breakdown voltage of the field exposed termination was measured and compared with initial one. All terminations showed sufficient level to the specification value (35kV).



**Figure 13: AC breakdown voltage**

**4.12 Lightning impulse breakdown voltage**

The lightning impulse breakdown voltage of the field exposed termination was measured and compared with initial one. All terminations showed sufficient level to the specification value (-95kV).



**Figure 14: Lightning impulse breakdown voltage**

**4.13 Appearance test (inside)**

The inside appearance of the termination insulator was investigated after the electric examination. Any water penetration at the terminal portion and the grounding clamp portion was not observed and an initial metallic luster was kept.



**Figure 15: Appearance of the inside of the termination**

The aged characteristic of the termination collected in each contamination area was the same from the above-mentioned test result, and it was confirmed that the deterioration tendency of passing year was not different. Then, we did the accelerated deterioration test that simulated the contamination area. The purpose of the test is to verify whether the cause that brings the decrease in physical properties of the insulator material is the contamination or the silicone rubber property.

**4.14 Accelerated deterioration test**

The accelerated deterioration test (3M contamination test (see reference [2])) was examined as a method of verifying the remaining performance. The examination of 2000 hours and 3000 hours was executed to the each collected termination. The remaining performance is confirmed on the AC break down voltage. The value of the general contamination area is shown in the following figures because there was no difference by the area from the above-mentioned result.

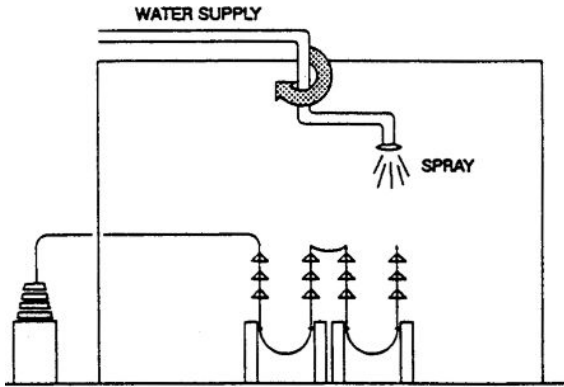


Figure 16: Test equipment

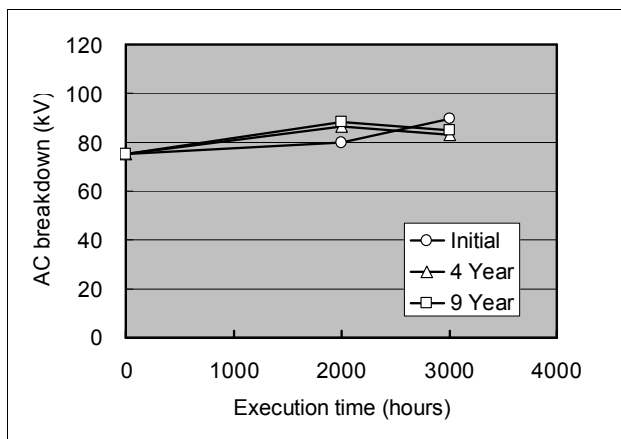


Figure 17: Remaining performance

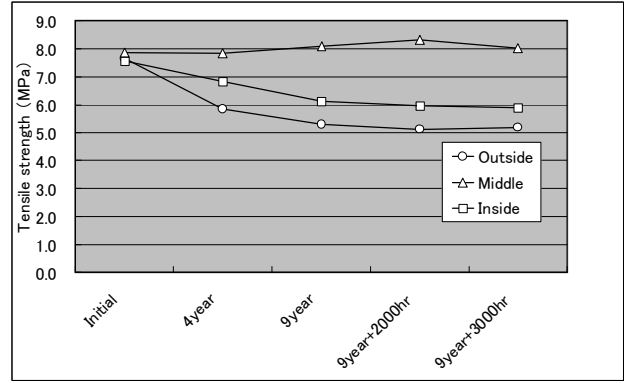


Figure 18: Tensile strength

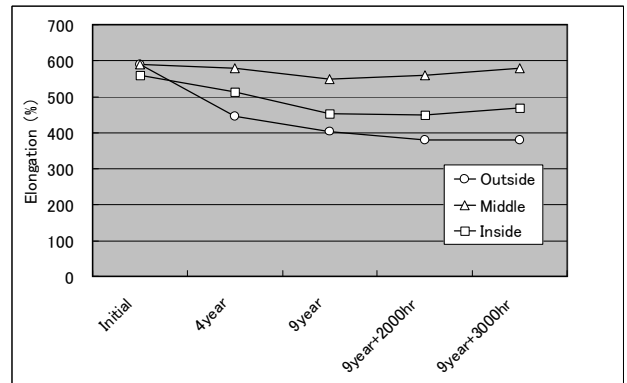


Figure 19: Elongation

**5. DISCUSSION**

**5.1 Insulator material analysis**

In insulator material analysis (tensile strength, elongation), the slightly degradation tendency was observed. It is thought that there is an influence such as ozone because the tendency is seen at the inside which is not being exposed to sunlight.

In elementary analysis, any changes on the ratio of O, C, Si, Al were not observed.

In investigation of aluminum content, the content in the field exposed insulator was equivalent to initial one. It was verified that the field exposed termination keeps the high tracking resistance performance. The chemical change in the surface of silicone rubber by the contamination was not seen.

The hydrophobicity of the surface of the field exposed insulator was equivalent to initial one and maintains high value. It was verified that high hydrophobicity of silicone rubber is maintained for a long period.

In the hardness measurement, softening tendencies have been observed. Moreover, by the quantitative analysis of low molecular weight siloxane, the tendency that polymer becomes to low molecule was observed. Therefore, it is thought that the softening degradation progresses on the surface of silicone rubber.

### **5.2 Electrical performance**

In the termination performance (partial electric discharge, AC breakdown voltage, lightning impulse breakdown voltage, and air-tightness), the performance of the field exposed termination was equivalent to initial one. Moreover, it was verified that sufficient margin to the standard was maintained.

And it was verified to maintain the performance though a long term was used in the contamination region.

### **5.3 Accelerated deterioration test**

3M contamination test is an examination method that simulates the dust stain region in an industrial region in the seaside etc. The decrease in the insulation performance of the CST termination was not observed though the accelerated aging test on 3000 hours was done by this method.

We thought that this termination have high insulation performance in spite of the surface contamination because dry band is always secured by bell shape shade.

On the other hand, the decrease tendency was seen as for the tensile strength and the elongation of the silicone rubber. However, the degree of the decrease is smaller than in actual field. Therefore, it is thought that the surface contamination that 3M acceleration aging test simulates doesn't influence the physical properties decrease in the silicone so much.

## **6. CONCLUSIONS**

We investigated aging characteristics of CST termination that had been used for nine years in the contamination environment. Though the softening degradation tendency on the surface of silicone rubber was confirmed, the insulation performance was not decreased, and it still has an enough remaining performance. However, it is long at the product-life that we expect of the CST termination for about 30 years. However, we expect the product-life cycle of 30 years to the CST termination. Therefore, we think that we should investigate aging characteristic continuously in the future, and evaluate long-term reliability.

## **Acknowledgments**

This research work has been conducted as a joint project between Chubu Electric Power Co., Inc. and Sumitomo 3M Ltd. And the authors acknowledge to the project members.

## **REFERENCES**

- [1] A K.Terada, M.Kawamura, N.Tsubouchi, KI.Tanaka, 1994, "*High Contamination Performance Polymeric Termination*", IEEE Transmission and Distribution Conference, April 1994.
- [2] L. A. Johnson, W. C. Osborn, "*Contamination Testing of Distribution Class Cable Terminations*," IEEE Underground T and D Conference, Pub. 76 CH 119-7-PWR, 1976.

## **GLOSSARY**

CST: Cold Shrink Tube

JIS: Japan Industrial Standard

EDS: Energy Dispersive X-ray Spectroscopy

GC: Gas chromatography