Insulation properties of Suspension Insulator depending on State of Snowfall near the Coast of Pacific Ocean

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Abstract **— The insulation properties of transmission line insulators installed near a coast are markedly affected by meteorological and environmental conditions. In particular, the snow accreted on sheds and the air temperature in the period of cold seasons from autumn to spring are factors that markedly change insulation properties. It is considered that the decrease in the level of insulation in the cold seasons is different from that in the warm seasons without snow and ice. We installed a test insulator string on the roof of a college building at Kushiro in Hokkaido Prefecture near the coast of Pacific Ocean. We have been measuring the real-time leakage resistance of a string of suspension insulators and collecting meteorological data since September 1993. Moreover, we designed a device for measuring equivalent salt deposit density (ESDD) using glass plates and installed at the same place as the string. We have been measuring ESDD since January 2001. We had already reported the relationships between leakage resistance and relative humidity, and ESDD. In this work, the insulation properties depending on the snow accreted on sheds and the air temperature in the period of cold seasons, which were observed for several years, were analyzed. Results showed that when there is high wetness on the surface of the insulators due to snow accretion on sheds, the leakage resistance of the insulators decreases, whereas when there is low wetness on the surface of the insulators due to snow accretion on sheds, the leakage resistance of the insulators increases. The wetness on the surface of the insulators depends on the amount of snow accretion and temperature. The leakage resistance decreased rapidly, depending on increases in the temperature, sunshine and the sea salt contamination. This rapid decrease in leakage resistance is due to the melting of water from snow accretion on sheds, which is caused by increases in temperature and sunshine. Moreover, the leakage resistance decreased considerably owing to the south wind carrying sea salt contaminants to the surface of the insulators.**

I. INTRODUCTION

The insulation properties of an insulator suspended by coastal power transmission lines have been reported to significantly change under meteorological and environmental conditions.[1]-[7] On the Pacific Coast in the east of Hokkaido, the insulation performance of insulators is affected by sea salt contamination. In addition, the insulation performance of the insulators is affected by the wetness on the surface of the insulators.

The authors aim to use the results of this study for the forecast and prevention of accidents involving power transmission lines.[1]-[7] In 1993, we installed a string of 3 unit 250mmϕ suspension insulators (specimen insulators) on the rooftop of a college building near the Pacific Coast at Kushiro, and in 2001, we installed equivalent salt deposit density (ESDD) measuring devices to estimate the level of sea salt contamination on the surface of the specimen insulators. Since installing these devices, we have been measuring the leakage resistance of the specimen insulators, ESDD and meteorological conditions.

We discuss the influences of snow accretion on the insulation properties of the specimen insulators in the snowfall period from November to April on the basis of observations from 2004 to 2005. In addition, we discuss the relationships between the wetness on the surface of the specimen insulators due to snow accretion and meteorological conditions. Moreover, we discuss the relationship between the levels of sea salt contamination and snow accretion in the case of a rapid decrease in leakage resistance.

II. GEOGRAPHIC AND METEOROLOGICAL CONDITIONS

A. Location of test site

The field test site was established on the rooftop of a building at Kushiro National College of Technology in Kushiro, Hokkaido, on the Pacific Coast, as shown in Fig. 1. The college building is 1.5km from the shore on flat land, about 20km west of Kushiro,[4],[6],[7] and the height of the building rooftop is about 30m.

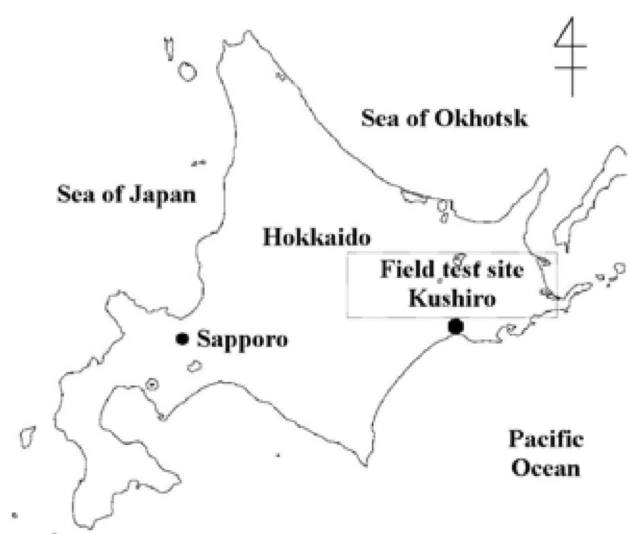

Fig. 1. Location of test site

B. Meteorological conditions of test area

The wind distribution and the ocean currents generating the sea fog peculiar to Kushiro are shown in Fig. 2.[4]-[7] The monthly temperature, snowfall depth and sunshine duration of Kushiro in 2004 provided by the Japan Meteorological Agency are shown in Figs. 3(a)-(c).

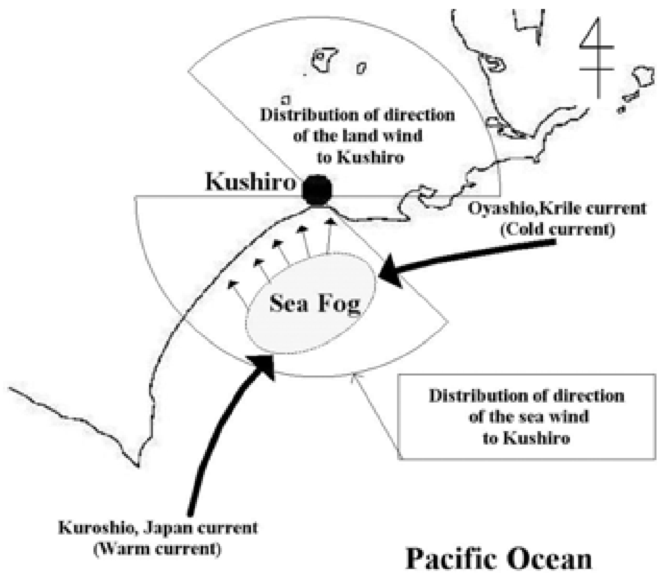

Fig. 2. Wind direction and ocean current

In Kushiro, a decrease in the leakage resistance of the specimen insulators due to sea salt contamination occurs.[4]-[7] The sea wind has a higher salinity than the land wind, and the sea wind strongly affects the insulation properties of the specimen insulators.[1],[4]

The meteorological factors other than wind that affect the insulation properties of the insulators at each season are described as follows.

Spring – Summer: Sea fog is generated by the confluence of the two currents shown in Fig. 2.

Summer: Relative humidity and the level of sea salt contamination are increased by typhoon passage.

The increase of relative humidity decreases further the leakage resistance of the specimen insulators due to sea salt contamination.[4]-[7]

Autumn: There are many fine days in autumn and the relative humidity shows low tendency. However, the monthly minimum temperatures are below 0 degrees since October, and there are snowfalls in November, as shown in Fig. 3(a). Because the monthly mean temperature exceeds 0 degrees in November, as shown in Fig. 3(a), the snowfalls are wet for melting.

Winter – Spring: Snowfalls are observed in the period from November to April in the Kushiro, as shown in Fig. 3(b). Because monthly mean temperatures are below 0 degrees, as shown in Fig. 3(a), the snowfalls are often dry from December to February. From March to April, because monthly mean temperatures are about 0 degrees or above and the sunshine duration increases, snowfalls are wet, as shown in Fig.3 (a) and Fig.3 (c).

The wetness of snowfalls markedly affects the leakage resistance of the specimen insulators.[1]-[3] However, it is considered that the wetness of snowfalls is affected by temperature, sunshine duration, and wind. In this work, the insulation properties of the specimen insulators in the snowfall periods of 2004-2005 were analyzed.

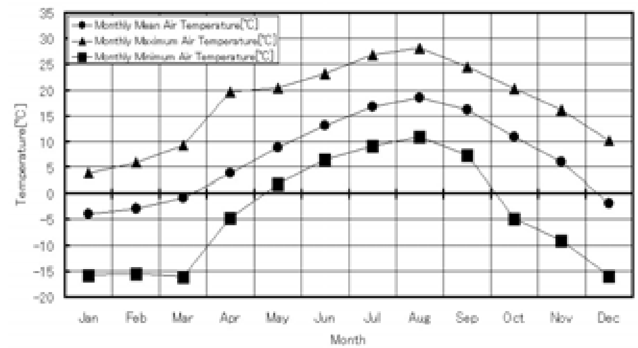

Fig. 3(a). Air temperatures of Kushiro in 2004 (Monthly): monthly mean, monthly maximum and monthly minimum (data provided by the Japan Meteorological Agency)

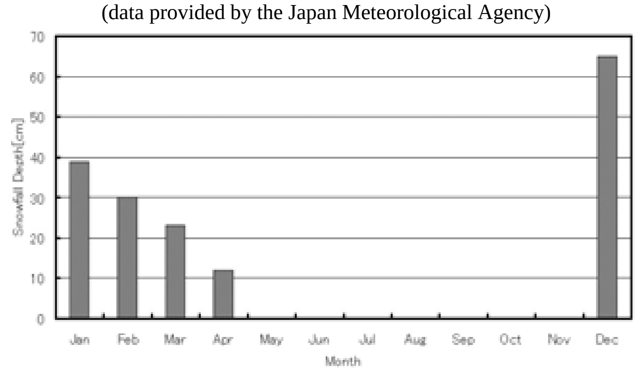

Fig. 3(b). Snowfall depths of Kushiro in 2004 (monthly total) (data provided by the Japan Meteorological Agency)

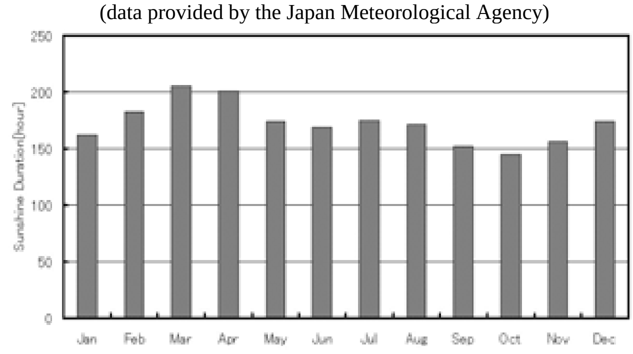

Fig. 3(c). Sunshine duration of Kushiro in 2004 (monthly total) (data provided by the Japan Meteorological Agency)

III. EXPERIMENTAL SETUP AND PROCEDURES

A. Meteorological data and measurement of leakage resistance

The specimen insulators and a weather measurement system (Weather Station System 5, Davis Instruments Corp.) were installed on the rooftop of a building, as shown in Fig.4.[4],[6],[7] Temperature, humidity, wind direction, wind velocity, and the amount of rainfall were recorded an interval of 15min by a personal computer (PC) connected to a meteorological data measurement system through an RS-232C system. The leakage resistance measurement system is shown in Fig.5. The leakage resistance data acquisition system consisted of the specimen insulators, the PC, a digital multimeter and a DCHV power source. A positive DC voltage of 200V was applied to measure the leakage resistance of the specimen insulators. Leakage resistance data was calculated using the PC through the RS-232C system with a digital multimeter at 15min intervals.

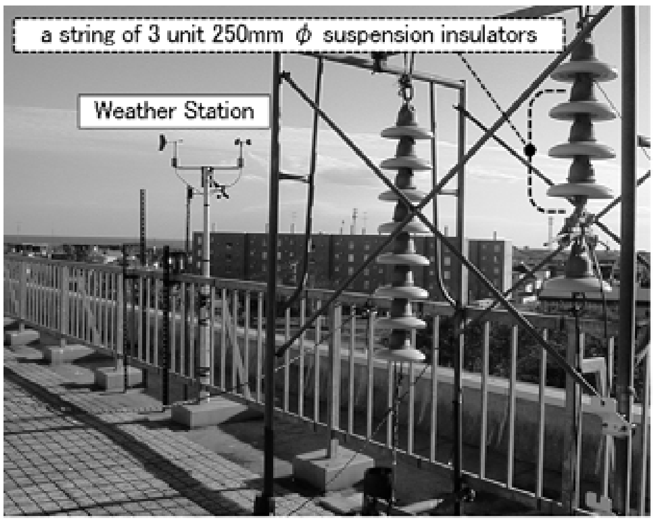

Fig. 4. A string of 3 unit 250mmϕ suspension insulators and weather station

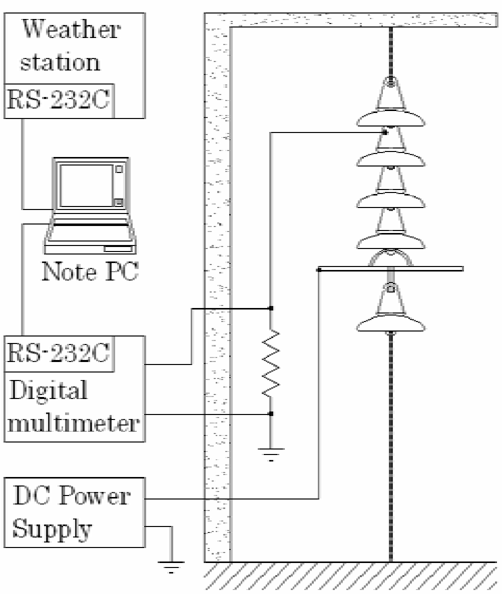

Fig. 5. Layout of data acquisition system

B. Measurement of contamination

An ESDD measurement device composed of 24 glass plates was used to estimate the salinity on the surface of the specimen insulators, as shown in Fig.6.[4],[6],[7] The surface of the porcelain insulators was glazed in the manufacturing process. Because the smoothness of the surfaces of the porcelain insulators and glass plates in this process are similar, the sea salt contamination levels of both surfaces are considered similar. The ESDD measured using this device has a trend similar to that of the ESDD of another nearby shore that was reported by K.Kawasaki, T.Mastunobu and M.Sekiya.[8] This ESDD measurement device is used to estimate the ESDD of the specimen insulators for the above mentioned reasons.

To estimate the ESDD of the upper surface of the insulators, the glass surface of the device is turned upward and exposed, and to estimate the ESDD of the lower surface of the insulators, the glass surface of the device is turned downward and exposed.

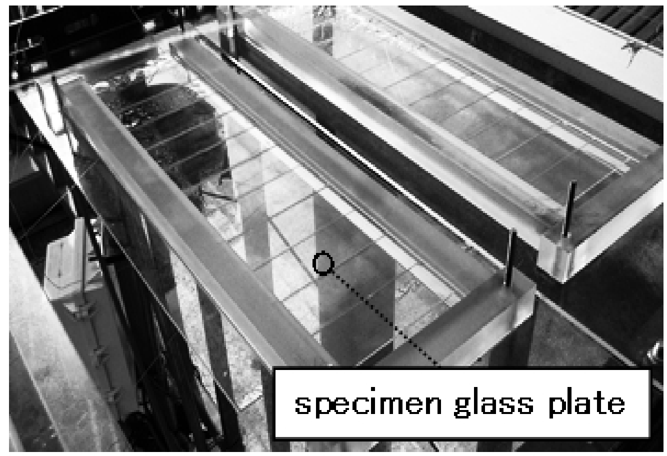

Fig. 6. Measurement setup of equivalent salt deposit density on glass plate surface (contamination on the upper surface)

The salinity on the upper surface of the specimen insulators per day is calculated by the following procedure.

Step 1: The glass plates of the ESDD device are turned upward to be exposed to the atmosphere for 24h.

Step 2: The glass plates are cleaned in an ultrasonic cleaner using about 70ml of pure water.

Step 3: The cleaning solution is concentrated by boiling and its salinity is measured.

Step 4: The ESDD on the upper surface of the specimen insulators is given as the salinity of the glass plates per unit surface area.

To calculate the salinity on the lower surface of the specimen insulators, the glass plates are turned downward in Step 1 and the procedure from Step 2 is executed.

IV. Results and Discussion

A. Relationship between leakage resistance and relative humidity

The characteristics of the leakage resistance of the specimen insulators and the relative humidity are shown in Fig. 7. From these characteristics, a negative correlation is observed between the leakage resistance and the relative humidity.[1],[2],[4],[6],[7] In addition, it is understood that a variation in wetness on the surface of the specimen insulators due to the relative humidity affects the insulation performance of the specimen insulators.

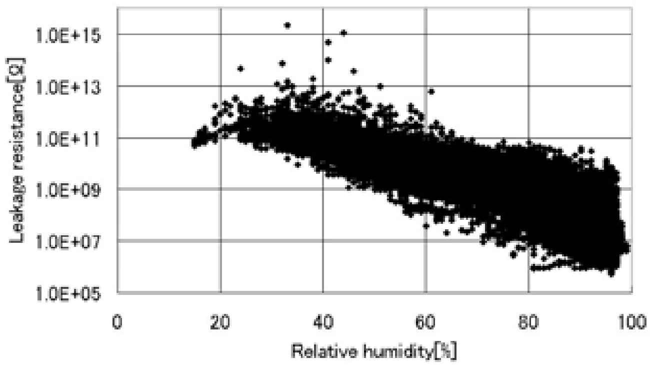

Fig. 7. Leakage resistance depending on relative humidity

B. Relationship between leakage resistance and level of sea salt contamination

We had already reported that the sea salt contamination on the upper surface of the insulators is a predominant factor that determines the insulation properties of the specimen insulators.[4],[6],[7] Moreover, we had already reported that the sea salt contamination on the lower surface of the insulators shows long-term accumulation and saturation tendency, and that the correlation between the level of sea salt contamination on the lower surface and the leakage resistance of the specimen insulators is low. The characteristics of the leakage resistance of the specimen insulators and the ESDD on the upper surface of the specimen insulators are shown in Fig. 8. When the ESDD increases, the leakage resistance decreases.[2],[4],[6],[7]

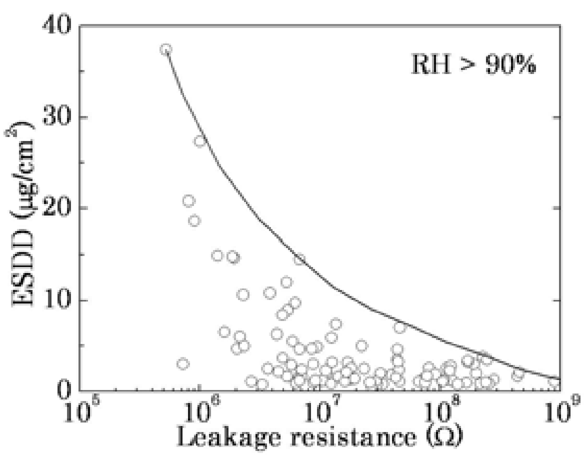

Fig. 8. ESDD on the upper surface of specimen insulator vs leakage resistance

C. Insulation properties of specimen insulators in a snowfall period

The snowfall period is from the latter half of November to April, as described in the preceding section. The snow accretion on the sheds of the insulators contained water, and this condition changed depending on meteorological factors, such as temperature.[2],[3] It is considered that such a change alters the leakage resistance of the insulators. Therefore, we discuss it on the basis of the results for each season and condition.

Case 1: November (autumn)

In November, the snowfall contained a lot of water because the temperature was high. Therefore, the snowfall often accreted on the sheds of the specimen insulators, as shown in Fig. 9. Fig.10 shows the result obtained from 27th to 28th of November 2005.

Fig. 9. Snow accretion on the specimen insulator in November 2005

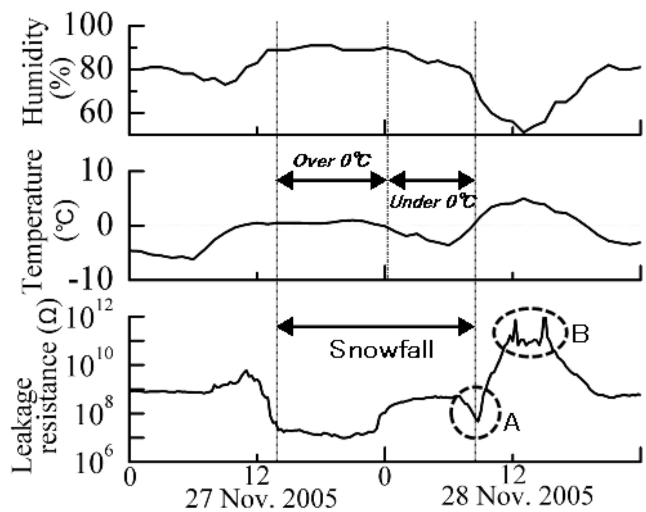

Fig. 10. Leakage resistance and weather data from 27th to 28th of November 2005

The leakage resistance was low in the first half of the snowfall. This low value of resistance was caused by the wet snowfall produced at temperatures exceeding 0 degrees and snow accretion on the specimen insulators.

The leakage resistance recovered in the latter half of the period. This was caused by the freezing of the water remained on the surface of the specimen insulators induced by a decrease in temperature below 0 degrees.

However, a rapid decrease in leakage resistance is observed in the A period in Fig. 10, though the relative humidity is low. This was caused by the melting of ice on the surface of the specimen insulators due to weather improvement, as shown in the A period in Fig. 10. The sunshine and temperature increases due to weather improvement are observed in the A period in Fig. 10. In the B period in Fig. 10, the leakage resistance increases again. This was caused by the drying of the surface of the insulators due to a decrease in relative humidity and an increase in temperature.

Case 2: Dec. – Feb. (winter)

The temperature and relative humidity are low in winter, and snowfalls are dry. Therefore, the snow did not accrete on the surface of the specimen insulators and fell to the ground, and the atmospheric moisture froze on the surface of the specimen insulators at temperatures below 0 degrees at night, as shown in Fig.11. Fig.12 shows the result obtained from 19th to 20th January 2005.

Fig. 11. Ice on the surface of specimen insulator in January 2005

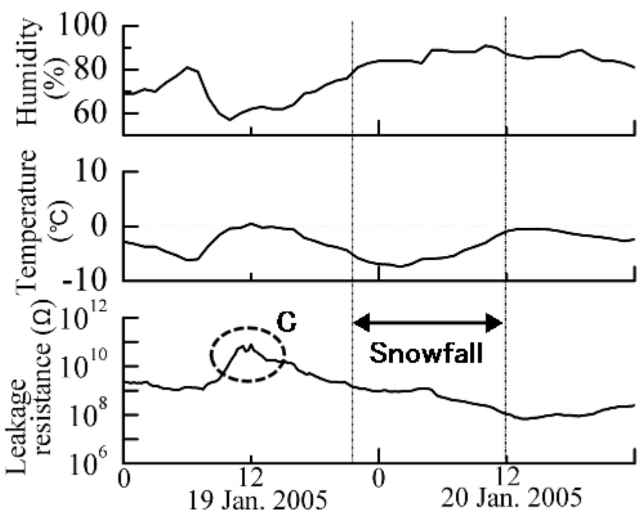

Fig.12. Leakage resistance and weather data from 19th to 20th of January 2005

In the snowfall period, the snowfall that fell on the surface of the specimen insulators did not accrete on the surface and fell to the ground. Moreover, the leakage resistance decreased by the relative humidity increasing. However, the leakage resistance did not have markedly change, compared with the result obtained on 19th January 2005 excluding the period C in Fig. 12. It is considered that the leakage resistance rapidly increased because the surface of the specimen insulators was dried by sunshine in the period C in Fig. 12, though the temperature was below 0 degrees.

Case 3 : Mar. – Apr. (spring)

The result obtained from 17th to 18th March 2005 is shown in Fig. 13. The snowfall was mixed with rain because the temperature was high in the snowfall period in Fig. 13. Therefore, the leakage resistance of the specimen insulators dispersed in the snowfall period in Fig. 13.

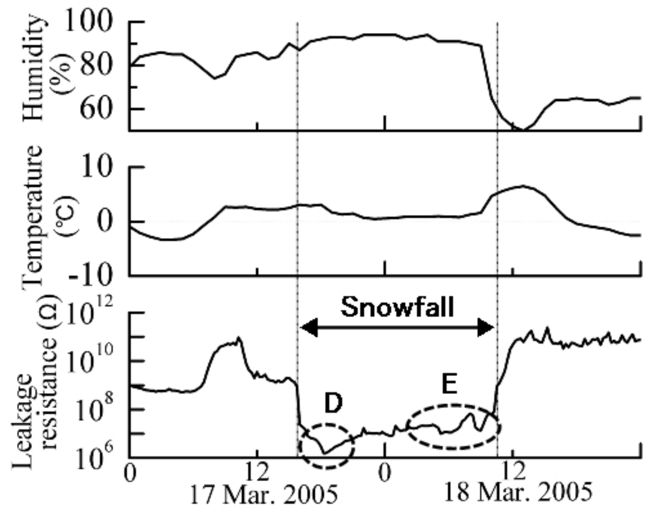

Fig. 13. Leakage resistance and weather data from 17th to 18th of March 2005

In the period D in the first half of the snowfall period shown in Fig. 13, the snow began to melt and fall like rain because the temperature increased. The surface of the specimen insulators was wet by the water contained in the snowfall, and the leakage resistance of the specimen insulators was decreased by this water.

Table 1. Wind direction and velocity in Kushiro in 18th March 2005 (data provided by the Japan Meteorological Agency)

Hours – Mar.18 , 2005	Wind Direction	Wind Velocity[m/s]
00:00	NNE	9.4
01:00	NNE	7.8
02:00	N	9.5
03:00	N	7.6
04:00	N	4.5
05:00	WSW	3.6
06:00	WSW	6.5
07:00	W	8.1
08:00	SW	5.9
09:00	WSW	8.1
10:00	WNW	4.2
11:00	NW	10.6
12:00	NW	10.9

The temperature decreased in the period E in the latter half of the snowfall period, and the rain changed into wet snow. The leakage resistance was increased by this change. However, the leakage resistance dispersed under a similar relative humidity condition. It is considered that this depends on the change in wind velocity. Table 1 shows the time courses of wind direction and velocity.

The water is blown off from the surface of the specimen insulators by strong wind and remains on the surface in the case of weak wind. It is considered that the leakage resistance of the specimen insulators disperses, as mentioned above.

Case 4 : Rapid decrease in leakage resistance

The result obtained from 10th to 11th December 2004 when the leakage resistance of the specimen insulators rapidly decreased during the snowfall is shown in Fig. 14.

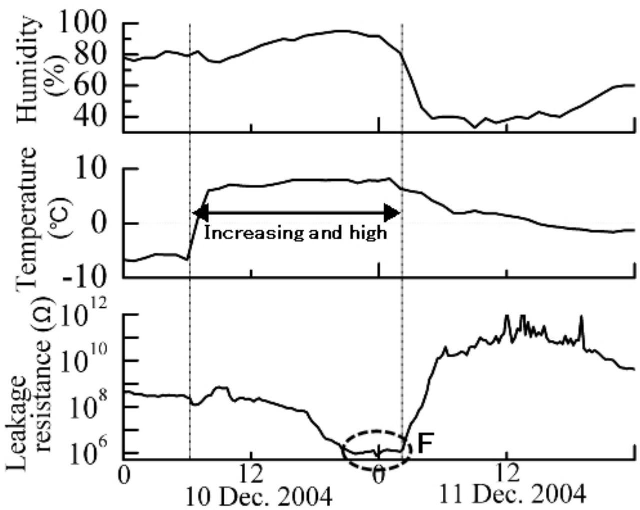

Fig. 14. Leakage resistance and weather data from 10th to 11th of December 2004

The temperature was below 0 degrees before the leakage resistance decrease, as shown in Fig. 14. Subsequently, the leakage resistance was decreased by the water from melting ice due to a temperature increase on the surface of the specimen insulators and by the wet snowfall. In addition, the period F in Fig. 14 indicated rain storm, and the leakage resistance decreased rapidly to 769K ohms at this period.

Table 2. Wind direction and velocity under rain storm in Kushiro from 10th to 11th of December 2004
(data provided by the Japan Meteorological Agency)

Hours – Dec , 2004	Wind Direction	Wind Velocity[m/s]
10th 21:00	SSW	11.1
22:00	SSW	12.5
23:00	SSW	11.7
11th 0:00	SSW	12.5
1:00	SW	9.3
2:00	SW	13.2
3:00	WNW	6.2

Table 2 shows the wind direction and velocity during rain storm in the period F in Fig. 14. At the lowest leakage resistance, the rain storm had the SSW direction and a wind velocity exceeding 11m/s. Moreover, the ESDD measurement was 3.66μg/cm^2 which means the sea salt contamination affected the insulation properties of the specimen insulators.

V. Conclusion

The following results for the insulation properties of the specimen insulators in the snowfall period were obtained.

1) The insulation properties of the specimen insulators changed with the wetness of the fallen snow. The leakage resistance decreased when wet snow fell. When dry snow fell, the leakage resistance increases.

2) The rapid decrease in the leakage resistance of the specimen insulators was due to the increase in temperature. The snow accreted and frozen on the surface of the specimen insulators melted owing to increases in temperature and sunshine duration, and wet the surface of the specimen insulators. In addition, the leakage resistance of the specimen insulators decreased with the wetness on the surface of the insulators.

3) The leakage resistance of the specimen insulators decreased rapidly was observed when the effects of sea salt contamination and wind were added to the leakage resistance.

VI. Acknowledgements

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