Verification of the Effects of PTFE Tapes on Reducing Snow Accretion on Overhead Power Transmission Lines

Masaki Nakagami
Chubu Electric Power Co., Inc
2-3-24,Yokota,Atsuta-Ku,Nagoya,Japan, 456-0022, *Nakagami.Masaki@chuden.co.jp*

Abstract— **Snow accretion on overhead power lines is one of the significant issues regarding overhead transmission lines in both rural and urban areas, because of snow falling from the lines causing damage to greenhouses and vehicles. As one measure against this problem, PTFE (polytetrafluoroethylene) tapes can be used. However, one issue has been that the effects of PTFE tapes on snow accretion reduction have not been quantitatively assessed.**

Therefore, a laboratory wind tunnel test simulating field conditions with wet snow was carried out to evaluate quantitatively the effect of the tape on reducing snow accretion. Aged PTFE tapes were also investigated to check water repellent performance. As a result, we showed that PTFE tapes have sufficient snow accretion reduction effect on overhead transmission lines and provide long-term reliability.

Keywords— PTFE tape, snow accretion reduction effect, overhead transmission lines, quantitative assessment

I. Introduction

Snow accreted on overhead transmission lines located in urban and suburban areas falls onto greenhouses and vehicles, damaging them. This presents one of the significant issues. Therefore, effective and economical measures have been also required from the viewpoint of public safety.

As one of the measures taken against this problem, a means of using PTFE tape has been applied up to now. These PTFE tapes have very high water repellency and have been used on transmission lines by spirally winding them around. It is believed that this water repellency causes snow to fall from the transmission lines at an early stage before the amount of accreted snow accumulates too greatly. However, the effect of this approach has not yet been assessed quantitatively.

Therefore, to verify snow accretion reduction effects quantitatively, an artificial snow accretion test was carried out in a laboratory using wet snow, in conditions that simulated the actual environment. To reduce the PTFE tape costs, the test was conducted with several types of winding patterns by changing the winding pitch. As a result, it was verified that winding PTFE tapes around the wires with a winding pitch of 5 mm reduces snow accretion on the transmission lines by approximately 80% compared with wires on which no measures were taken. Moreover, a field examination was also performed to verify the effect of the tape on reducing snow accretion under field conditions.

In addition, to verify the water repellency of aged PTFE tapes, we examined the static contact angle of PTFE tapes that had been serviced on actual transmission lines over a period of 14 years.

As a result, it was revealed that the PTFE tapes have sufficient snow accretion reduction effect on overhead transmission lines and provide long-term reliability. This paper describes these tests and the verified results.

II. Damage Caused by Falling of Accreted Snow on Electrical Wires

A. Damage from Falling of Accreted Snow

Figure 1 shows an example of damage to a greenhouse that was caused by falling of accreted snow on the wires. From the shape of the fallen accreted snow sampled at that time and the weather conditions, it was verified that damage from fallen snow was caused at a phase prior to the formation of cylindrical-shaped accretion of wet snow (formed during snowfall with much water content at atmospheric temperatures higher than the freezing point).

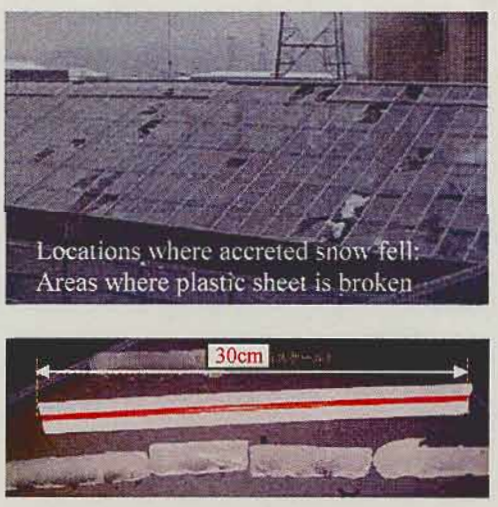


Fig. 1. An example of Damage to a greenhouse from fallen accreted snow

B. Types of Snow Accretion

From the description in subsection II.A, it is assumed that damage from the falling of accreted snow is caused by the accretion of wet snow; it was therefore decided here to focus attention on the accretion of wet snow.

It has been verified [1], [2] that the accretion of wet snow in Japan is generally caused under the following weather conditions:

- In winter, an atmospheric low-pressure system travels north along the Japanese archipelago while developing.
- Atmospheric temperature on the ground is 0 to 2°C.
- Snow contains much water content and its specific gravity is 0.3 g/cm^3 or more.
- Snow accretion occurs even at a wind velocity of 10 m/s or more.

III. Overview of PTFE Tapes

PTFE tapes are those in which polytetrafluoroethylene (PTFE) has been impregnated into glass fiber and silicone adhesive applied to one side. These tapes have the features shown in Table 1.

The method of using PTFE tape is to wind it spirally around transmission lines as shown in Figure 2 to cause accreted snow to fall at an early stage of accretion.

TABLE 1.
Features of PTFE Tapes

Item	Features
Friction coefficient	The surface of PTFE tapes has a very low friction coefficient, contributing to increased sliding. Because the tapes are water repellent, they also can prevent the accretion of snow and ice.
Heat resistance	The temperature range for continuous usage is from −55°C to 260°C.
Chemical resistance	Have excellent acid and alkaline resistance and are unaffected by them.

Fig. 2. Example of application of PTFE tape

IV. Verification of Snow Accretion Reduction Performance

To verify the snow accretion reduction effect of PTFE tapes quantitatively, the following three verification tests were performed.

TABLE 2.
Details of Verification of the Snow Accretion Reduction Effect of PTFE Tapes

Item		Purpose
Snow accretion reduction effect	Artificial snow accretion test	To quantitatively verify the snow accretion reduction effect on transmission lines with spirally wound PTFE tape, using natural snowfall
	Actual field test	To observe the snow accretion reduction effects of PTFE tapes during natural snowfall by winding PTFE tape around actual transmission lines
Long-term reliability		To verify adhesive force and snow accretion resistant effects by partially removing PTFE tapes applied to actual transmission lines for 14 years

A. Testing Method of Artificial Snow Accretion

Figures 3 and 4 show the experimental setup of artificial snow accretion.

Currently, a tape spacing of 5 mm has been set with consideration given to corrosion on electrical wires; however, the influence of tape spacing on snow accretion has not yet been assessed. Thus, to also examine the optimal winding pitch of the tapes, winding patterns were changed in three types as shown in Figure 4. The effective length of the tested wire was 1 m and equipped with plastic rings. These rings also work to reduce snow accretion and enable the tapes to stay on the wire.

In the artificial snow accretion test, naturally fallen snow was used and a block of snow was changed to flakes using a wire netting above the air outlet. Air-conditioning equipment was used to keep the temperature constant (from −20°C to +30°C) in the examination chamber and to enable highly accurate testing.

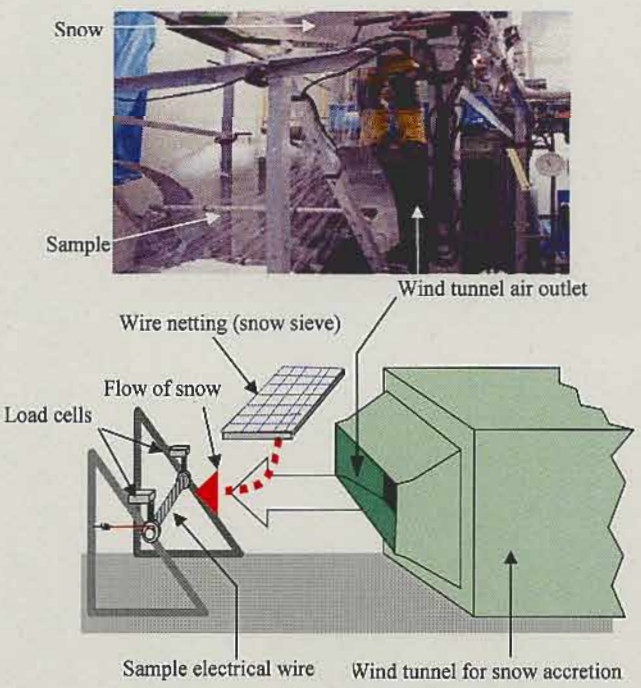
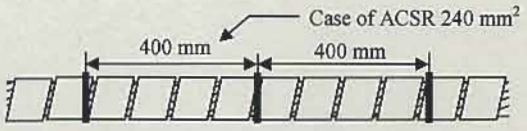


Fig. 3. Schematic diagram of the test equipment

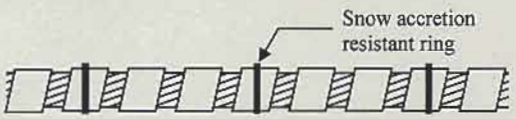
TABLE 3.
Details of the Artificial Snow Accretion Test

Item	Description
Sample	ACSR 240 mm^2, ACSR 810 mm^2
Items measured	Snow accretion density, water content Mass of accreted snow (compact load cells) Cross-sectional shape (still photos and video)
Test conditions	Set based on actual field weather conditions Atmospheric temperature: 2°C snowfall period: 20 min (1,200 s) Wind velocity: 5.0 m/s to 7.0 m/s snow accretion density: 0.4 g/cm^3
Assessment	Snow accretion resistant effects resulting from differences in the winding pitch and electrical wire sizes were verified on the basis of accretion of snow on electrical wire without any measures.



(a) Tape winding (5 mm spacing) + snow accretion resistant ring

(b) Tape winding (20 mm spacing) + snow accretion resistant ring



(c) Tape winding (30 mm spacing) + snow accretion resistant ring

(d) Electrical wire with only snow accretion resistant rings
(no measures against snow accretion taken)

Fig. 4. Patterns of PTFE tape winding for comparison and study of snow accretion conditions

As a result of changing the tape spacing to 5 mm, 20 mm and 30 mm as shown in Figure 4, it was made clear that the smaller the tape spacing, the earlier the accreted snow falls, indicating a trend toward greater snow accretion reduction effect as shown in Figure 5. It has also been shown that when comparing the masses of accreted snow on the wire for which no measures against snow accretion (ACSR 810 mm^2 were taken versus the sample with PTFE taping at 5 mm winding pitch, the snow accretion reduction effect of the sample with 5 mm winding pitch were approximately 80% higher than those of the wire without any measures. For wires with 5 mm or 20 mm tape spacing, tendencies were shown of accreted snow falling when the mass of accreted snow reached a certain value.

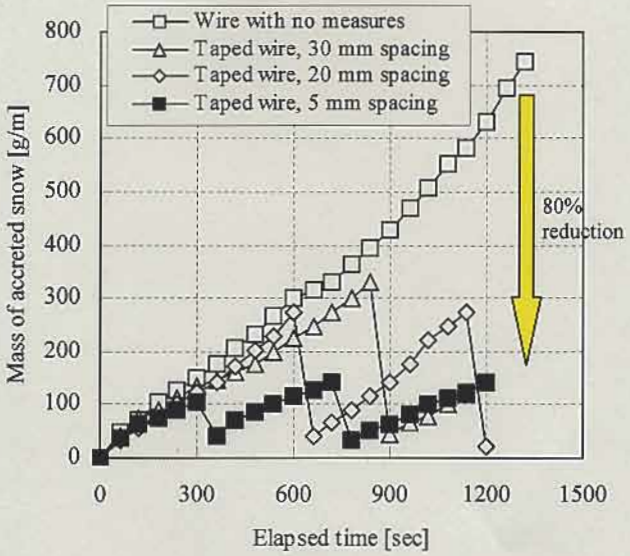


Fig. 5. Snow accretion time – mass of accreted snow characteristics (ACSR 810 mm^2)

Therefore, the relationship between the maximum mass of accreted snow and tape spacing was investigated and it was recognized that there is correlation between them for both ACSR 240 mm^2 and ACSR 810 mm^2 as shown in Figure 6. This is assumed to be attributable to surface areas of the electrical wires not including the areas covered by the PTFE tape. Figure 7 shows the conditions of snow accretion for the same elapsed time.

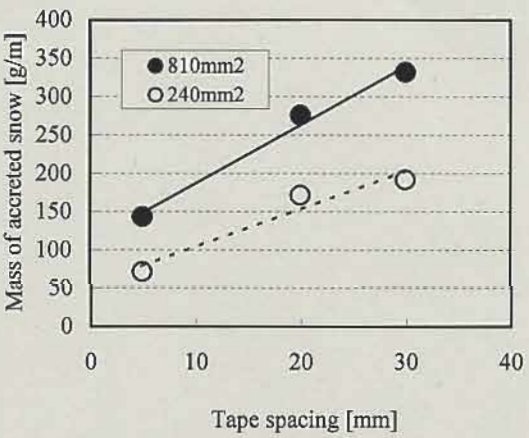
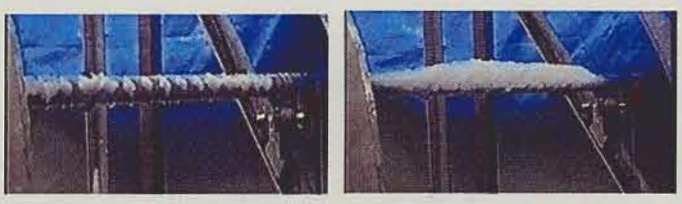


Fig. 6. Tape spacing – mass of accreted snow characteristics



(a) PTFE taped wire, 5 mm spacing (b) Wire with no measures (with rings)
Fig. 7. Conditions of snow accretion (at same time of day)

Figure 8 shows the maximum masses of accreted snow when the tape spacing of ACSR 240 mm^2 and that of ACSR 810 mm^2 were parameterized. Figure 9 shows the ratios of snow

accretion on the wires wound with PTFE tape obtained based on the maximum mass of accreted snow on the wire for which no measures were taken. From these results, it was verified that the measure taken against snow accretion using PTFE tape does have a snow accretion reduction effect and that winding the PTFE tape with 5 mm spacing (which provided the greatest countermeasure effect) was able to reduce the amount of accreted snow to approximately 20% or less of the maximum amount of accreted snow observed on the wire for which no measures were taken. For reference, the conditions of snow accretion were examined in the state where accretion of dry snow was simulated (at atmospheric temperature of 0°C and snow accretion density of 0.2 mg/cm^3), but basically the tendency of snow growing to accretion on the wires was not identified.

From the artificial snow accretion test results, it could be quantitatively assessed that measures for snow accretion reduction using PTFE tape (with 5 mm spacing) is sufficiently effective against the accretion of wet snow.

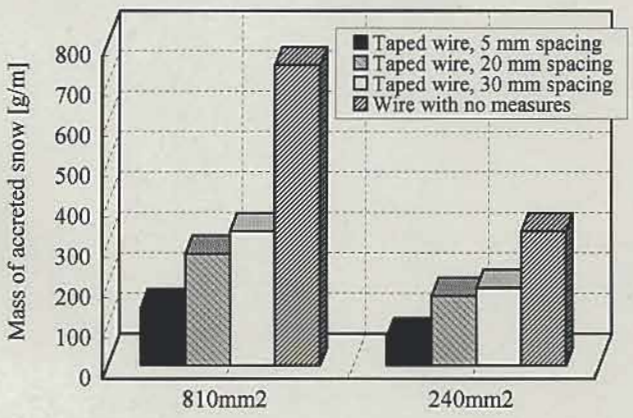


Fig. 8. Comparison of maximum weights of accreted snow

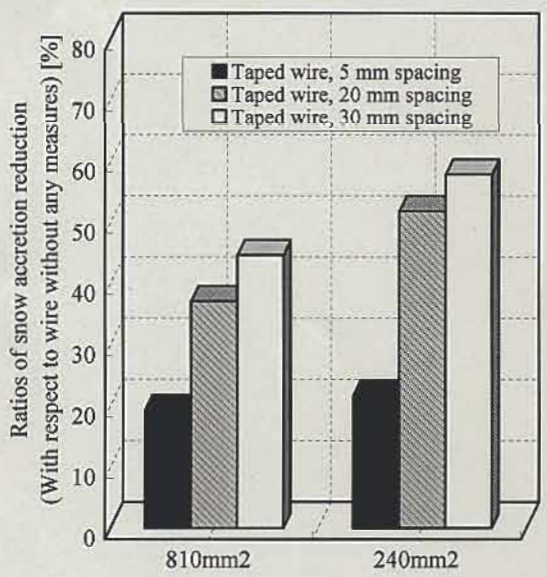


Fig. 9. Comparison of snow accretion reduction

B. Actual Field Verification

The effect of the PTFE on reducing snow accretion in field conditions was verified by using an actual overhead transmission line. The winding tape pitch was varied in three ways as shown in Figure 4, and a night-vision CCD camera captured the snow accretion on the wires as shown in Figure 10. The details of the observation are shown in Table 4.

TABLE 4.
Details of the Observation of Snow Accretion Reduction Effect

Item	Description
Items measured	Atmospheric temperature, wind velocity, wind direction, humidity, snowfall density
Measurement conditions	Conditions of snow accretion were observed using a night-vision CCD camera during snowfall. Total observations: 4 days(8:00 pm to 8:00 am)
Assessment	Snow accretion resistance effect achieved by changing the tape winding pitch was verified based on the conditions of snow accretion on the wire for which no measures were taken.

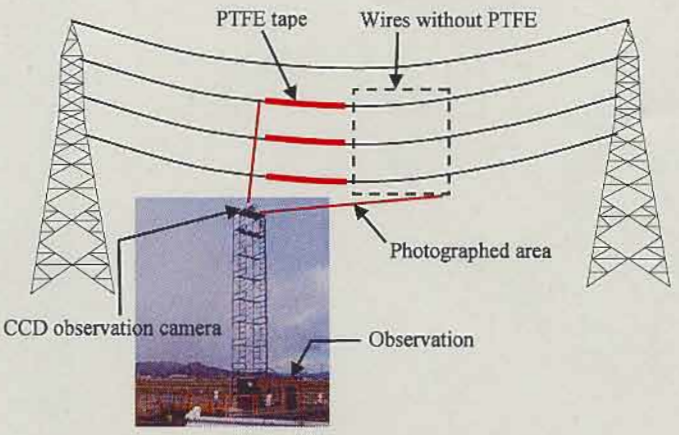
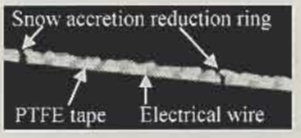


Fig. 10. Facility for observing snow accretion reduction effect

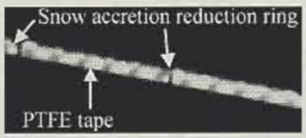
For observation results, it was visually checked that the snow accretion reduction effects of the areas covered with PTFE tapes were conspicuous compared with wires on which no measures were taken, as shown in Figure 11. In the same way as in the artificial snow accretion test, it was confirmed that the shorter the tape spacing, the faster accreted snow fell. Therefore, it is also judged from field verification that the measure of winding PTFE tape at a spacing of 5 mm is most effective.

Moreover, it has also been confirmed that snow accreted on the electrical wires fell around 7:00 to 8:00 in the early morning due to direct sunlight during the observation period. This agrees with the actual conditions that damage caused by fallen accreted snow occurs in the early morning hours. As to areas in which measures of winding PTFE tape were taken, however, it is considered that they have sufficient accreted snow falling prevention effect because the amount of accreted snow was very small. This thought presents no problems because there has been no fallen snow-caused damage in the areas for which the measures of winding PTFE tapes (at 5 mm spacing) were taken in the past.

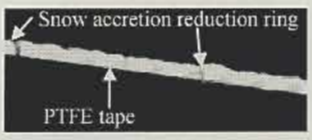
(a) Wire with no measures (with rings)



(b) PTFE taped wire, 5 mm spacing



(c) PTFT taped wire, 20 mm spacing



(d) PTFT taped wire, 30 mm spacing

Fig. 11. Photos of observation circumstances

C. Long-term Reliability Verification

The 14-year-old PTFE tapes that were installed on the transmission lines in our service area were sampled to verify the water repellency taken as a snow accretion reduction effect index. In taking this sample from the field, tape adhesion was also checked.

Table 5 shows the results of the investigation of the static contact angle rendered as the water repellency index of the PTFE tapes between the new tape and removed tapes. From this, it can be verified that the removed PTFE tapes have a static contact angle of 90° or more, generally indicating that water repellency exists. Moreover, PTFE tape surface conditions were checked under a scanning electron microscope as shown in Figure 12, showing the absence of any large instances of damage on the surfaces of the removed PTFE tapes.

From these results, it is clear that the removed PTFE tapes have no significant water repellency reduction resulting from ultraviolet ray deterioration, even after a lapse of 14 years, and have water repellency similar to that of new PTFE tape. Thus, it shows that PTFE tapes provide long-term reliability.

Tape adhesion capability at removal was examined and it was found that the tape adhesive was lost. Therefore, it was determined that long-term capability cannot be expected for the tape adhesion properties. However, PTFE tapes were *securely wound around the transmission lines in a spiral* manner even in the absence of any pressure sensitive adhesive on the tapes. Moreover, because the tapes had been installed in regular intervals with snow accretion reduction rings, it is conceivable that there is no concern of PTFE tapes peeling off. For PTFE tapes without adhesive, it has been determined that the tape tends to have deviated during the winding work, resulting in a significant decrease in effectiveness. Thus, it was determined that PTFE tapes with adhesive are required from the viewpoint of the winding properties.

TABLE 5.
Water Repellency of PTFE Tapes

Samples		Static contact angle*
New tape		111.8°
Removed tapes	Top phase	108.6°
	Bottom phase	96.0°

* Generally, water repellency is considered to exist when the static contact angle is 90° or higher. The measured values show average values of five random locations on the respective tapes.

(a) Contact angle measurement

(b) New tape surface

(c) Removed tape surface

Fig. 12. Check of the PTFE tape surface condition (using a scanning electron microscope)

V. Conclusion

The artificial snow accretion test and field test were carried out to quantitatively assess the snow accretion reduction effects of PTFE tapes. To determine the long-term capability of the tapes, aged PTFE tapes in the field was also investigated to verify water repellency.

As a result, the following points were shown:

- PTFE tapes have sufficient snow accretion reduction effect.
- Particularly, PTFE tapes wound around electrical wires at a tape spacing of 5 mm (with snow accretion resistant rings installed) delivered the largest effects. They had the effect of reducing the amount of accreted snow by approximately 80% compared with wires on which no measures were taken.
- PTFE tapes have sufficient water repellency even when they had aged 14 years, proving long-term reliability of the snow accretion reduction effect.

Therefore, it has quantitatively become clear that PTFE tapes (wound at 5 mm spacing) can be applied to existing facilities as one measure taken against damage caused by the falling of accreted snow. Currently, the tapes are gradually being applied in turn to facilities in the field.

VI. References

[1] " The Institute of Electrical Engineers of Japan Technical Reports No. 856 – Electrical Wire Technical Trend of Overhead Transmission Lines, " Institute of Electrical Engineers of Japan, pp. 42–45, 1998.

[2] N.Maeno, Y.Endo, E.Akitaya, S.Kobayashi and M.Takeuchi, "Avalanche and Snowstorm, " Basic Glaciology Course, pp. 220–226.