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Electrical Tests on Fire Retardant Contaminated Cap and Pin Insulators

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SUMMARY

In 2016, the vegetation surrounding five transmission line structures on two BC Hydro 230 kV transmission lines were doused by firefighter aircrafts. Porcelain suspension insulators of one transmission line and toughened glass suspension insulators of the parallel transmission line were contaminated with fire retardant residue. The fire retardant contaminated the top and bottom shell of both porcelain and toughened glass suspension insulators. After the wildfire subsided, forty porcelain and glass insulators were shipped to Powertech for assessment. The test program included the following tests: 1) Visual inspection, 2) equivalent salt deposit density (ESDD) testing on selected insulators in accordance with IEC 60815-1 Standard, and 3) wet power frequency flashover voltage test with and without fire retardant residue in accordance with CAN/CSA-C411.1 Standard. Six porcelain and six glass suspension insulators were visually examined. The results of the visual inspection show that the fire retardant residue on the porcelain and glass insulator shell was easy to remove unlike the fire retardant residue on the insulator cap, which was more difficult to remove. The visual inspection found that the porcelain and glass insulators had some fire retardant residue and there was no major damage or electrical activity on them. An ESDD measurement was done on three porcelain and three glass suspension insulators. The ESDD pollution level on the insulators was below 0.03 mg/cm^2, which is very low according to IEC/TS 60815-1. A wet power frequency flashover voltage test was done on three porcelain and three glass insulators with and without fire retardant residue. The insulators passed the wet flashover tests and there was no significant difference in the wet flashover voltage test results with and without fire retardant. In summary, the test results show that the fire retardant did not compromise the electrical insulation strength of the examined porcelain and glass suspension insulators. This approach can be utilized to evaluate the effect of fire retardant residue on cap and pin insulators on existing transmission and distribution lines.

KEYWORDS

Suspension insulator, fire retardant, high voltage testing, visual examination, equivalent salt deposit density (ESDD), wet power frequency flashover voltage test.

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1 INTRODUCTION

Rural overhead transmission and distribution lines often pass through forested areas. In the past decade, wildfire events are more frequent and their impact on the environment and infrastructure has had devastating consequences. Firefighting methods incorporate fire retardant released from aircrafts to mitigate the rapid propagation of wildfires.

Transmission and distribution lines are not only threatened by wildfires, but also can accidentally be contaminated with fire retardant products during fire suppression efforts. There are a few technical publications that deal with the consequences of fire retardant contamination on cap and pin insulators. These studies focus on high voltage laboratory testing using industry standards on artificially contaminated cap and pin insulators rather than practical case studies of fire retardant contaminated insulators.

These two transmission lines run parallel, are in-service, and were exposed to a wildfire in 2016. The vegetation surrounding the 230 kV structures affected by the wildfires were doused by firefighter aircrafts. The fire retardant residue affected five transmission structures, insulators and hardware on both circuits.

Porcelain suspension insulators of one transmission line and toughened glass suspension insulators of the parallel transmission line were contaminated with fire retardant residue. The fire retardant contaminated the top and bottom shell of both porcelain and toughened glass suspension insulators. Figure 1 and Figure 2 show the fire retardant contamination on lattice tower and transmission line hardware, respectively.

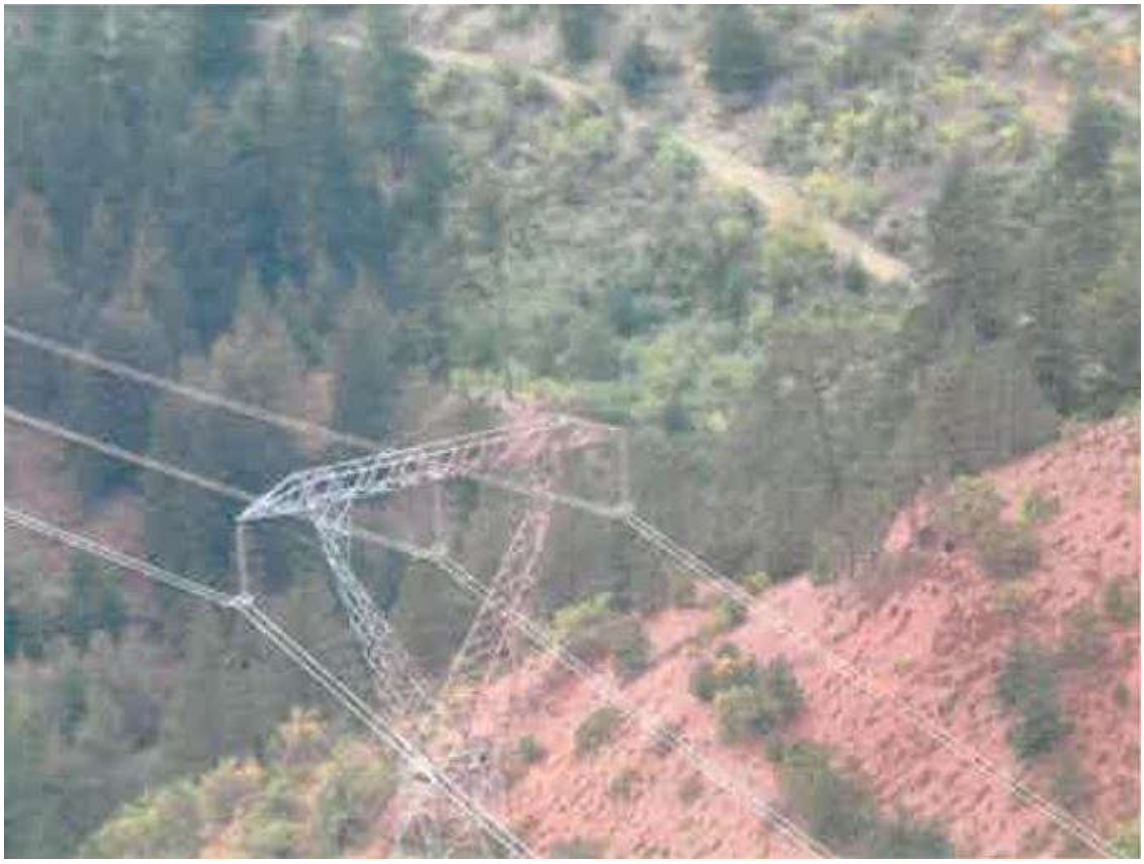

Figure 1. Fire Retardant on Steel Tower.

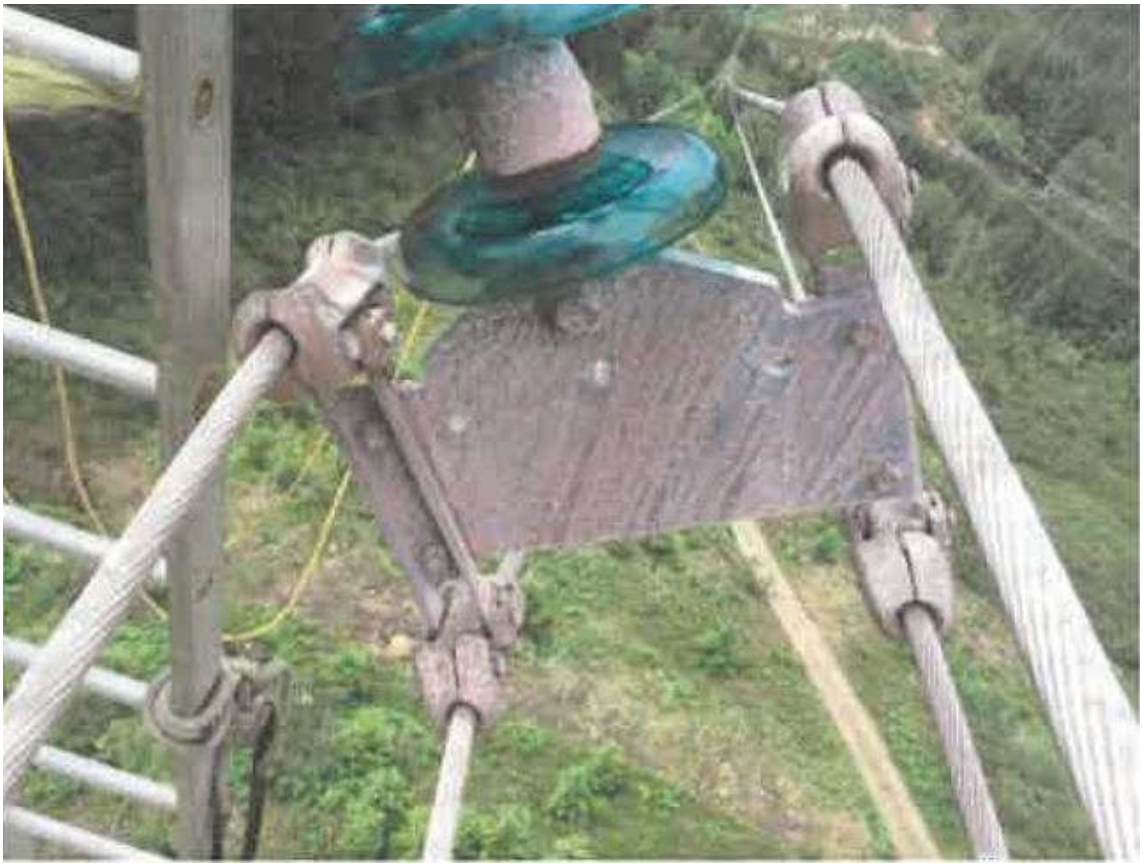

Figure 2. Fire Retardant on Transmission Line Hardware.

After the wildfire subsided, BC Hydro line crews, system operators and asset managers wanted to estimate how the fire retardant impacted the electrical strength of the contaminated porcelain and toughened glass cap and pin insulators. A total of forty porcelain and glass suspension insulators removed from five structures were shipped to Powertech for assessment.

The test program included the following tests:

- Visual inspection on twelve suspension insulators
- An equivalent salt deposit density (ESDD) test, pollution level measurement, on six insulators
- Wet power frequency flashover voltage test on six insulators with fire retardant residue
- Wet power frequency flashover voltage test on six insulators without fire retardant residue

2 FIRE RETARDANT TYPES

There are two major types of fire retardants in British Columbia to fight wildfires [1]:

Medium-term fire retardant:

It is a concentrated liquid that includes fertilizers, sticking agents, and proprietary compounds. It is produced in red colours among other colors.

Short-term fire retardant:

It is a fire retardant gel used with water to provide a watery shield to protect objects from fire.

3 VISUAL INSPECTION

Each of the insulator samples was examined and classified by insulator type, brand, vintage, and strength rating.

The following items were covered by the visual inspection:

- Top & bottom shell contamination
- Top & bottom shell flashover damage
- Shell radial cracking
- Grout radial cracking, spalling and loss of filling
- Cap and pin corrosion

Figure 3 through 6 exhibit samples of suspension insulators, as received.

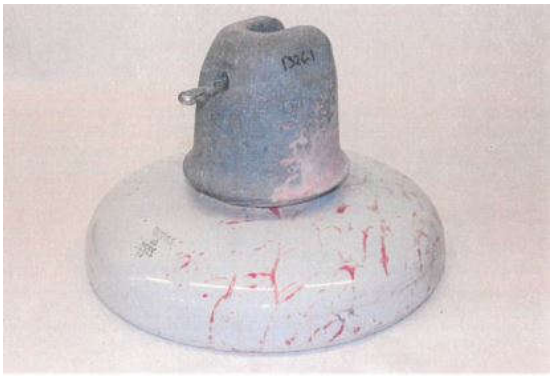

Figure 3.
Fire Retardant Residue on Top Porcelain.

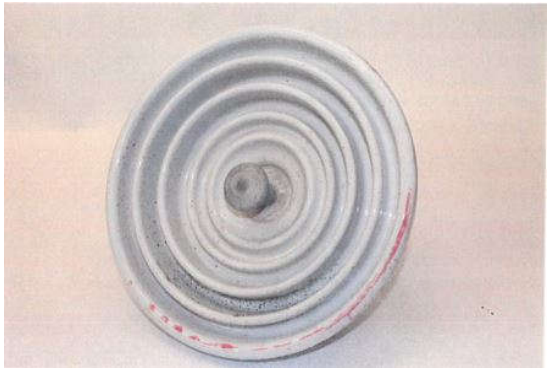

Figure 4.
Fire Retardant Residue on Bottom Porcelain.

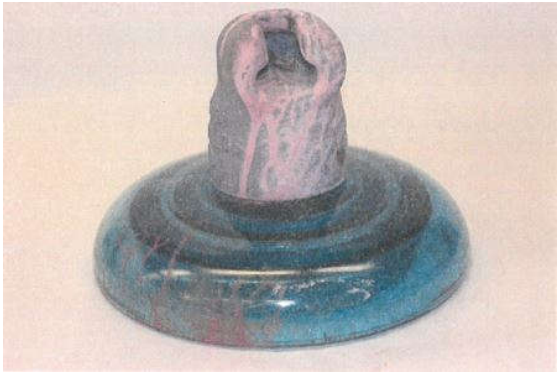

Figure 5.
Fire Retardant Residue on Top Glass.

Figure 6.
Fire Retardant Residue on Bottom Glass.

	Condition Rating
No defect and damages	1
Minor defect and damages	2
Moderate defects and damages	3
Severe defects and damages	4

Table 1. Insulator Condition Ratings.

The definition of the abovementioned condition rating was determined based on BC Hydro's Transmission Line Maintenance Standards.

The visual inspection of the selected twelve porcelain and glass suspension insulators shows that they had some fire retardant residue. There was no flashover damage, no radial cracking, no loss of filling and no corrosion. The overall insulators' condition rating equals 3 – Moderate defects and damages.

4 EQUIVALENT SALT DEPOSIT DENSITY (ESDD) MEASUREMENT

Three porcelain and three glass suspension insulators were tested in accordance with IEC/TS 60815-1. For each insulator, all the pollutant on the top and bottom shell was washed off into a one-litter volume of de-mineralized water.

The temperature and the conductivity of the solution were measured. The solution temperature was corrected to 25 °C. Then, the top/bottom shell area and the ESDD of each insulator were calculated in accordance with Annex C of IEC/TS 60815-1.

The ESDD measurements results of the selected porcelain and glass suspension insulators demonstrate that the calculated ESDD is less than 0.03 mg/cm which is classified as a very light pollution level according to IES/TS 60815-1.

Insulator No.	**Section**	**Surface Area [cm^2]**	**Solution Temperature [°C]**	**Solution Conductivity [µS/cm]**	**ESDD [mg/cm^2]**
Porcelain insulator No. 1	Top	806.37	13.0	26.8	0.019918
	Bottom	1,561.30	13.2	31.2	0.011967
Porcelain insulator No. 2	Top	806.37	13.2	29.5	0.021872
	Bottom	1,561.30	12.9	30.6	0.011823
Porcelain insulator No. 3	Top	806.37	13.4	24.2	0.017743
	Bottom	1,561.30	13.2	27.5	0.010508
Glass insulator No. 1	Top	810.55	13.4	23.5	0.017126
	Bottom	1,505.60	13.4	25.7	0.010110
Glass insulator No. 2	Top	810.55	13.9	24.9	0.017942
	Bottom	1,505.60	13.5	29.1	0.011460
Glass insulator No. 3	Top	810.55	13.4	23.4	0.017051
	Bottom	1,505.60	13.6	30.7	0.012078

Table 2. ESDD Measurement Test Results.

5 WET POWER FREQUENCY FLASHOVER VOLTAGE TEST

A wet AC flashover voltage test was completed in accordance Clause 6.4 of CAN/CSA C411.1-16 Standard. The test was performed on six insulators with and without fire retardant.

5.1 ACCEPTANCE CRITERION

The insulators pass the test if the average wet flashover voltage of the three tested insulators is equal to or exceeds 90% of the rated wet flashover value of 45 kV_{rms} and no insulators are punctured.

5.2 TEST PROCEDURE

The applied voltage to the insulator was increased to 75% of its estimated flashover voltage value. Then, it was increased at a rate of rise of 2% per second until the flashover voltage was reached.

5.4 TEST RESULTS WITH AND WITHOUT FIRE RETARDANT RESIDUE

Five flashover values were obtained per porcelain and glass insulator. The average of those five flashover voltages per insulator was determined.

The corrected wet power frequency flashover voltage test values were calculated in accordance with IEC 60060-1:2010 Standard. The following ambient and precipitation conditions were included in the voltage correction calculations.

Atmospheric Test Conditions		**Precipitation**	
Barometric pressure:	757.1 [mmHg]	Rate vertical:	1.1 [mm/minute]
Temperature:	16.5 [°C]	Rate horizontal:	1.3 [mm/minute]
Relative humidity:	26.8 [%]	Conductivity:	95.3 [µS/cm]

Table 3. Atmospheric and Precipitation Test Conditions.

Table 4 shows the test results of insulators contaminated with fire retardant.

Insulator No.	**Uncorrected Flashover Average [kV_{rms}]**	**Corrected Flashover Average [kV_{rms}]**		**Acceptance Criterion [kV_{rms}]** (90% of 45 kV_{rms})	**Test Result**
		Individual Insulator	**Average**		
Porcelain insulator No. 4	54.3	54.2	53.2	> 40.5	**Passed**
Porcelain insulator No. 5	53.4	53.3			
Porcelain insulator No. 6	52.6	52.6			
Glass insulator No. 4	51.4	51.4	50.8	> 40.5	**Passed**
Glass insulator No. 5	50.6	50.6			
Glass insulator No. 6	50.9	50.9			

Table 4. Wet Power Frequency Flashover Voltage Test Results with Fire Retardant.

Table 5 presents the test results of insulators without fire retardant.

Insulator No.	**Uncorrected Flashover Average [kV_{rms}]**	**Corrected Flashover Average [kV_{rms}]**		**Acceptance Criterion [kV_{rms}]** (90% of 45 kV_{rms})	**Test Result**
		Individual Insulator	**Average**		
Porcelain insulator No. 4	50.2	50.2	51.2	> 40.5	**Passed**
Porcelain insulator No. 5	51.8	51.8			
Porcelain insulator No. 6	51.8	51.8			
Glass insulator No. 4	51.2	51.2	52.1	> 40.5	**Passed**
Glass insulator No. 5	52.2	52.2			
Glass insulator No. 6	52.9	52.9			

Table 5. Wet Power Frequency Flashover Voltage Test Results without Fire Retardant.

Analysis of Test Results:

The porcelain and glass insulators with and without fire retardant residue passed the requirements of CAN/CSA Standard C411.1-16, Clause 6.4: “Wet power frequency flashover voltage test”.

6 CONCLUSIONS

- Porcelain and glass insulators contaminated with fire retardant residue had no flashover damage and electrical activity.
- The porcelain and glass suspension insulators had no corrosion, shell cracking, spalling or loss of filling defects were found.
- The overall insulators' condition rating equals 3 – Moderate defects and damages.
- The ESDD measurements found that the pollution level is very low.
- The found pollution level demonstrates that the fire retardant did not have a significant effect on the insulator pollution level.
- The porcelain and glass insulators passed the wet flashover voltage tests with and without fire retardant residue.
- Theere was no significant difference in the wet flashover voltage test results with and without fire retardant residue.
- The insulators contaminated with fire retardant had no significant effect on the insulator strength of both porcelain and glass suspension insulators.

ACKNOWLEDGEMENT

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BIBLIOGRAPHY

[1] BC Centre for Disease Control, "Health and safety around fire retardants/suppressants", Environmental Health Services, Wildfire Notes, Fire retardants / Suppressants. Access date: June 20, 2020. http://www.bccdc.ca/Documents/WildfireNotes.pdf

[2] IEC/TS 60815-1-2008, International Electrotechnical Commission, Selection, and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 1: Definitions, information, and general principles.

[3] CSA C411.1-16 AC suspension insulators, Standards Council of Canada, July 1, 2016.

[4] IEC 60060-1:2010, International Electrotechnical Commission, High-voltage test techniques - Part 1: General definitions and test requirements.

[5] L. Cui, R. S. Gorur, D. Chipman, Evaluating Flashover Performance under Fire Fighting Conditions, IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 24, No. 2; April 2017.