Arnold Schwarzenegger
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CORONA TESTING OF DEVICES USED TO MITIGATE BIRD COLLISIONS

Prepared For:
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and

The U.C. Santa Cruz Predatory Bird Research Group

Prepared By:
EDM International, Inc.

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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Energy Commission), annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy-Related Environmental Research
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Energy Systems Integration

What follows is the final report for Corona Testing Devices Used to Mitigate Bird Collisions**,** contract number 500-01-032, conducted by EDM International, Inc. The report is entitled *Corona Testing Devices Used to Mitigate Bird Collisions.* This project contributes to the PIER Energy-Related Environmental Research program.

For more information on the PIER Program, please visit the Energy Commission's website www.energy.ca.gov/pier/ or contract the Energy Commission at (916) 654-4628.

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Abstract

Bird deaths resulting from power line collisions are a violation of the Migratory Bird Treaty Act and can result in federal fines. Accordingly, utilities often mark wires with various devices in bird concentration areas to prevent such collisions.

Placing such devices on energized power lines can reduce avian collisions with those lines; however, one of the issues associated with marking devices is corona discharge. Corona activity on power lines can result in audio noise (AN) or radio interference (RI) complaints. Because corona may result in customer complaints, it is important to know how marking wires might influence corona. This information will give biologists and engineers the information they need to determine the voltage of wires they can mark without creating unacceptable levels of AN or RI.

Below 115 kilovolts (kV), all of the devices are suitable from an AN and RI perspective. The best-performing devices at 115 kV were the Bird Flight Diverter and the Swan Flight Diverter, neither of which had any detectable corona discharge. At 230 kV, the Swan Flight Diverter and the Bird Flight Diverter had a medium level of corona, but still outperformed the flapper-type diverters. At 345 kV, all the devices had very high levels of corona.

Executive Summary

Introduction

One of the most effective ways to reduce avian collisions with power lines is to mark wires, making them more visible. Although several products are available to mark lines, there can be engineering/maintenance issues associated with placing these devices on energized wires. Corona discharge is one of the issues associated with using the marking devices. These discharges occur when surface electric field intensity surrounding an energized electrode exceeds a critical value, resulting in a localized ionization of the surrounding gas—in most cases, air. Corona activity generates light (mainly in the UV spectrum), sound waves, electromagnetic radiation, ozone, and other by-products that can result in unacceptable audio noise (AN) and/or radio interference (RI). Corona activity may occur from sharp edges on energized hardware, broken conductor strands, or defective insulators.

Purpose

The purpose of this project was to determine whether various marking products could be used on energized wires (at different voltages) without creating significant corona discharge.

Project Objective

The objective of this project was to test a variety of flight diverter devices at simulated 115-kV, 230-kV, and 345kV phase-to-phase line voltages, to measure the corona produced by each device.

Project Outcomes

The best-performing devices at 115 kilovolts (kV) were the Bird Flight Diverter and the Swan Flight Diverter, neither of which had any detectable corona discharge. At 230 kV, the Swan Flight Diverter and the Bird Flight Diverter had a medium level of corona, but still outperformed the flapper-type diverters. At 345 kV, all the devices had very high levels of corona.

Conclusions

Below 115 kV, all of the devices are suitable from an AN and RI perspective.

Recommendations

The levels of AN and RI generated by the devices above voltages of 115 kV do not invalidate their use at these voltages. Rather, device installations should be in areas that will not elicit complaints of the resulting AN and RI. Material degradation may occur at 115 kV and higher, resulting in premature failure. Utilities should have sufficient test data to know if the proposed device can withstand the long-term effects of corona at 115 kV and higher.

Benefits to California

This results of this research will enable biologists and engineers to determine on which voltages they can install flight diverters without creating excessive AN or RI. As a result, flight diversion efforts can proceed without concerns about these impacts, thereby removing a potential barrier to the use of these devices.

1.0 Introduction

Electric corona occurs when the voltage of an overhead conductor, typically 115 kilovolts (kV) or greater, is raised to such a value that the surrounding air is ionized and becomes a conductor. Corona manifests itself by bluish tufts or streamers appearing around the conductor, being more or less concentrated at irregularities on the conductor surface. This discharge is accompanied by a hissing sound, the odor of ozone and local radio interference. Corona forms at the sharp corners of energized parts so the radii on the corners of such parts are typically engineered large enough to avoid corona formation. However, voids, bubbles and other non-homogenous compositions within solid materials can promote the formation of corona. Over time, corona can degrade certain materials such as organic insulation.

Along with audible and radio noise, corona emissions produce ultraviolet light in proportion to the strength of the corona emissions. Thus, the amount of ultraviolet light produced creates a relative measure of the amount of corona emission. The ultraviolet light cannot be seen with the naked eye during daylight conditions but can be observed in dark nighttime conditions. However, recently developed cameras can detect the level and location of ultraviolet light in the field of view during the day. These cameras superimpose the detected ultraviolet light as white pixels or small squares on a video image. The DayCor®II camera used in this test performs that function.

Bird deaths resulting from power line collisions are a violation of the Migratory Bird Treaty Act and can result in federal fines. One of the most effective ways to reduce avian collisions with power lines is to mark wires, making them more visible. Although several products are available to mark lines, there can be engineering and/or maintenance issues associated with placing devices on energized wires. Some these devices have many uneven surfaces and sharp corners that project or hang from the conductor, so it is likely they can be a source of corona emission. The goal of this research project was to determine the relative extent of corona emission caused by ten commercially available flight diverters at typical transmission voltages. Table 1 identifies the flight diverters tested, and Figure 1 displays them.

In addition to testing bird flight diverters, the Bird Strike Indicator (BSI) was tested for corona. The BSI is an impulse-based sensor being developed to remotely detect and record bird strikes. The BSI is being developed under a separate research project supported by the California Energy Commission and Western Area Power Administration. The testing of the bird flight diverters created an opportunity to test the BSI at no additional cost.

Table 1. List of flight diverter manufacturers and models tested

Device #	Manufacturer	Model
2	Tyco Electronics	Bird Flight Diverter, BFD2460
3	Tyco Electronics	Swan Flight Diverter, SFD1960
4	Mission Environmental	Bird Flapper
5	Bird Safe Inc.	Bird Diverter™
6	Mission Environmental	Bird Flapper - Prototype
7	Preformed Line Products	Bird Flapper LSFB 0416
8	Preformed Line Products	Bird Flapper FB0515
9	P&R Technologies	BirdMark
10	Midsun Group	Bird Flapper - Prototype
11	P&R Technologies	Firefly Bird Flapper

Note: The Bird Strike Indicator (BSI) was device #1, and is not considered a diverter.

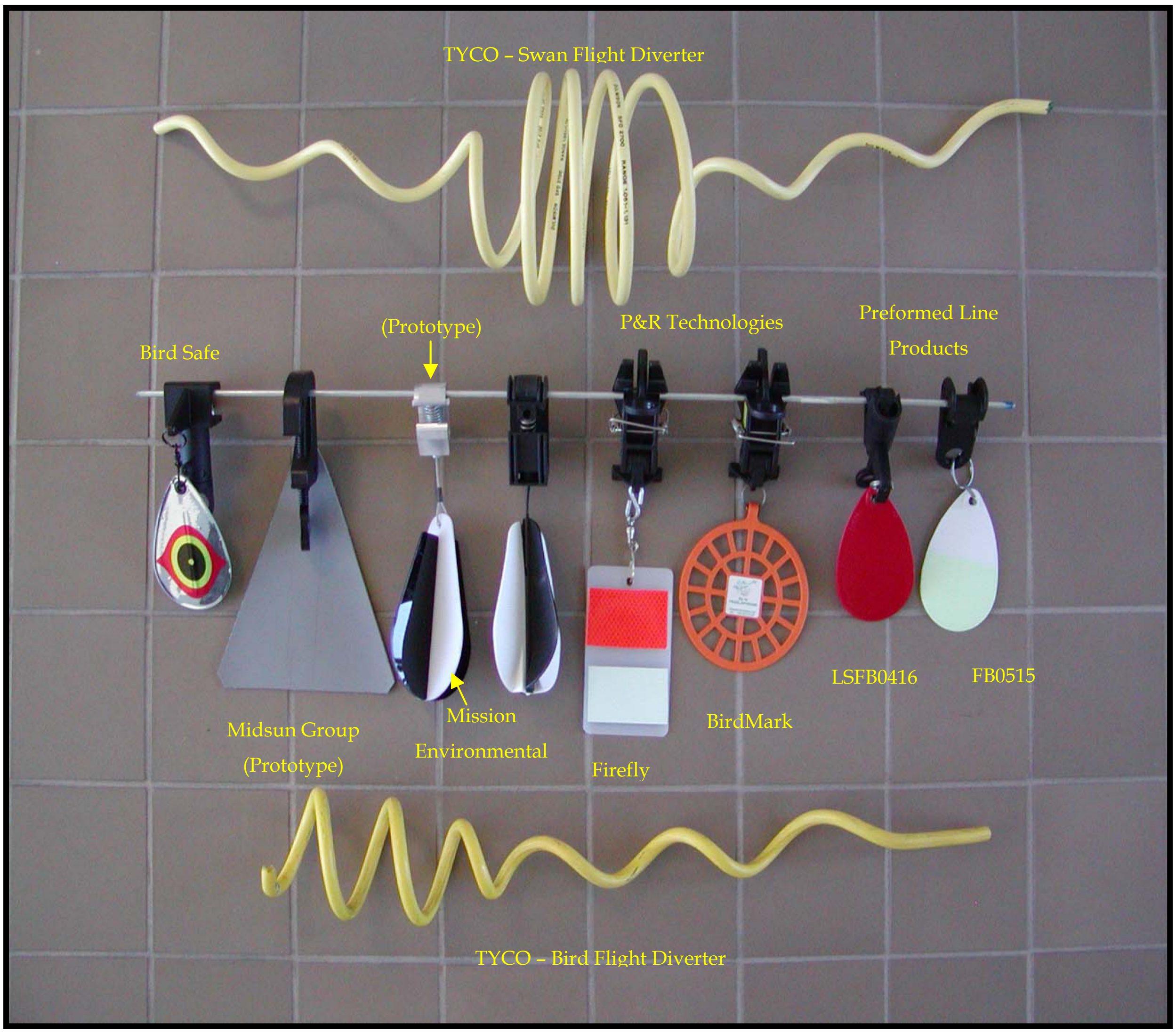

Figure 1. Flight diverters tested as part of the project

Each of the devices was mounted to an overhead conductor, which was energized to simulate a real overhead transmission line with system voltages of 115 kV, 230 kV, and 345 kV. Corona observations with a DayCor II corona camera were made on each device at all three voltages. Levels of corona on the devices were recorded on a 0 to 5 scale representing a range from no corona to very high corona.

2.0 Project Approach

2.1. Overview of Test Setup

- The devices were attached to an existing 550-ft test line at the EPRISolutions laboratory in Lenox, Massachusetts (Figure 2).
- The devices were attached 10 feet apart so as not to influence the corona performance of adjacent samples.
- The conductor was 1.1 inches in diameter. Note that the diameter of a conductor has a significant effect on the surface gradient (and, therefore, the corona inception voltage) of the conductor; however, the surface gradient of an attached object does not depend significantly on the diameter of the conductor. Therefore, the results obtained will apply to any size single-conductor configuration.
- The height above ground was set at approximately 40 feet. Surface gradients of overhead conductors (including small attached objects) are only affected by changes in ground clearance when that clearance is very small. The results obtained in these tests will apply to any ground clearance that is practical for the voltage classes considered.
- Perceptible amounts of corona rarely occur below system voltages of 115 kV. Thus the voltages chosen for this test were 115 kV, 230 kV, and 345 kV—the three main transmission voltages used in North America. Transmission systems divide the power across three phases, with each phase having its own wire. Such voltages are called *line-to-line* voltages, where the voltage is measured between any two phases. For a three-phase system, the magnitude of voltage surface gradient on each wire is determined by both the voltage on the wire and the influence of the electric fields from adjacent phase wires.

  However, in this test, only the conductor bearing the devices was energized, creating a single-phase system instead. This difference in number of phases is not a problem so long as the voltage surface gradient of the single phase system matches that of the equivalent three-phase system. In a single phase system, the voltage is defined in terms of line-to-ground, where the voltage is measured between one phase conductor and ground potential. Three-phase system voltages can be alternatively defined in terms of line-to-ground voltages, through dividing the line-to-line voltages by the square root of three. Thus, a 115-kV,three-phase system has a line-to-ground voltage of 66.7 kV. However this line-to-ground voltage must be increased to raise the voltage surface gradient to a level equivalent to the three-phase, 115-kV system, which is 78 kV. Table 2 shows this relationship for the three system voltages used during testing.

Table 2. System voltages and corresponding test voltages

Three-phase line-to-line voltage (kV)	Equivalent line-to-ground voltage (kV)	Test Voltage (kV)
115	66	78
230	133	157
345	199	234

- The DayCor II camera was placed on the ground adjacent to the test line. Starting at the lowest voltage—and then increasing the voltage to the other two levels—observations of each sample were made and photographed with the DayCor II camera to determine corona activity. Figures 3 and 4 show the DayCor II camera during field use.

Figure 2. Test setup

Figure 3. DayCor II camera

Figure 4. DayCor II camera

2.2. Testing

The Bird Strike Indicator was tested and labeled as Device #1. Ten separate flight diverters were tested and labeled 2 through 11. Below are photos (numbered accordingly) of all the installed flight diverters. Both Mission Environmental and Midsun Group supplied a prototype unit for testing. Mission Environmental also submitted their final design.

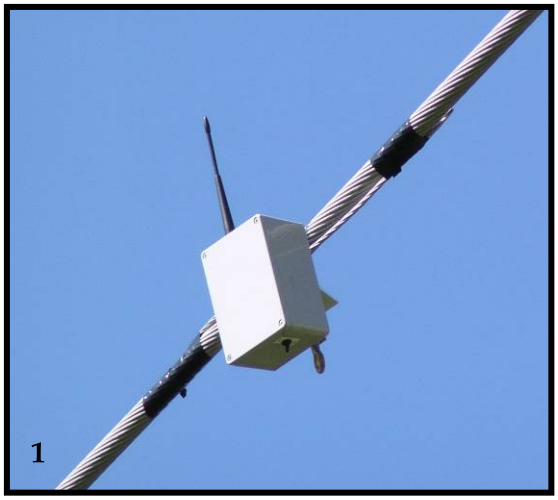

Figure 5. Bird Strike Indicator

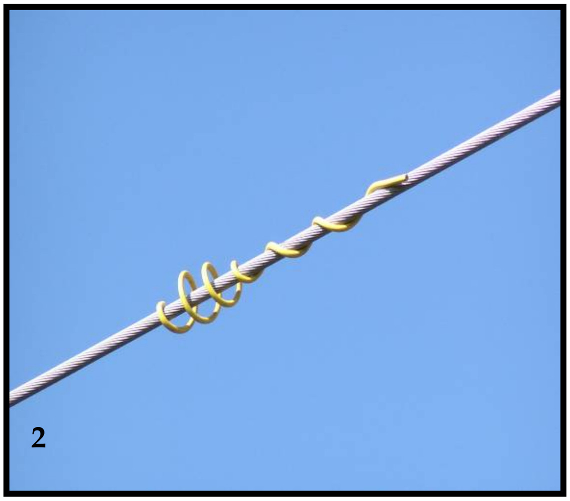

Figure 6. Bird Flight Diverter, Tyco Electronics (BFD2460)

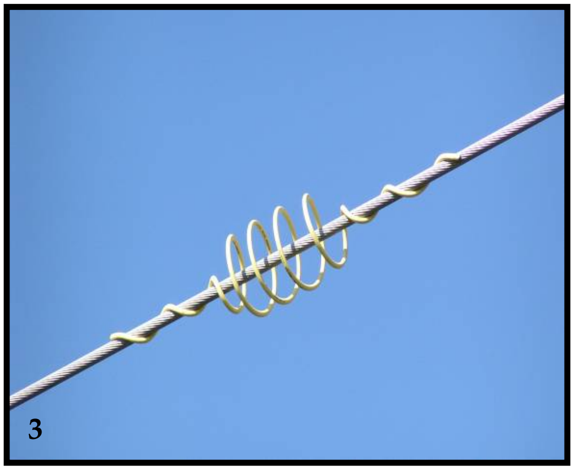

Figure 7. Swan Flight diverter, Tyco Electronics (SFD1960)

Figure 8. Bird Flapper, Mission Environmental

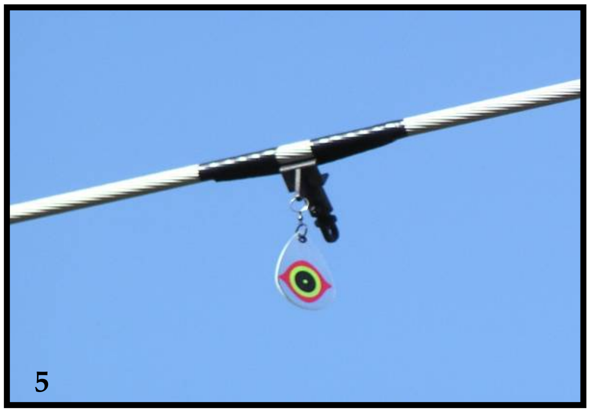

Figure 9. Bird Diverter, Bird Safe

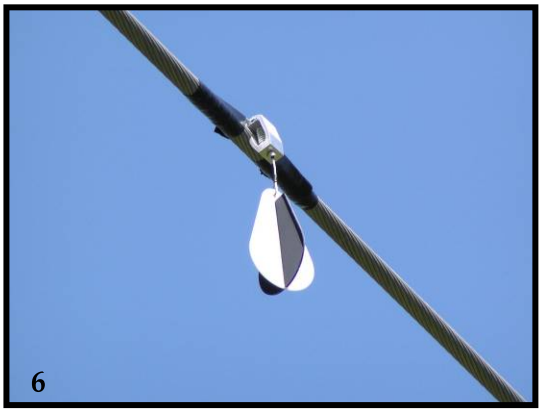

Figure 10. Bird Flapper - Prototype, Mission Environmental

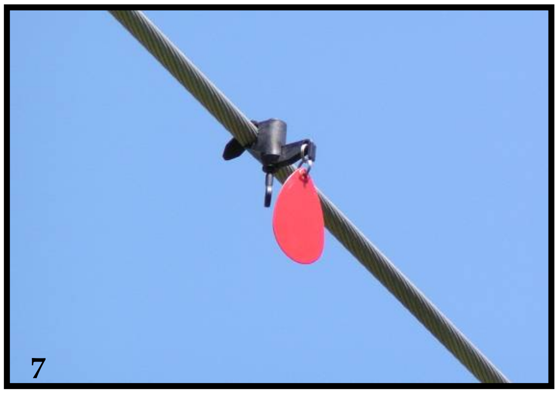

Figure 11. Bird Flapper, Preformed Line Products (LSFB0416)

Figure 12. Bird Flapper, Preformed Line Products (FB0515)

Figure 13. Bird Mark, P&R Technologies

Figure 14. Bird Flapper - Prototype, Midsun Group

Figure 15. Firefly Bird Flapper, P&R Technologies

3.0 Project Outcome

The DayCor II camera does not provide a quantitative measurement of corona activity, but instead displays the intensity of corona by the presence of white pixels superimposed on the video image where the sources of corona exist. The user must then determine the relative amount of corona present through visual observation of the video image. Thus, for each voltage level and each device, the testing team observed the video display of the DayCor camera and judged the level of corona on each device on a scale of 0 to 5, as follows:

0 = No corona

1 = Barely detectable corona

2 = Definitely detectable corona

3 = Medium level of corona

4 = High level of corona

5 = Very high level of corona

Figures 16 through 21 are images captured from the video stream and illustrate the relative levels of the scales described above.

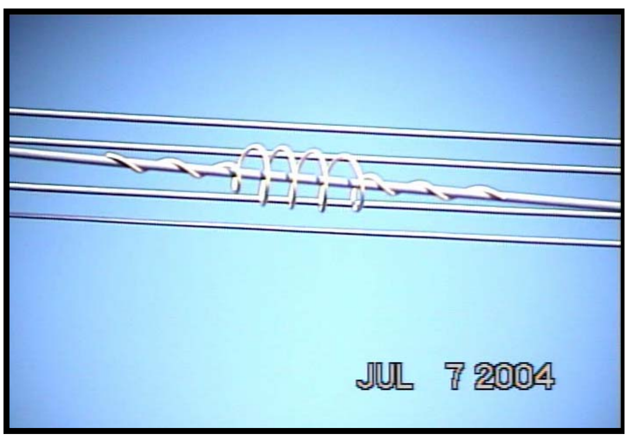

Figure 16. Level 0: No corona

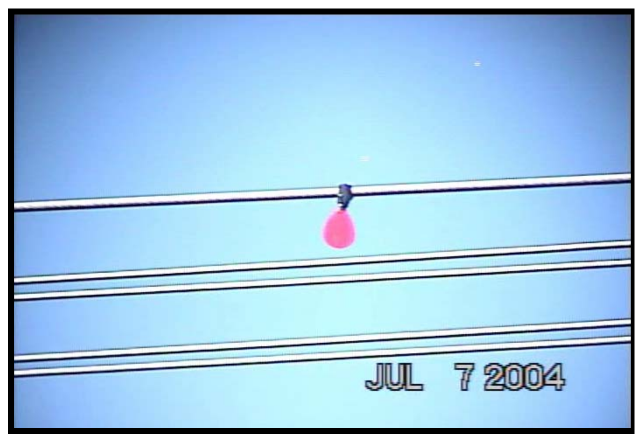

Figure 17. Level 1: Barely detectible corona

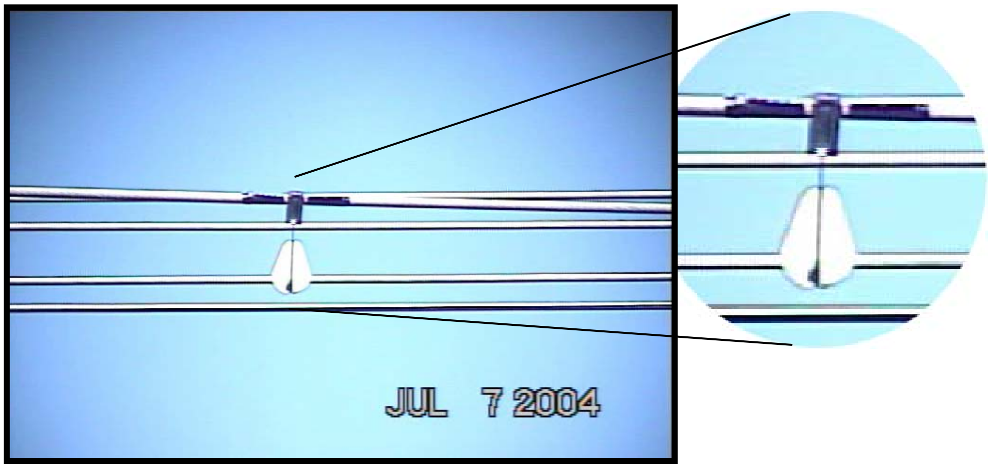

Figure 18. Level 2: Definitely detectable corona *(at bottom of cable clamp)*

Figure 19. Level 3: Medium level of corona

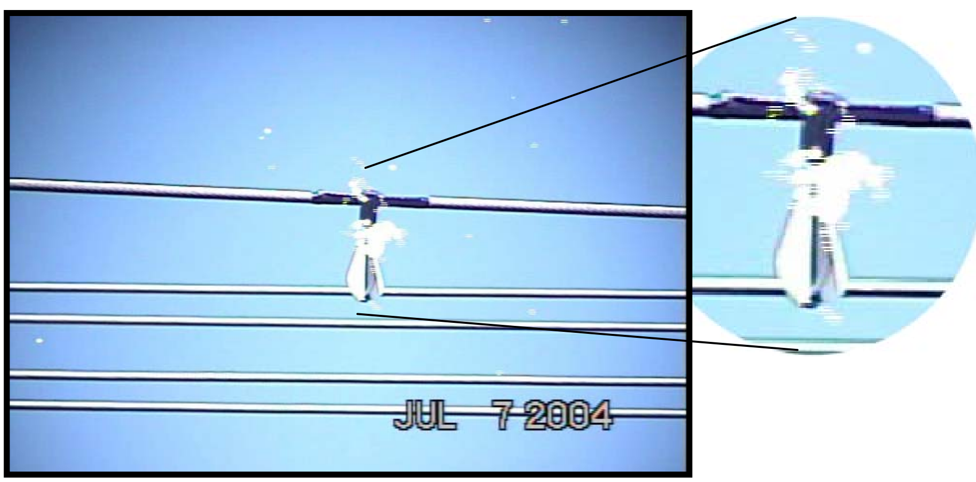

Figure 20. Level 4: High level of corona

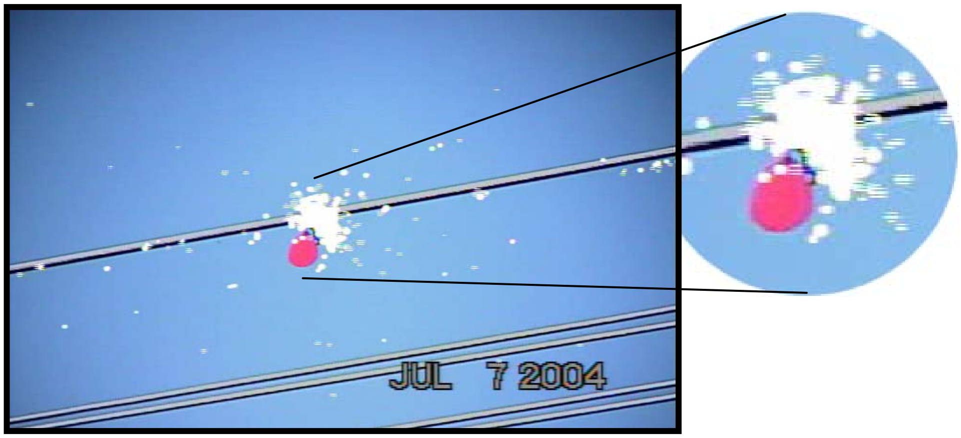

Figure 21. Level 5: Very high level of corona

Table 3 summarizes the results and is shown below.

Table 3. Corona levels for all the devices tested

Device Number	Model	Corona Level		
		78 kV (simulating a 115-kV line)	157 kV (simulating a 230-kV line)	234 kV (simulating a 345-kV line)
1	Bird Strike Indicator	2	4	5
2	Bird Flight Diverter, BFD2460	0	3	5
3	Swan Flight Diverter, SFD1960	0	3	5
4	Bird Flapper-Mission Environmental	2	4	5
5	Bird Diverter-Bird Safe	1	4	5
6	Bird Flapper–Prototype-Mission Environmental	4	4	5
7	Bird Flapper-LSFB0416	1	4	5
8	Bird Flapper-FB0515	1	4	5
9	BirdMark	1	4	5
10	Bird Flapper-Prototype-Midsun	0	4	5
11	Firefly Bird Flapper	1	4	5

The most receptive sites for corona are on flapper-type devices (e.g., devices 4–11). The flapper-type diverters are susceptible on the top of the flapper and at the point of attachment to the conductor.

After testing was completed, the flight diverters were visually inspected for any signs of physical damage due to corona discharge. No damage was observed, save for device #5, where the mylar label on the flapper had disintegrated around the attachment grommet (Figure 22).

During testing this was the only flapper where the entire flapper was engulfed in corona at 345 kV.

Figure 22. Corona-induced damage on diverter #5

4.0 Conclusions

At the 115-kV voltage, all the devices had very little or no corona, except for device #6, which had a high level of corona at 115 kV and a high and very high level at 230 kV and 345 kV, respectively. This device is the prototype to device #4, which had a reduced amount of corona at 115 kV.

At the 230-kV voltage, all the flapper type devices (devices 4–11) had a high level of corona, and this corona increased on the 345-kV line. The corona generally occurred at the point of attachment to the conductor and at the top of the flappers.

Given the small amount of corona emission found on the devices at 115 kV, all devices will not emit any significant amounts of corona. Based on the observed performance at 115 kV and 230 kV, corona emission at the intermediate transmission voltages of 138 kV and 161 kV also used in the industry should be slightly higher than that at 115 kV.

The extent or rate of decay the flapper materials experience due to the corona discharge is unknown and was not ascertained from the test results. The only visibly detectable decay was found on device 5, where a portion of the mylar film on the flapper disintegrated around the mounting grommet.

Although similar materials have been known to withstand the effects of corona for some time, further testing is required to confidently determine the ability of the device materials to withstand ongoing corona emissions.

Corona also emits audible noise and radio interference. These emissions are not a problem unless people sufficiently frequent the immediate area to be annoyed by the emissions. The magnitude of both audible noise and radio interference decreases quickly over distance, typically limiting the effective range to hundreds of feet. Further reducing the range is the height of the wires above the ground. Such heights above the ground begin at 25 feet and may often rise up to 100 feet. Complaints of AN and RI are rarer in a rural environment. In urban environments, RI may cause more complaints than AN, which can be reduced in effectiveness due to ambient noise conditions.

However, the audible noise and ultraviolet light emitted by corona may provide a positive effect. One or both emissions might be sufficiently detected by certain species of birds, thus providing a further aid for avoiding a collision with the line.

The selection of the appropriate bird collision device depends on a variety of factors, including the effects on ice and wind loading, cost of the product and installation costs, product effectiveness for a particular bird species, aesthetics, and product durability. Devices also must adhere to safety requirements. In addition to these factors, corona discharge can occur resulting in audio noise, radio interference, and material degradation. The two commercially available products that performed the best at 115 kV were the TYCO Bird Flight Diverter and the Swan Flight Diverter, with no detected corona. These devices also were the best-performing devices at 115 kV with a medium level of corona discharge. Although flapper type devices may be more effective to deter collisions because of the movement of the swinging plates, they will generate greater corona at 115 kV and higher.