CORONA TESTING OF PROTOTYPE AVIONICS CONNECTORS

by

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Abstract

The increasing power requirements for avionics in advanced airframes mandate that distribution voltage levels be elevated to meet the requirements and minimize the conductor weight penalty. One such system is proposed to operate at a nominal system voltage of 270 volts d.c. This system will be required to operate at altitudes up to 100,000 feet. At such partial atmospheric pressures (8.36 torr), conductor geometries which are quite acceptable on the ground, can experience either Townsend-like or corona discharges. These can often be enhanced by moisture condensation due to pressure gradients induced by rapid airframe ascent/decent.

The feedthrough connector, which must transition the power cabling to the individual avionics packages, is a critical region for the initiation of such discharge activity. The corona performance of several prototype avionics connector designs has been evaluated in an altitude simulation chamber. The control parameters for the testing include: pressure, temperature, and applied voltage. A sophisticated test stand was developed to provide control of pressure gradients in order to better simulate airframe mission profiles. Test results indicate that gas desorption or outgassing from insulating surfaces subjected to pressure excursions may play a major role in the level of discharge activity.

Introduction

Contact tests were run on three prototype avionics connectors intended for use in a 270 volt direct current aircraft electrical system. These connectors are sized for standard SEM E size avionics modules. Previous voltages in this size package are typically 5 to 28 volts. The increased voltage in the same size package raises corona concerns. Failure to suppress or eliminate corona activity will result in performance degradation via the introduction of noise into the systems and, in the extreme, system failure due to catastrophic electrical breakdown. These connectors could be highly susceptible to this phenomena because of the close contact spacing and the exposure to the ambient atmosphere which is implicit in their applications. For these reasons corona testing was included in the test program along with the more traditional contact resistance testing, vibration testing, etc. Corona testing is non-destructive if properly done [1]. The nondestructive nature of corona testing is important since the prototype connectors must also undergo a series of environmental tests.

Test Apparatus

A commercial corona detection system employing direct electrical connection was used to record the discharge activity. The test system incorporates a coupling capacitor of 2000 pF, bandpass filter and amplifier. The conditioned signals are routed to a DOS computer containing a multichannel analyzer board. Custom software has been developed to enhance the acquisition and analysis of corona testing data. A typical multichannel analyzer compiled histogram of number of discharge counts versus discharge magnitude is shown in Figure 1.

![Corona spectrum for a 360 second test of a connector at 500 volts, 8.4 torr, and 85 degrees C.]

Figure 1. Corona spectrum for a 360 second test of a connector at 500 volts, 8.4 torr, and 85 degrees C.

The design of the mechanical system for the testing included a 12"x18" vacuum chamber pumped by a rotary mechanical pump with in-line molecular sieve. Absolute pressure is measured by commercial capacitance manometer type instruments. Test stand modifications included the installation of a closed-loop
feedback controller to regulate a butterfly valve on the vacuum roughing line. The pressure controller responds to an input signal from an arbitrary waveform signal generator. The controller will successfully adjust the pressure in the test chamber provided the pumping capacity is not exceeded. For this series of tests, the signal generator was programmed to linearly ramp the pressure between the extrema in 6 minutes, to simulate a typical aircraft ascent or dive.

Test Program and Test Articles

The corona testing involved the three independent variables of voltage, pressure, and temperature. The dielectric withstand voltage of these connectors was specified at 500 volts. All test runs in this paper were conducted at 500 volts. One static and two dynamic pressures were used. The static pressure was at 8.4 Torr which corresponds to a simulated altitude of approximately 100,000 feet. The two dynamic pressures simulated a fighter aircraft's climb from ground level to 100,000 feet or a fighter aircraft's dive from 100,000 feet to ground level. Preliminary connector testing indicated that maximum corona activity occurs when the connectors were subjected to their worst case service temperature of 85 °C. Active feedback controlled heating of 85 °C was applied to the SEM E blank circuit boards on which the connectors were mounted.

Controlling these three variables resulted in corona pulse count and magnitude being the dependent variables. A corona pulse was counted if its magnitude was between 5 picocoulombs and 100 picocoulombs. The cutoff level of five picocoulombs was chosen because of background electrical noise considerations and previous research. Several papers [2], [3], [4] have suggested that a low level cutoff of 1-5 picocoulombs is appropriate. Three connector designs were supplied for the testing, each having a slightly different geometry. All connectors had to fit within the maximum SEM E interior width of 13.5 millimeters. Eight connectors of each geometry were tested. The data shown in Figures 2, 3 and 4 is averaged for measurements taken on all 8 sample connectors of a given geometry. All corona test runs lasted six minutes. From a testing viewpoint, two subjects seemed worthy of further consideration. First, total integrated charge criteria were examined. Second, pressure gradients that might better simulate airframe mission profiles were considered.

Total Charge Measurements

Total charge can be calculated by summing the multiplication of the number of pulses in each channel of the charge spectrum by the charge value. The average charge rate is simply the total charge divided by the run time. The equation can be written

\[ R_Q = \frac{\sum n_i Q_i}{t} \]

where \( R_Q \) is the charge rate, \( n \) is number of counts, \( Q \) is the charge/channel, \( i \) is the channel number, \( k \) is the total number of channels, and \( t \) is the run time in seconds. While \( R_Q \) has the same units as current, it should not be confused with average current. All discharges below 5 picocoulombs are neglected in these tests. The corona detection system used cannot discriminate actual pulse durations nor resolve simultaneous pulses from spatially different discharge sites. Hence, the amplitude of a count may actually be due to multiple sources.

Total charge measurements may have more applicability to corona measurements rather than to partial discharge as described in the following context. Corona can be defined as a high impedance electrical discharge in a gas surrounding a charged electrode. Partial discharge can be defined as an electrical discharge in a gas filled insulation void. The ambiguity with total charge measurements for partial discharge is the relation of the apparent partial discharge magnitude to actual partial discharge magnitude [5]. The actual amount of charge transfer within the void is often unknown and the relationship to insulation damage is hard to correlate. With corona, the actual charge transferred in a corona pulse is the same as the measured charge, for a discrete discharge site. The total charge measurement due to corona may point to problems not seen in simple peak picocoulomb measurements.

A case in point are the results from Connector Geometry 3. Peak picocoulomb measurements are the lowest for this geometry as seen in Figure 2.

![Figure 2. Peak charge for three connector geometries tested for 360 seconds at 500 volts, 8.4 Torr, 85 degrees Celsius.](image-url)
On this basis Geometry 3 is superior. However, when looking at charge rates in picocoulombs per second shown in Figure 3, Geometry 3 is clearly inferior.

![Figure 3. Charge rates (above 5 pC) for three connector geometries at 500 volts, 8.4 Torr, 85 degrees Celsius.](image)

Pressure Gradient Effects

The drive to better simulate aircraft conditions for valid corona testing lead to introducing pressure gradients as a variable. Static pressure electrical testing for aircraft electrical components goes back to at least the Second World War. With the vastly improved climb and dive speeds of modern fighter aircraft, a comparison of simulated climb and dive pressure gradients seemed worthwhile to investigate. This area of investigation might also prove useful to expendable launch vehicles. These vehicles only see a large negative pressure gradient in their flight profiles. While both aircraft and launching spacecraft spend only a short period of time in steep climbs or dives, if the discharge activity is greatly enhanced compared to static pressure, such gradient pressure testing is justified. Also, the difference in the level of activity between simulated climbs and simulated dives must be considered. In the case of the expendable launch vehicle, knowing whether positive or negative pressure gradients produce disproportionate discharge activity would be essential. Therefore simulated climbs and dives were run separately rather than running a “roller coaster” flight profile. As anticipated, the test results indicate that gas desorption or outgassing from insulating surfaces may play a significant role in the level of discharge activity.

Two main concerns need to be addressed from the pressure profile testing. The first is the difference in connector performance on simulated climbs and simulated dives. Outgassing on the climb runs can produce performance variations. It is realized that the different vacuum pumping rates for the constituents of air may affect the tests, however the effect should be minimal since the pressure excursions are primarily in the viscous flow regime. From looking at Figure 4, peak picocoulombs were always higher on the simulated climbs compared to the simulated dives.

![Figure 4. Peak Charge for three connector geometries tested for 360 seconds at 500 volts, gradient and static pressures, 85 degrees Celsius.](image)

However, due to the high measurement variability from connector to connector of the same geometry, statistical F-tests at the 95% confidence level were calculated on the three design geometries to see if the differences between climb and dive performance were statistically significant. The calculations summarized in Table 1 show that only for Connector Geometry 1 was the difference statistically significant.

<table>
<thead>
<tr>
<th>Geometry</th>
<th>Condition</th>
<th>Mean Peak PC</th>
<th>Standard Deviation</th>
<th>F-Test</th>
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<tr>
<td>1</td>
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<td>52.8</td>
<td>21.4</td>
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<td></td>
<td>dive</td>
<td>23.6</td>
<td>36.9</td>
<td>not significant</td>
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<td>2</td>
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<td>25.1</td>
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<tr>
<td></td>
<td>dive</td>
<td>42.0</td>
<td>33.2</td>
<td>not significant</td>
</tr>
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<tr>
<td></td>
<td>dive</td>
<td>27.7</td>
<td>25.9</td>
<td>not significant</td>
</tr>
</tbody>
</table>

Table 1. Mean peak charge, standard deviation, F-Test results for performance of all samples of each of three connector design geometries.
The second concern is the relationship of climb and dive performance to static pressure performance. Again looking at Figure 4, all three geometries show that simulated dives perform better than the static 8.4 torr tests. F-tests at the 95% confidence level show that only for Geometry 1 is the difference statistically significant. Conversely, simulated climbs versus static 8.4 torr tests show no clear trends.

Conclusions

Two different corona measurement techniques were examined. The first technique concerned total charge rate measurements as compared to the more typical peak picocoulomb measurement. Results showed that at least in some cases a combination of both measurements provides a more complete picture of performance. The second technique concerned using pressure gradients to simulate steep dives or climbs. Again, at least in some cases, pressure gradient measurements are significantly different from static pressures.

Through the use of a multichannel analyzer in conjunction with commercial corona test equipment, the discharge activity during these pressure excursions can be better quantified. Current military specifications (primarily based on discharge magnitude) may not be specific enough to address these issues. It is possible that total integrated charge criteria may be necessary to establish valid acceptance criteria. Before valid specification changes can be proposed, more statistically significant data should be generated and evaluated by extensive testing.

Acknowledgement

The Naval Air Warfare Center, Aircraft Division, Indianapolis, Indiana sponsored this work by the Wright Laboratory, Wright-Patterson Air Force Base, Ohio.

References


