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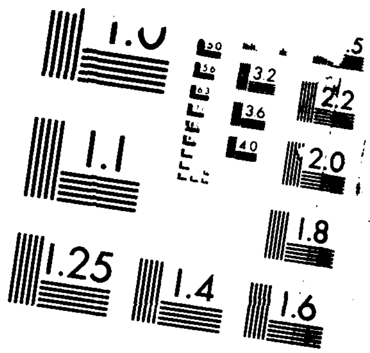

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PRELIMINARY MATERIAL TESTING OF CERAMIC AND WOOD

Raymond W. Nethers
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May 1986

Final Report

Approved for public release; distribution unlimited.

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This final report was prepared by the Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico, under Job Order 12091501. Mr. Raymond W. Nethers (NTAO) was the Laboratory Project Officer-in-Charge.

This technical report has been reviewed and is approved for publication.

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Results of preliminary tests of various construction materials subjected to high voltage electrical discharge are reported along with test conduct. Two high voltage construction materials, a wood post and a ceramic insulator, were tested. As a corollary a typical wood fastening system, similar to a TRESTLE joint, was tested. Flashing over of the ceramic insulator caused no damage, while flashing over of the wood at high overvoltages causes considerable damage. Fastening systems in sparse patterns does not appear to change the standoff voltage of the wooden beam used as an insulator.

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INTRODUCTION

This note presents the results of preliminary tests of various construction materials subjected to high voltage electrical discharge. The purpose of these tests was to determine the high voltage breakdown point of these materials. Of the most commonly used materials in high voltage construction, a ceramic insulator and a wood post were first to be tested.

As a corollary a typical wood fastening system, similar to a TRESTLE wooden joint, was the second test. The purpose of the wood joint test was to investigate the effects of the wooden beam fasteners used in the TRESTLE structure on the electrical breakdown strength of the wood beams and the effect of the breakdown on the physical strength of the joint.

The tests were performed using negative voltages only as this polarity provides the highest standoff voltages.

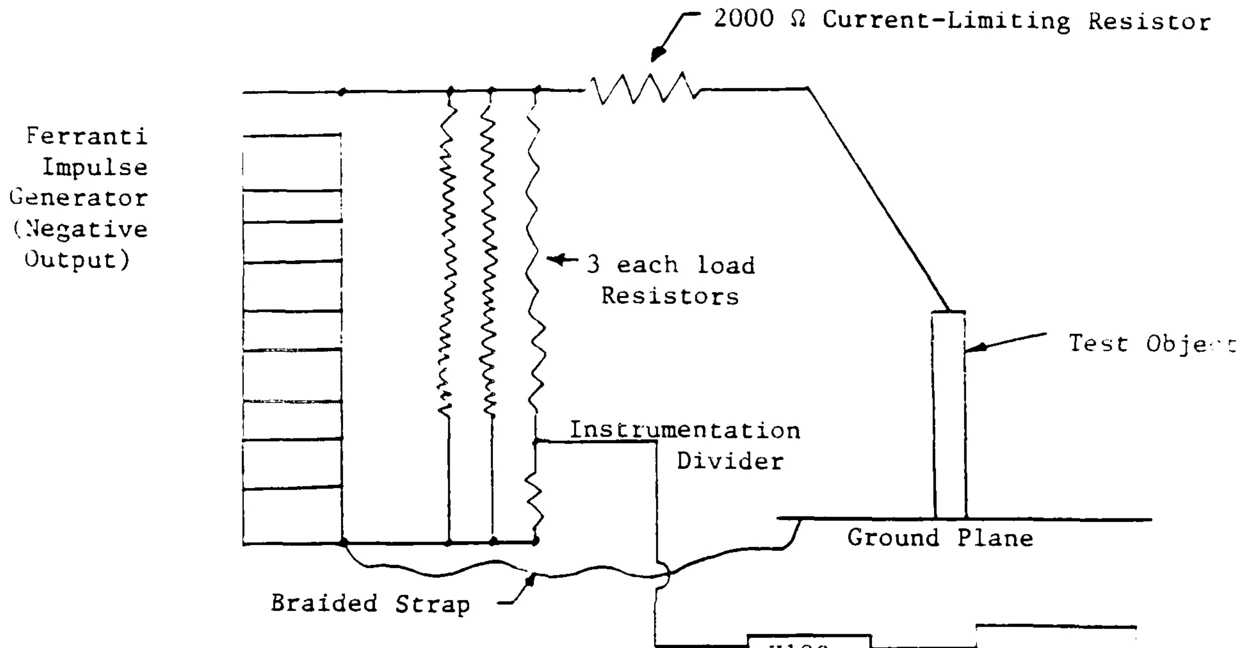
TEST CONDUCT

CERAMIC INSULATOR

The twenty stage marx Ferranti Impulse Generator (FIG) was configured to produce the waveshape recommended for the Trailing Wire Antenna (TWA) tests [risetime (10-90 percent) 1.7 μs, decay time (50 percent) 37 μs]. A spare ceramic insulator for the FIG was selected for the test. This insulator is of English manufacture and no information is available for it although it must withstand about 400 kV for its use in the FIG. The insulator is 45-in high and 17-in in dia.

The insulator was connected to the FIG as shown in Fig. 1. Most of the data was taken with a 2000 Ω copper sulfate current-limiting resistor in series with the insulator, but some was taken with this resistor omitted.

The up-down method was used to determine the 50 percent breakdown voltage and sigma, the standard deviation. This method requires at least 30 test shots to gather sufficient data for results.



Ferranti Parameters

Front resistors	24 Ω
tail resistors	20,000 Ω
Load resistors	5,000 Ω
Instrumentation divider ratio	1/8845

Figure 1. Insulator test setup.

WOOD POST

A 6 by 6-in fir wood post 5.6 ft long with steel mounting brackets on both ends was selected for this test. This post had been painted with white enamel, but exposure to the weather for some years had caused some minor splits and cracks. The post also had a high pitch content and high density.

The first test was with the generator connected to the top steel mounting bracket. The current-limiting resistor, shown in Fig. 1, was not used for any of the wood post tests. The second test was with the top steel bracket removed and a 19-in-dia metal donut anticorona ring mounted to the top of the post. The third test was with a larger 30-in-dia anticorona ring fashioned from copper mesh and an inflated tire inner tube. For the fourth test, the FIG was connected to a pointed 3/8-in steel rod that was placed in a hole about 4-in deep drilled in the top of the post.

The up-down test method was not used for these tests due to the probability of tracking occurring on or in the wood which would prevent the conductivity of the post from remaining constant over the period of the tests.

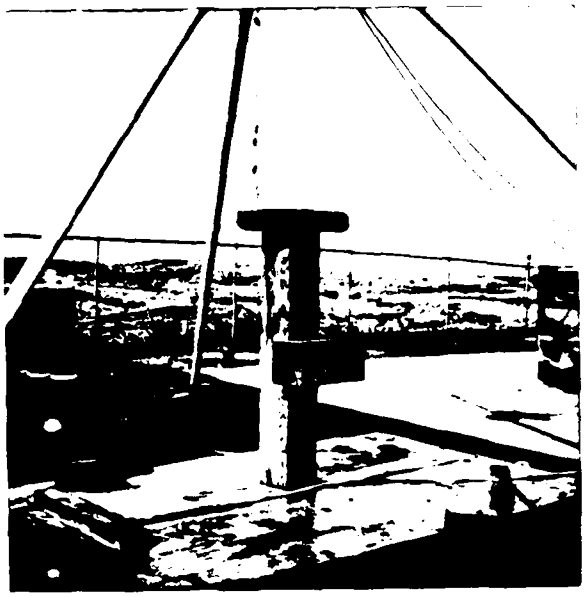
After initial testing, a number of overvoltage shots were taken. This was done to determine the effect of large overvoltages on the wood.

TRESTLE WOOD JOINT

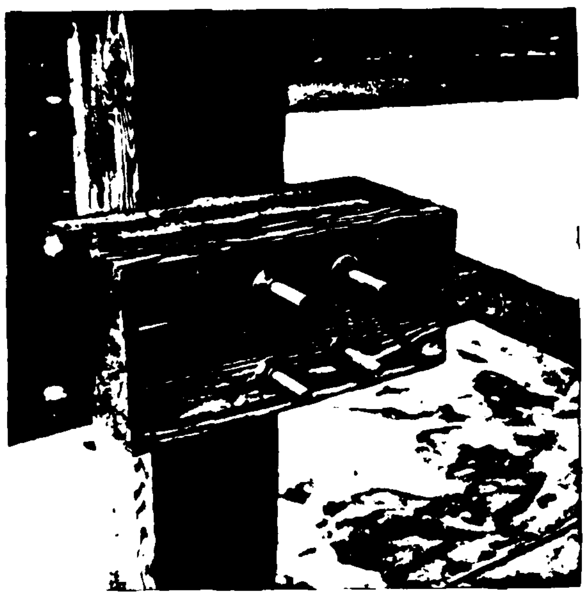
A beam was fastened to another beam as shown in Fig. 2. Two different sizes of metal rings were installed in the joint as well as the four bolts to simulate a typical TRESTLE beam joint.

A 30-in anticorona ring fashioned from copper mesh and an inner tube was mounted on top of the beam for connection to the FIG. An attempt was made to use the standard up-down 50 percent test method, but the repeatability of the data made this method unnecessary.

The first test was conducted with four wood bolts in place and no split rings. The second test was conducted with four wood bolts and four split rings in place. The third test was conducted with four metal bolts and four split rings in place.



(a) Test setup with anticorona ring.



(b) Metal bolts.

Figure 2. TRESTLE wood joint test setup.

RESULTS

CERAMIC INSULATOR

The breakdown time for the ceramic insulator varied from 3 to 8 μs with the most typical time being about 4 μs. The 50 percent breakdown voltage was calculated to be 580 kV and sigma was calculated to be 62,741 V.

During the ceramic insulator test the decay time of the FIG varied from 30 to 27.5 μs for 50 percent decay. This was probably due to temperature variation as most of the pulser load consists of copper sulfate solution resistors which are very sensitive to temperature variation.

WOOD POST

Seven shots were made for the first wood post test with the steel bracket mounted on top of the beam. Five flashovers were observed.

The breakdown voltages with the resistor were 608, 540, and 501 kV. The time delay for breakdown was from incomplete risetime to 5 μs. For all breakdowns, the arc tracked on the surface of the post in a new position and peeled off a few small splinters. No structural damage was observed.

Four shots were made with the small 10-in-dia donut on top of the p t. Two flashovers were observed at 529 kV for both. The time to breakdown was less than 1 ms. As for this test, no structural damage was observed and only minor splinters were loosened by surface tracking.

Seven shots were made with the large 30-in-dia donut attached to the post. Two flashovers were observed at 814 and 760 kV. Times were 5 and 10 μs. Once again, only a few small splinters were ejected.

Five shots were made with a pointed rod installed in a vertical hole drilled in the top of the post. Four shots flashed over at 936, 707, 576, and 557 kV. Time to flashover varied from incomplete risetime to less than 1 ms. The flashovers for this test were through the wood. No structural damage or burning was apparent. The only sign of flashover was a slight smell of ozone around the top of the post.

Ten overvoltage shots (nominal 1.5 MV) were taken. These caused the corners of the post to be ejected in large 1 by 1-in shards.

TRESTLE WOOD JOINT

The flashover voltage for the joint with wooden bolts and no split rings was 538 kV; with split rings was 518 kV. The flashover voltage for the joint with metal bolts and split rings was 540 kV.

The time to breakdown was approximately 1 to 2 μs. The breakdown usually occurred just before the pulser output wave shape reached its peak value.

The flashovers tracked on the surface of the wood and through the split rings. Voltages just above flashover value caused no structural damage.

One pulser shot was made at 120 kV charge voltage (nominal 1.5 MV output). This shot caused considerable structural damage as a 1 by 1-in shard was ejected (Fig. 3).

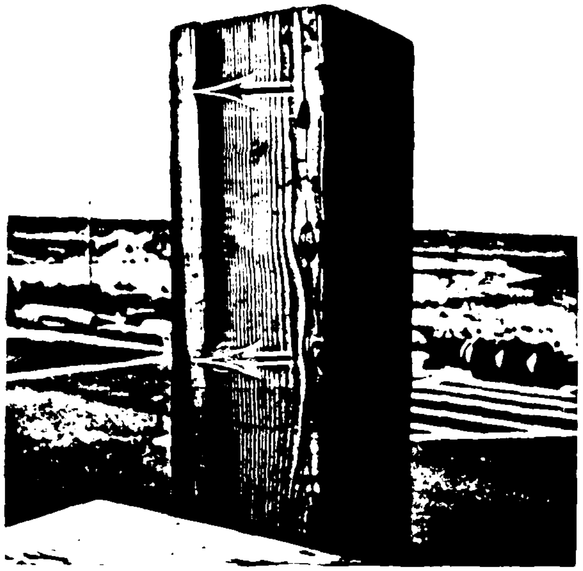
CONCLUSION

Flashing over the ceramic insulator did not harm it. The wood post withstood low voltage flashovers with no structural damage, but when shots were taken with a high overvoltage, major structural damage resulted.

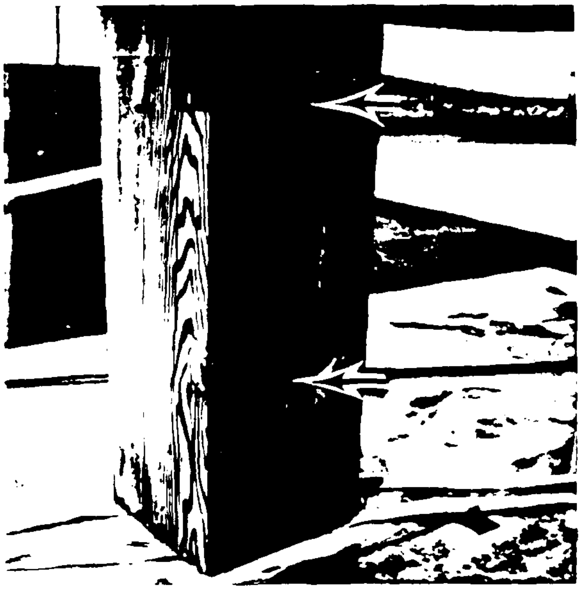
Use of a large 30-in-dia field shaping donut seems to increase the breakdown voltage level approximately 40 percent for a wooden post.

The results of the TRESTLE wood joint test shows that metal rings and bolts in sparse patterns have little effect on the standoff voltage of the wooden beam used as an insulator.

In general, a large overvoltage can cause extensive structural damage to wood beams; however, an overvoltage slightly above the standoff voltage of the wood seems to cause only minor damage with surface tracking.



(a) Damage to upper part of post.



(b) Damage to lower part of post.

Figure 3. Damage to TRESTLE wood joint post.

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