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PERFORMANCE OF THE SANDIA LIGHTNING SIMULATOR DURING F-14A AND F/A-18 AIRCRAFT LIGHTNING TESTS

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ABSTRACT

Two Navy Aircraft (F-14A and F/A-18) were subjected to high-level lightning tests using the Sandia Lightning Simulator. The peak pulse currents applied were varied from 9 to 170 kiloamperes. The nominal rise time to peak was 2 microseconds. Double-pulse and continuing currents were also applied. Several high current, high voltge pulses were also obtained. Ninety-six test pulses were applied to the F-14A and sixty-four pulses were applied to the F/A-18. Approximately eighty percent of these pulses met the test specifications and essentially all pulses produced useful data.

THE F-14A and F/A-18 AIRCRAFT were tested as part of Operation FLLASH (Full Level Lightning Aircraft System Hardening) sponsored by the Naval Air Systems Command of the U. S. Department of the Navy. This paper will present a summary of the performance of the Sandia Lightning Simulator during these tests. The results and interpretation of the tests and measurements made on the aircraft will not be discussed here.

FACILITY DESCRIPTION

The purpose of the Sandia Lightning Simulator is to provide a facility for studying the effects of lightning-like currents on components and systems of interest to the weapons community. Use of the Sandia Lightning Simulator is described in detail elsewhere in these proceedings (See: White, R. A., Full Systems Tests Using the Sandia Lightning Simulator.). The electrical currents are designed to simulate an extremely severe (up to 99th percentile) lightning ground return stroke. In addition, a multi-stroke capability and a continuing current component are provided. The simulator is in the development stage, and all tests are considered to be experimental.

The current pulses are provided by oil-insulated Marx generators located in two separate tanks, each containing about 16,000 gallons of oil. Two Marx generators are located in each tank. In most tests, the object to be tested is suspended in a coaxial fashion over the output terminal, located between the tanks. The continuing current is produced by a motor-generator set built from modified diesel-electrical traction motors. The operation of the simulator is controlled from an adjacent shielded control room that also serves as the data collection center.

AIRCRAFT TEST CONFIGURATIONS

The aircraft were located outdoors, on a concrete pad adjacent to the building housing the simulator. An oil-filled coaxial line and high voltage bushing were constructed to connect the output terminal of the simulator to the nose of the aircraft, located over twenty feet apart. The outer conductor of this line served as the ground return path for the injected current. The coaxial line also contained a dummy load coil that could be switched into the circuit for the purpose of adjusting the simulator parameters without applying pulses to the aircraft. The high voltage bushing used two atmospheres of SF_6 gas for electrical insulation.

The aircraft test fixture arrangement is shown in Figure 1. The output of the high voltage bushing was hard-wired to the nose of the aircraft. The aircraft was insulated from ground by resting the landing gear on individual insulating pads. The current could be extracted from the tail, wing tip, or fins of the aircraft, depending upon the particular test. The extraction point could be hard-wired or an air gap provided. Air gaps up to eleven inches were used to cause the aircraft to charge up to several hundred thousand volts prior to breakdown and current discharge. A system of cables around the fuselage and wing of the aircraft was used as the ground return system to provide an approximately coaxial arrangement.

SIMULATOR OUTPUT

The peak current output of the simulator was varied from 9 to 170 kiloamperes by controlling the charge voltage applied to the Marx generators and by connecting one, two or three Marxes in parallel. The lowest currents were obtained by using a single Marx generator and shunting part of the current away from the aircraft. The simulator current was measured using a five milliohm current viewing resistor in series with the ground current return circuit. Three current waveforms obtained during these tests are shown in Figures 2, 3 and 4. The negative going currents are shown here as they were displayed on the recording digitizers.

Figure 2 shows a low current test using a single Marx with a shunt located in the oil tank. The current reaches peak value, about 15 kiloamperes, in just under 2 microseconds. A laser-triggered gas discharge switch ("crowbar") located at the output of the Marx, is triggered about one microsecond after peak current. This crowbar switch changes the circuit to produce an exponentially decaying current that falls to half value in about 100 microseconds.

Figure 3 shows the current waveform obtained by using three Marx generators in parallel. The time to peak is just under 3 microseconds, and the crowbar switches were triggered at about 3.8 microseconds.

Double pulses were also produced in these tests, using two Marxes to produce the first pulse, and a single Marx for the second. Figure 4 shows one such result on a variable time base as it appeared on the digitizer display. The time intervals between time scale changes (vertical lines) are indicated. The first pulse and crowbar are shown in the initial 10 microsecond interval. The time sweep was then slowed down to show the exponential decay of the current. A further reduction in sweep speed shows the 16 millisecond interval between pulses. The sweep is then switched to the original speed to show the second pulse and crowbar. The final 448 microsecond interval shows the decay of the second pulse.

A continuing current that averaged about 300 amperes for a duration of 1 second was added to both single and double pulses for some tests.

For one series of high voltage tests the simulator was configured as an underdamped circuit without the crowbar switch. This produced the current waveform shown in Figure 5, with a peak current of about 54 kiloamperes. A capacitive divider was used to measure the voltage at the end of the high voltage bushing, producing the result shown in Figure 6. The peak voltage obtained was about 1.2 million volts.

SIMULATOR PERFORMANCE SUMMARIES

The F-14A was tested over a two week period in April 1982. Tests were accomplished in 9 days. Two night operations with extensive photographic coverage were completed. The aircraft was passive for these tests; that is, no on-board systems were functioning. The number of test attempts and successes are shown in Table 1 for each of the three current levels. Only single pulses were used in these tests, and continuing current was provided on two tests. A test was considered a success if the desired current level was attained and the level at which the crowbar switch operated was at least 70 percent of the peak level.

The F/A-18 was tested over a four week period in August 1982. Tests were accomplished in 18 days. One night operation was completed. On sixty percent of the tests, the auxiliary power unit of the aircraft was operating and the on-board aircraft systems were functioning. In addition, two motion picture cameras were photographing the cockpit display area during these active tests. The attempts and successes are tabulated in Table 1. The high current tests are subdivided into single pulse, double pulse, double pulse and continuing current, and triple Marx with continuing current.

CONCLUSIONS

Essentially all of the test objectives for the Sandia Lightning Simulator were achieved during these tests. This includes low, intermediate, and high level pulses, double pulses and continuing current. In addition, several high current, high voltage (1.2 megavolt) tests were achieved, and two pulses in excess of 140 kiloamperes were applied. Of the 160 test pulses applied to the aircraft, 129 (about eighty percent) were successful, where success indicates that the desired peak current level was attained and the crowbar, or exponentially decaying current, was obtained. Most of the pulses that did not meet the success criteria still produced useful data. A successful night operation with extensive photographic coverage was carried out on each aircraft.

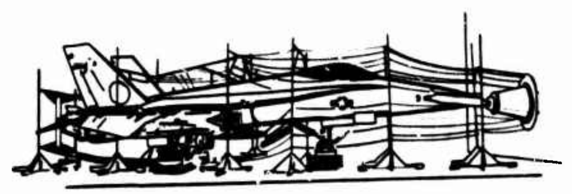

Fig. 1 - F/A-18 test arrangement

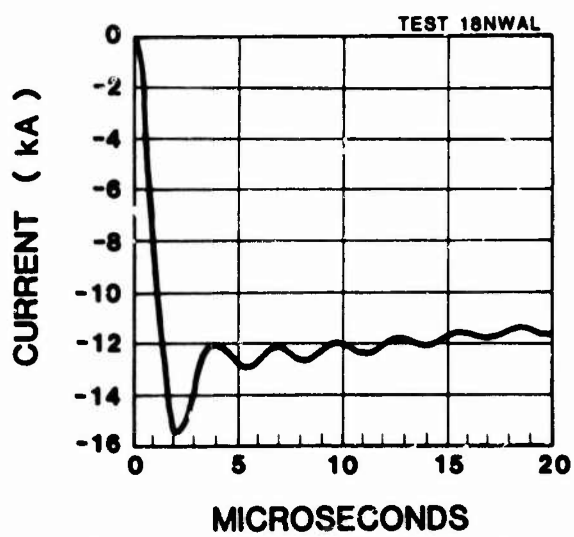

Fig. 2 - Current vs time, low level test

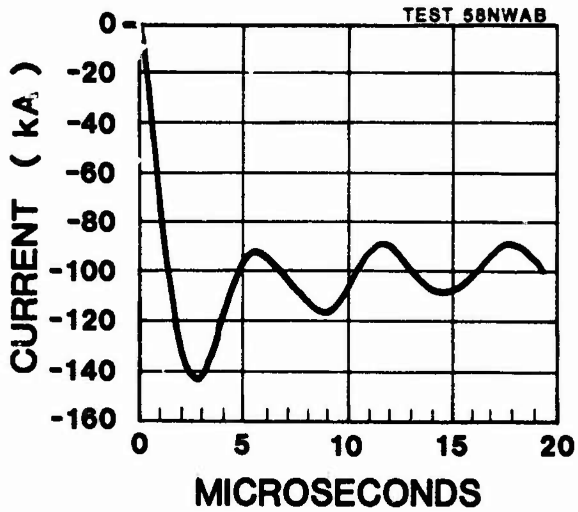

Fig. 3 - Current vs time, high level test

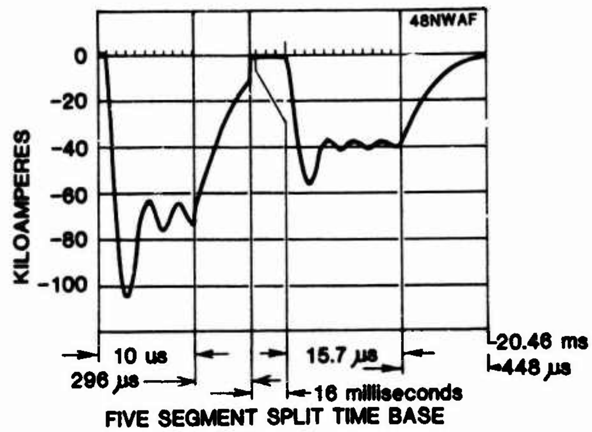

Fig. 4 - Current vs time, double pulse

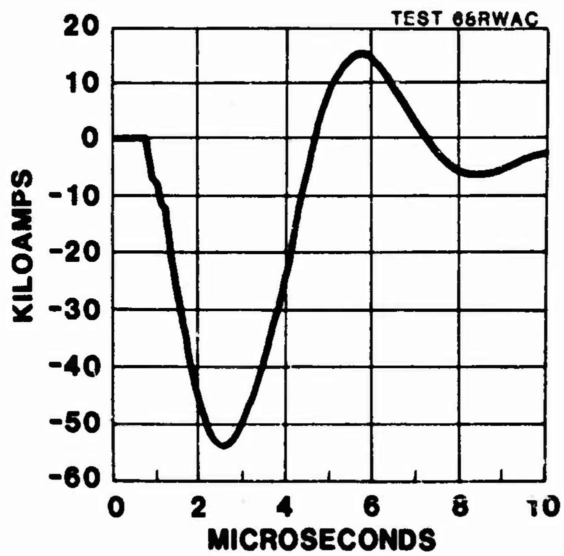

Fig. 5 - Current vs time, high voltage test

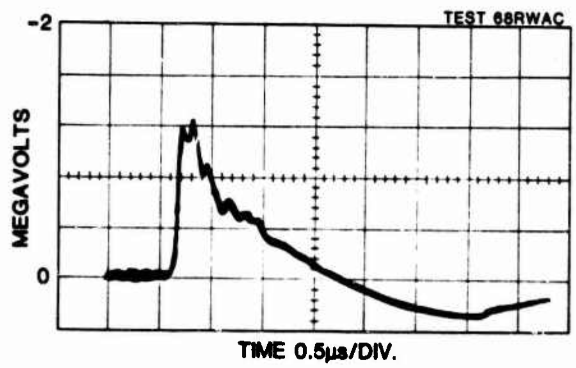

Fig. 6 - Output voltage vs time, high voltage test

Table 1 - Sandia Lightning Simulator Aircraft Tests, 1982

	Current Level (kA)	Attempts	Successes
	Low (10)	66	54
F-14A	Intermediate (40)	24	21
	High (80)	6	3
		96	78
	Low (15)	26	25
	Intermediate (<100)	9	9
	High (>100)		
F/A-18	Single	11	5
	Double	3	2
	Double + CC	8	5
	3 Marx + CC	3	2
	High Voltage	4	3
		64	51