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WINDMILL GENERATOR FULL-SCALE DROP TEST RESULTS

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C. F. Muehlenweg - 5143
R. C. Maydew - 5141

ABSTRACT

Three windmill generator power supply units were successfully tested on two drops of modified Mk 6 units. The configurations tested and the results obtained are presented.

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(17 pages)

Case No. 409.10

October 19, 1956

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WINDMILL GENERATOR FULL-SCALE DROP TEST RESULTS

Introduction

The windmill generator program was originally initiated to develop an alternate power supply for the Mk 5 and Mk 6 class of weapons.

Results of wind-tunnel tests have been reported in previous memorandums.[1,2] The purpose of this memorandum is to present results of full-scale drop tests of three windmill generator power supply units.

Physical Characteristics

Standard Mk 6 fins were shortened and modified for mounting the windmill ducts as shown in Fig. 1. The units were used in pairs and mounted on diametrically opposite fins. Figure 2 shows the drop test configuration. The fin-duct assemblies fit in the box of the original fins. Each fin-duct assembly and voltage regulator unit weighed 25 pounds more than a standard fin.

Figure 3 shows the major dimensions of the duct and the ram air turbine. The only changes from the wind-tunnel model of Reference 1 are the duct inside diameter and the turbine blade tip diameter. The inside diameter of the duct has been increased to 7 inches (from 6.62), and the tip diameter to 6.81 inches to give a blade span of 1.53 inches (from 1.4). The increased turbine blade span increases the developed power by approximately 25 per cent over the first models.

A photograph of the turbine-generator assembly and the voltage regulator is presented in Fig. 4. The voltage regulator is mounted inside the weapon afterbody.

A photograph of the turbine-generator-shroud assembly mounted on the modified Mk 6 fin is presented in Fig. 5.

The generators are three-phase, six-pole, self-excited alternators rated at 700 volt-amps and 115/208-volt output at 400 cycles/second (8000 rpm). The voltage regulator was designed to regulate output voltage to ± 5 per cent over the rotational speed range of 6800 to 9200 rpm and from no-load to 700 volt-amps.

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The variable-pitch turbine and governor are the same type as the wind-tunnel model with only minor refinements. The governor is basically a simple direct-acting mechanical governor. A change in rotational speed causes a movement of the governor weights to maintain a balance with the spring force. This movement of the governor weights is directly linked to the turbine blades to cause a change in pitch.

Drop Test Conditions

Both test drops were made from a B-47 aircraft. On the first test, the Mk 6 was released at 42,700 feet altitude at a true airspeed of 401 knots. A generator unit was installed in the upper fin position shown in Fig. 2, and a dummy unit, which simulated the drag and weight of an actual unit, was installed in the lower position. The following step loads were applied during the drop:

Time (sec)	Load (watts)
0-5	None
5-20	200
20-Impact	400

On the second test, the Mk 6 was released at 19,800 feet altitude at a true airspeed of 420 knots. Two generator units were installed for this test. The following step loads were applied to each power unit during the drop:

Time (sec)	Load (watts)
0-10	500
10-Impact	1000

Plots of altitude, velocity, and Mach number versus time for each test are presented in Figs. 6 and 7. Rotational speed, output voltage, and output current were telemetered as well as weapon pitch, yaw, and roll.

Test Results

The rotational speed (rpm), output voltage, and electrical load (watts) plotted versus time for test No. 1 are presented in Fig. 8. When the bomb-bay doors opened, the reverse air flow in the bomb bay caused the turbine

to rotate in reverse. The rotational speed built up to 3000 rpm at release. It took 2.5 seconds after release for the unit to reverse direction and accelerate to 7200 rpm (115-volt output).

The voltage regulator was sensitive to vibration which caused some voltage fluctuations. There were two periods of instability of the mechanical governor which lasted approximately 5 seconds each.

During these unstable periods, the rotational speed varied between peak values of 7300 to 8500 rpm for four or five cycles during each period. During the remainder of the test, the rotational speed varied between 7800 and 8300 rpm. The output voltage ranged between the limits of 110 and 125 volts during these unstable periods.

The results of test No. 2 are presented in Figs. 9 and 10 for the upper and lower locations of the windmill power supplies, respectively. A ratchet was installed to prevent the reverse rotation which occurred in test No. 1.

The upper unit accelerated to a rotational speed of 7200 rpm (110-volt output) 1.7 seconds after release. The output voltage remained between 106 and 115 volts during the entire test. The rotational speed for the first 22 seconds of flight held between 7850 and 8000 rpm. From 22 seconds flight time to impact (39 seconds), the rotational speed steadily increased to a final value of 9000 rpm. It is believed that this latter effect was caused by the minimum turbine blade angle stop being set at too high a value (i.e., the turbine developed too much torque at the minimum pitch setting).

Data obtained from the generator in the lower position (Fig.10) indicated that the unit started rotating immediately after the bomb-bay doors opened due to the circulation in the bomb bay. The unit was rotating at 4800 rpm at release and reached 7200 rpm 1.25 seconds after release. The output voltage remained between 117 and 122 volts throughout the test. The rotational speed varied between 7800 and 8200 rpm during the test.

The differences in the output voltage levels for the three units were due to difficulty in setting the regulators.

The addition of the windmill ducts did not appreciably alter the stability characteristics of the Mk 6 shape.

Discussion

Prior to the drop tests of the windmill power supply, a great deal of testing was carried out on the present governor as well as other types of governors. This testing was done by spinning units on a dynamometer, blowing air through the duct with the Sandia blowdown facility, and testing in a large wind tunnel. The experience gained in the program indicates that a direct-acting mechanical governor is best suited to the application.

With minor design refinements, the governor used in the drop tests will reliably hold speed to ± 3 per cent. With this speed regulation and different type alternator, a voltage regulator is not required. This would also reduce the over-all weight, since the present regulator weighs 4.4 pounds. The same governor and windmill could be adapted to operate at 12,000 rpm with a 4-pole alternator (400 cycles) if power requirements are increased. The windmill and governor could be scaled either up or down in size to meet other power requirement applications.

Conclusions and Recommendations

1. The drop test results indicate that the windmill generator is a feasible power supply.

2. Any future work on a windmill power supply should be carried on for a particular application.

C. F. MUEHLENWEG - 5143

R. C. MAYDEW - 5141

Case No. 409.10
October 19, 1956

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REFERENCES

1. Maydew, R. C., Status of Windmill Generator Power Supply Program, Sandia Corporation Technical Memorandum, 281-54-51, Ref. Sym: 5141 (552), Confidential, December 21, 1954.

2. Maydew, R. C., Windmill Performance, Sandia Corporation Technical Memorandum, 71-54-51, Ref. Sym: 5141 (503), Confidential, May 7, 1954.

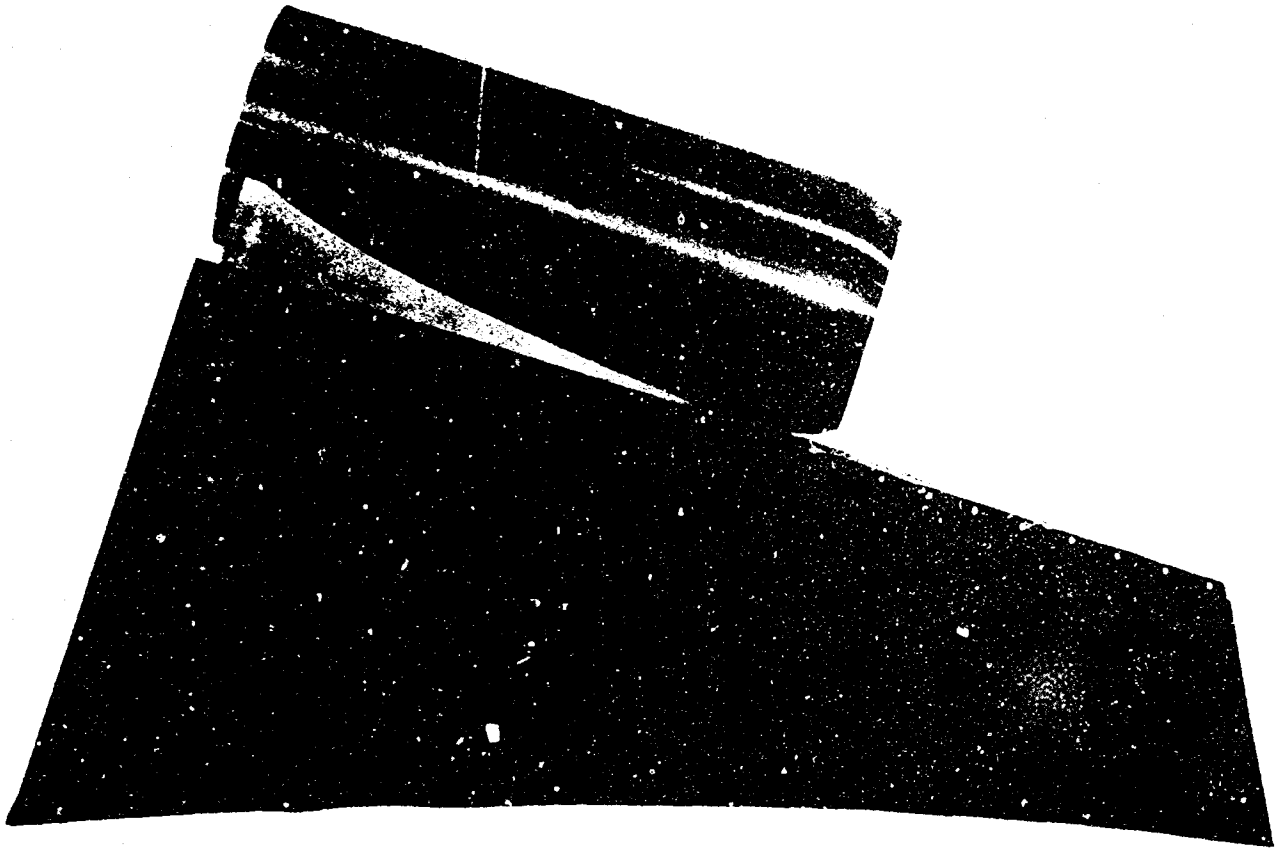

FIGURE 1 - MK-6 FIN-WINDMILL DUCT ASSEMBLY

[redacted]

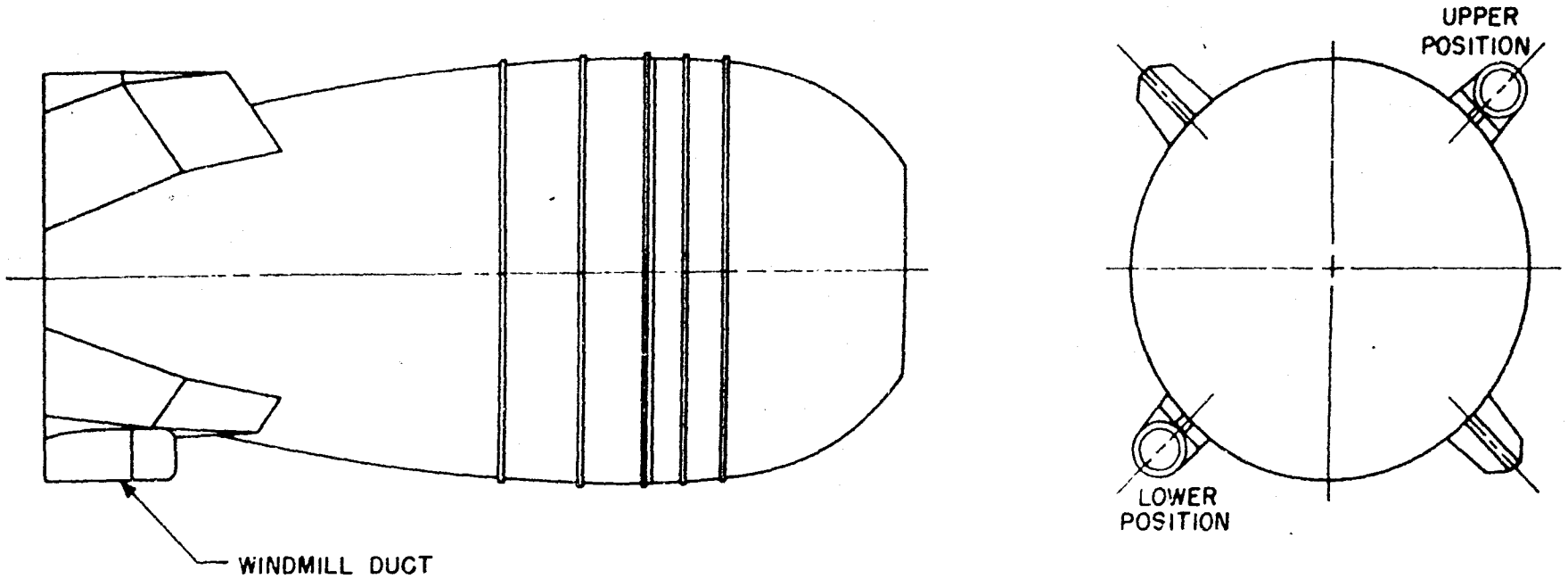

FIGURE 2 - MK-6 WINDMILL GENERATOR CONFIGURATION

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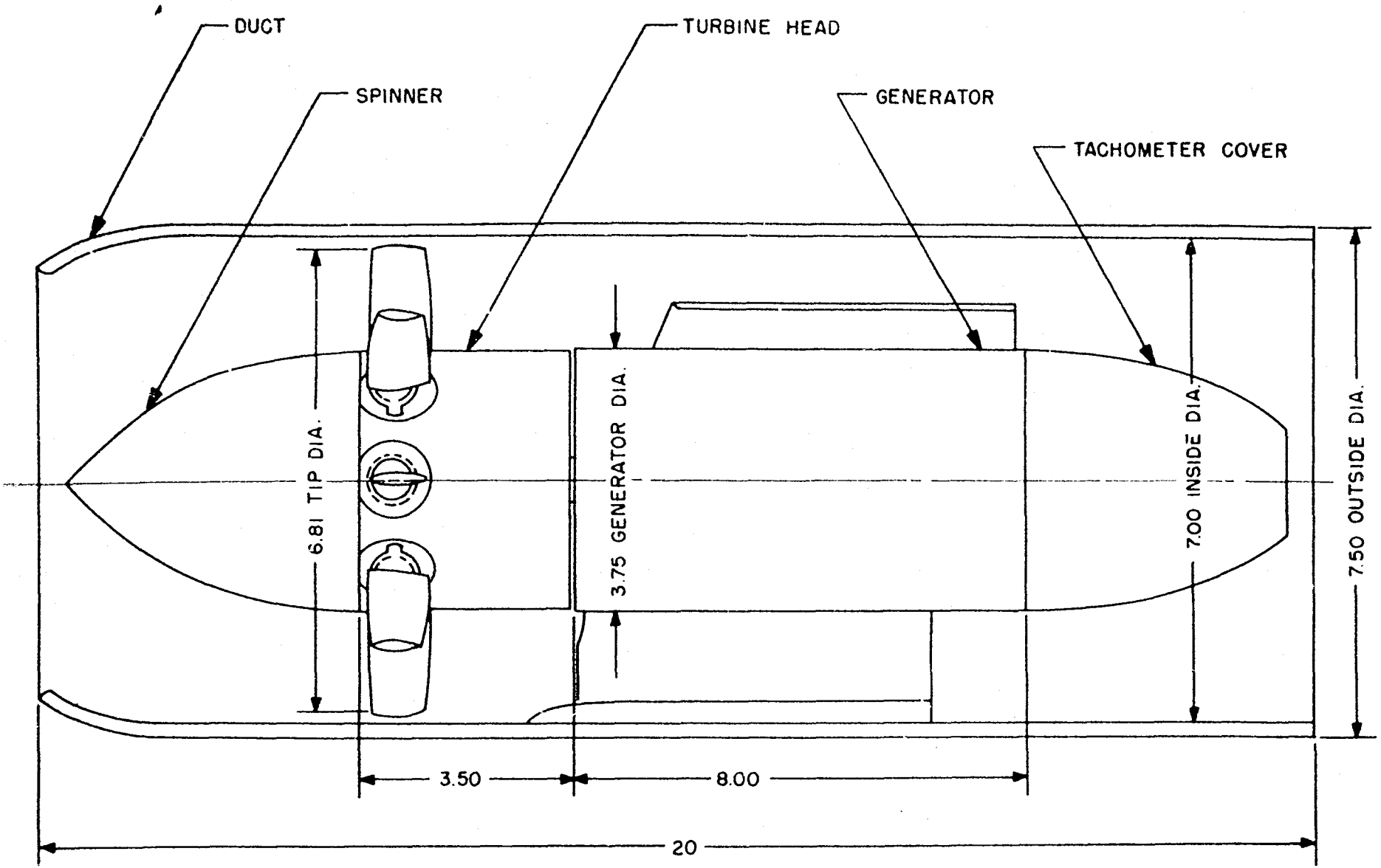

FIGURE 3 - TURBINE-GENERATOR AND DUCT ASSEMBLY

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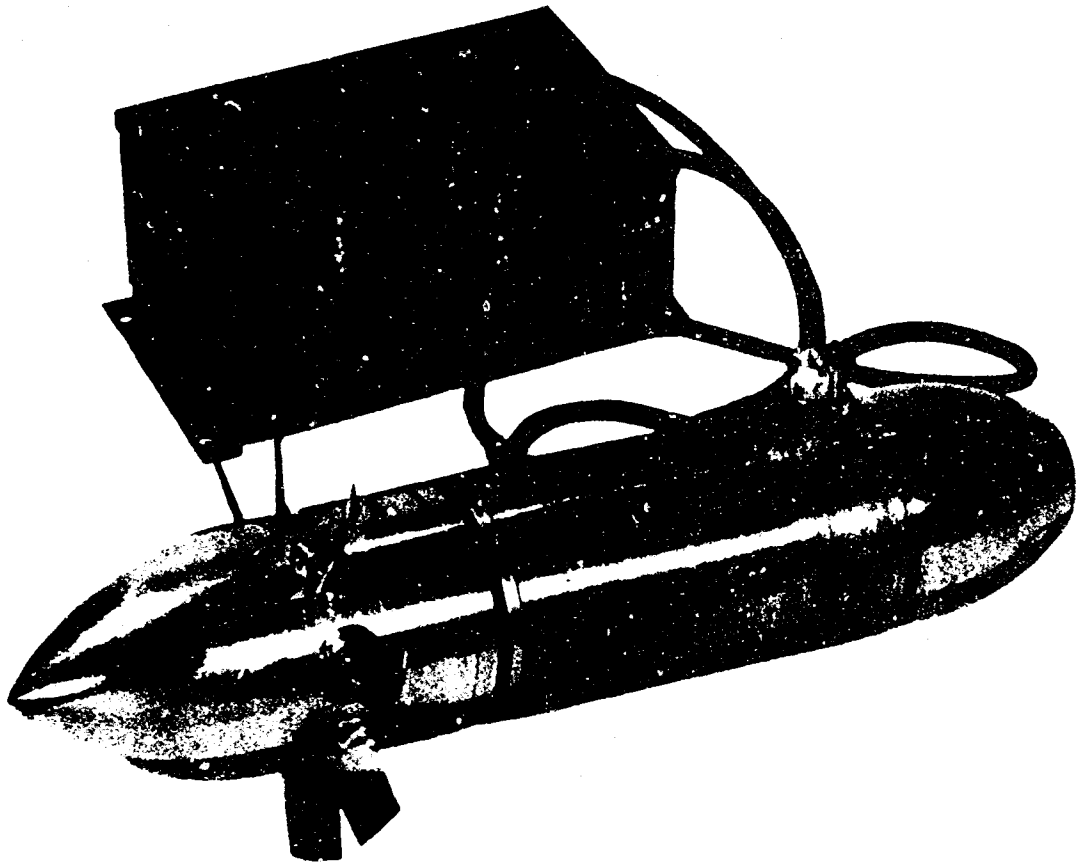

FIGURE 4 - TURBINE-GENERATOR ASSEMBLY

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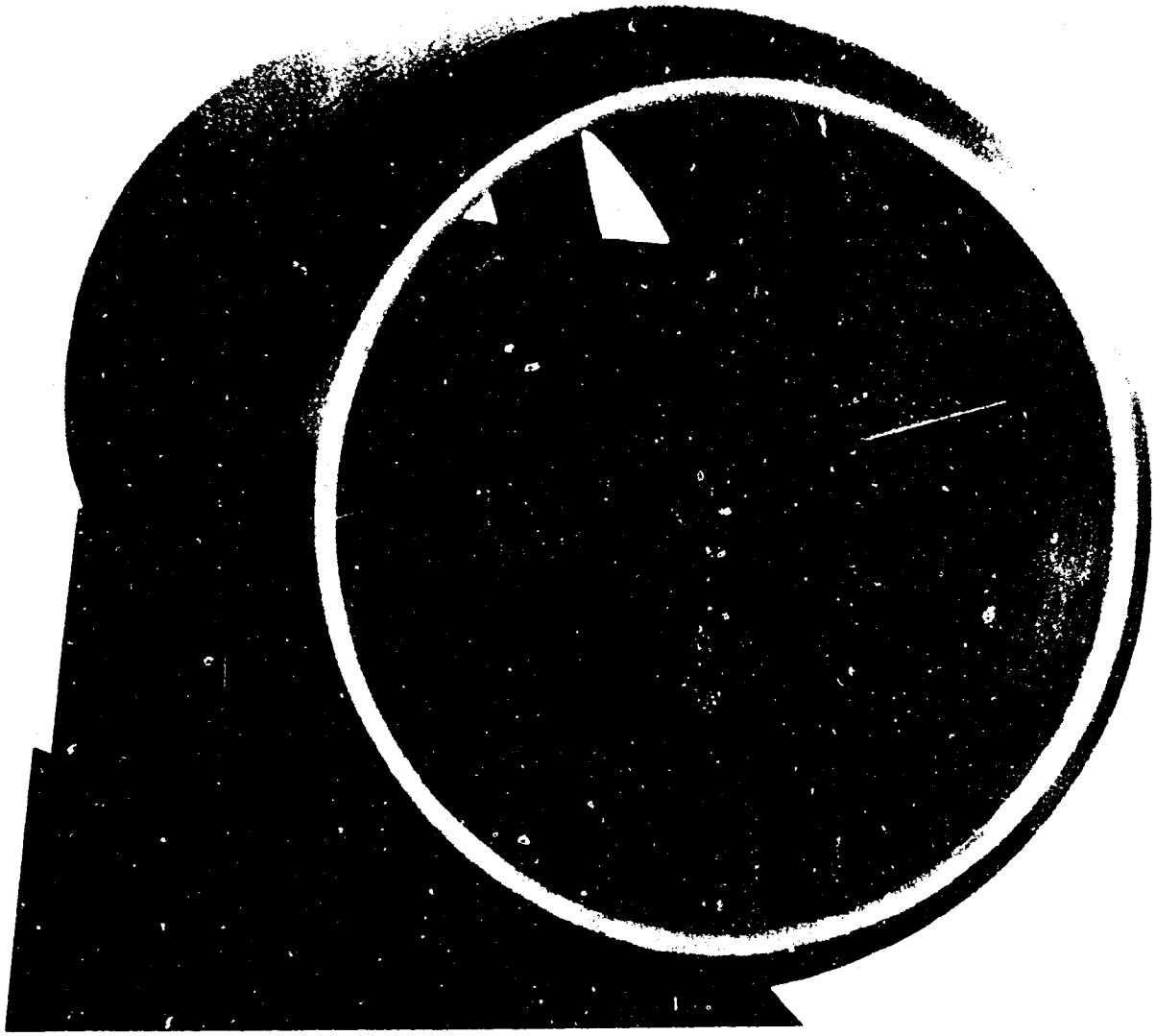

FIGURE 5 - TURBINE-GENERATOR-SHROUD ASSEMBLY

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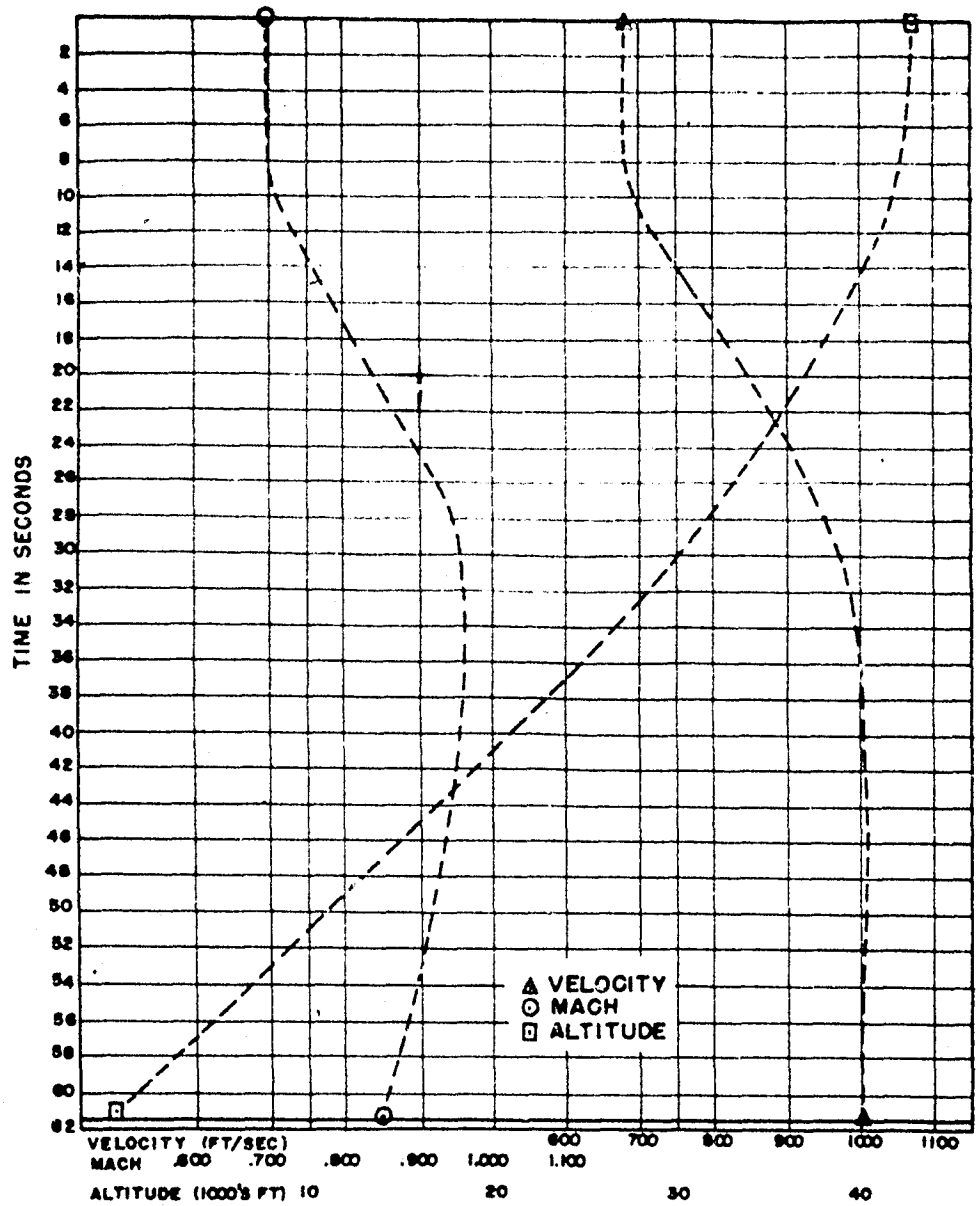

VELOCITY AND MACH GRAPH WINDMILL DROP TEST #1

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FIGURE 6

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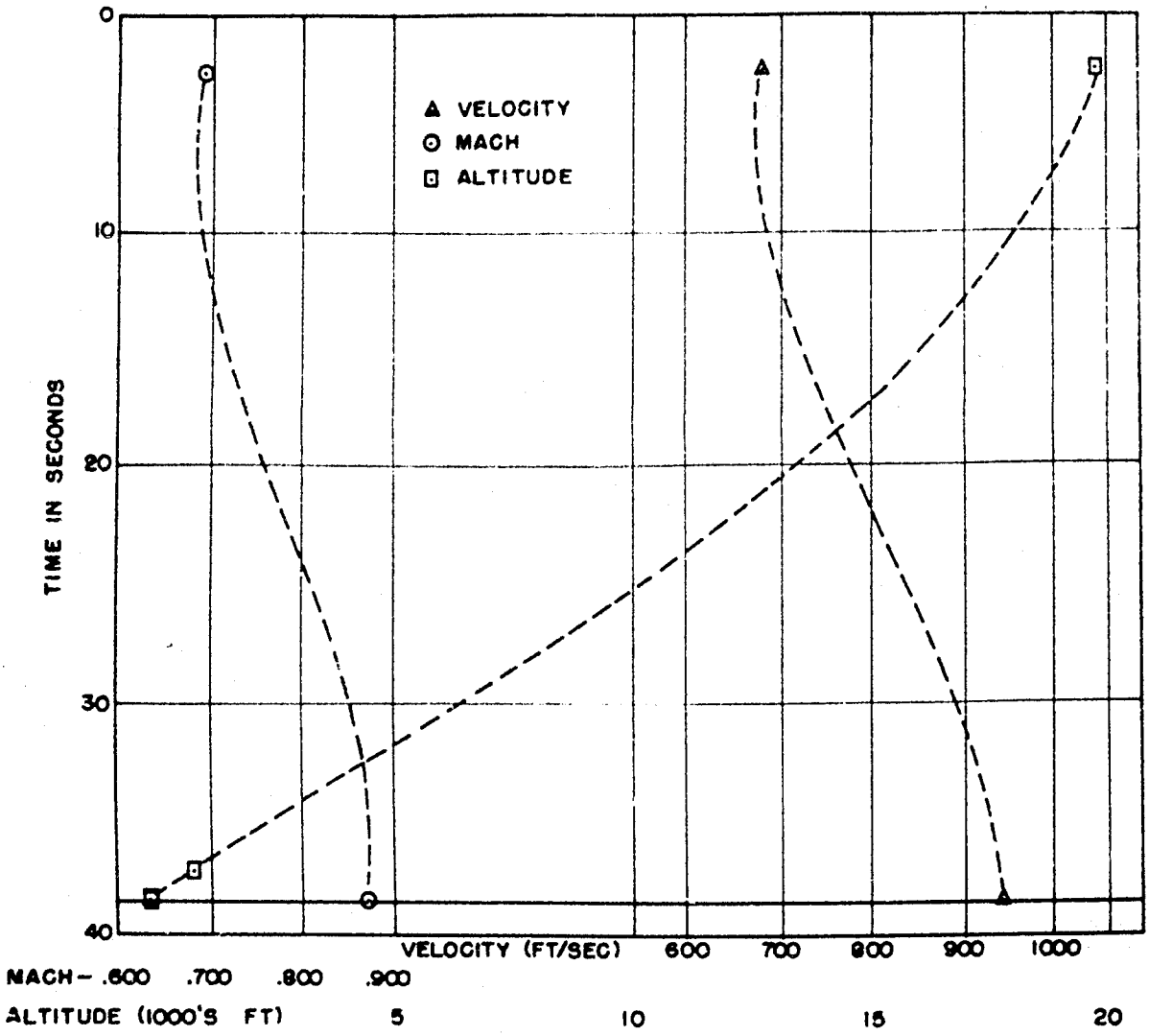

VELOCITY AND MACH GRAPH WINDMILL DROP TEST #2

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FIGURE 7

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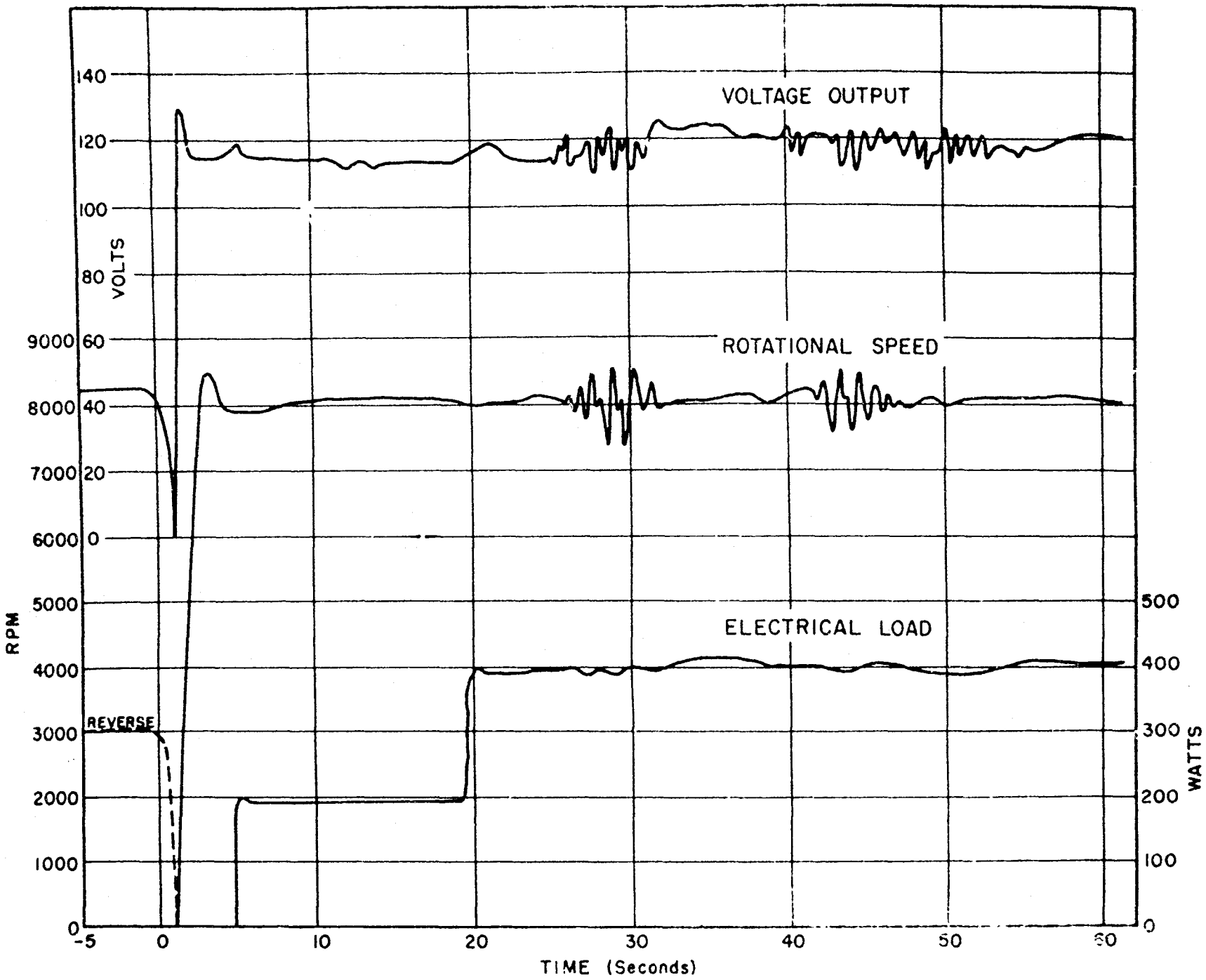

FIGURE 8 - WINDMILL DROP TEST NO. 1

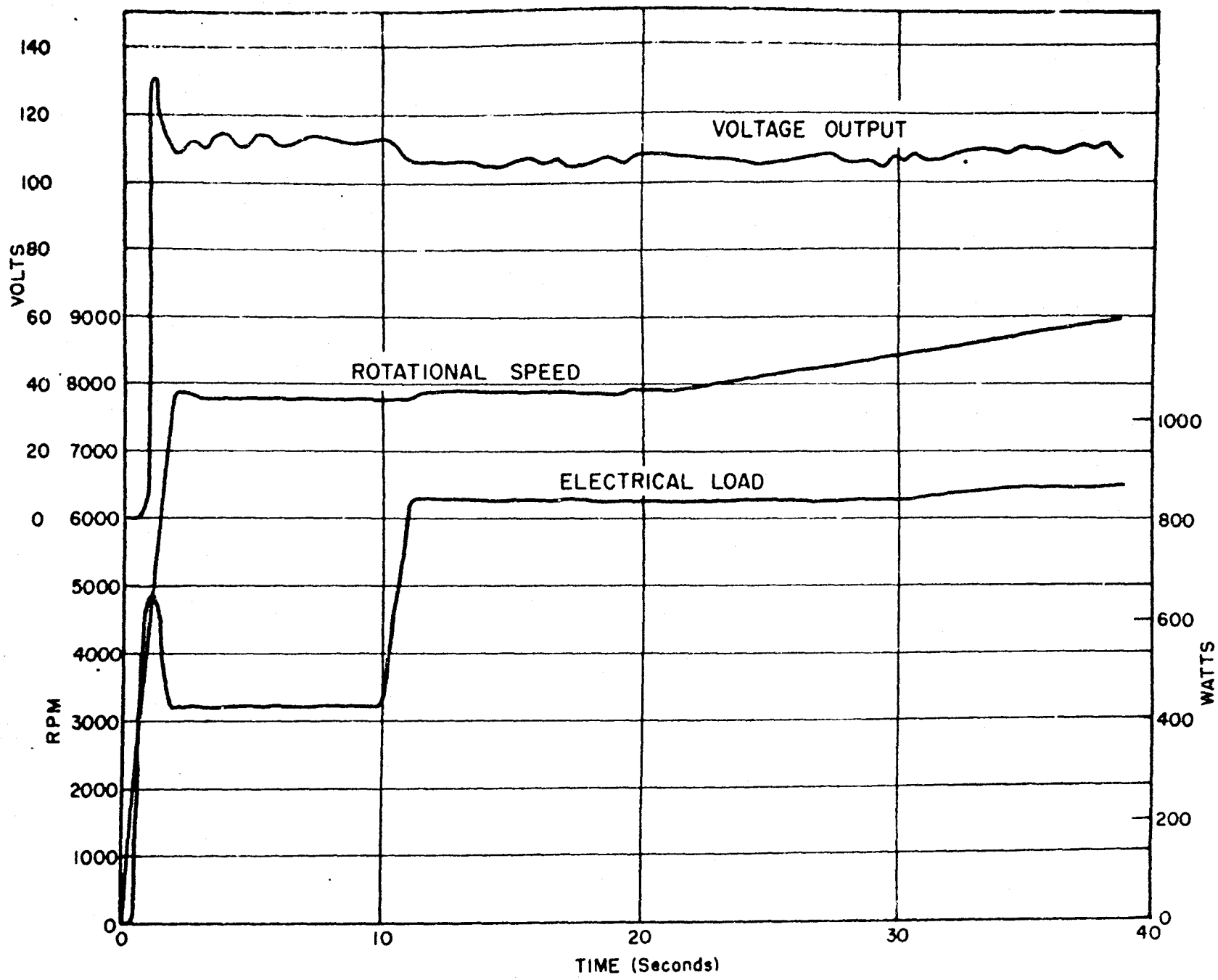

FIGURE 9 - WINDMILL DROP TEST NO. 2 (UPPER POSITION)

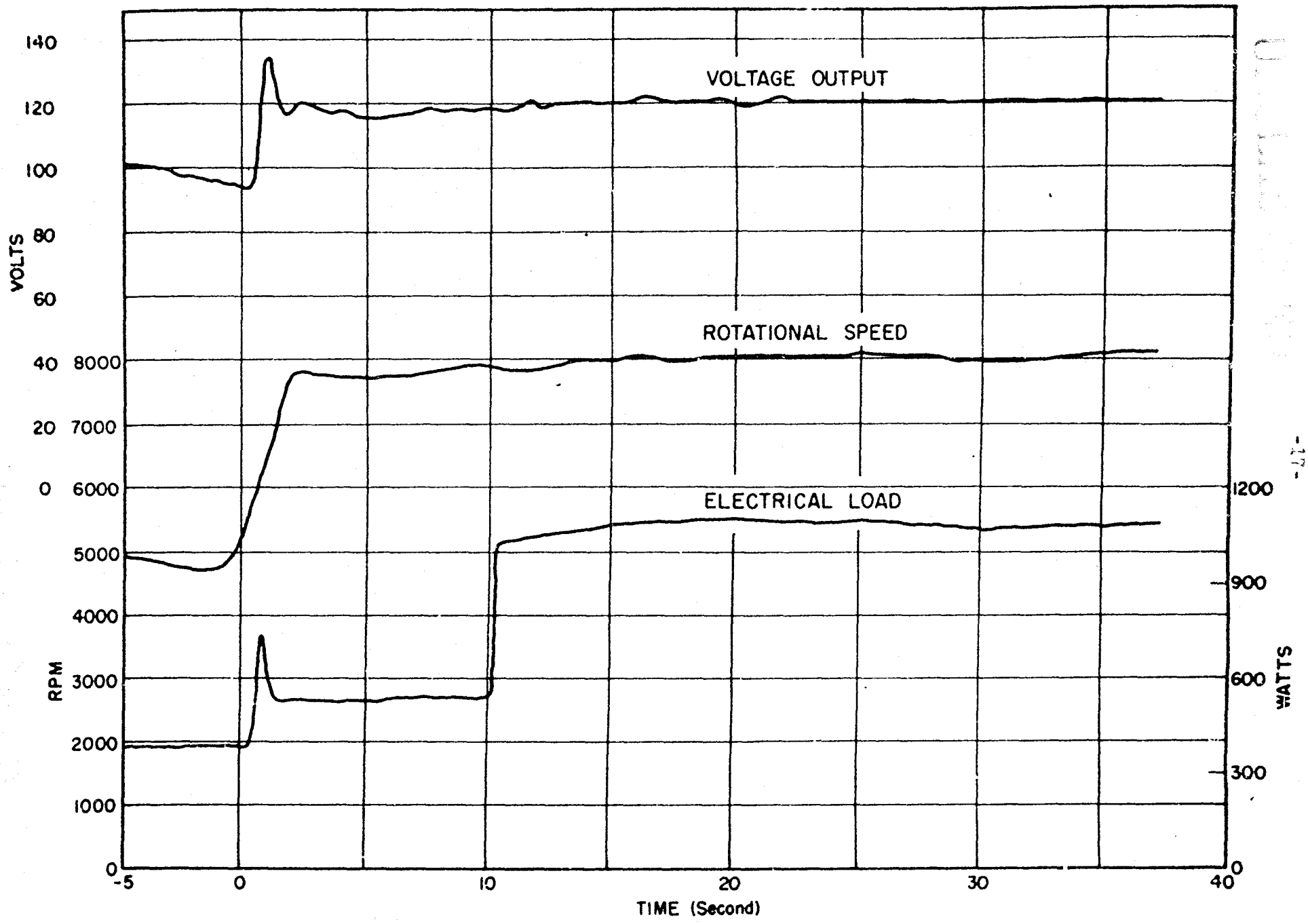

FIGURE 10 - WINDMILL DROP TEST NO. 2 (LOWER POSITION)