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AFATL-TR-75-72

PIRANHA WIND TUNNEL TEST

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BALLISTICS BRANCH
GUNS, ROCKETS, AND EXPLOSIVES DIVISION

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20. ABSTRACT (Concluded)

(cont fr p 1473A)

m/sec

speed of 60.5 meters per second. Safety and Arming mechanism function was obtained twice during the test.

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(p1473B)

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PREFACE

This report contains data collected from wind tunnel tests in October 1974 of the Piranha air-deliverable underwater mine (BLU-94) developed under Air Force Contract F08635-74-C-0033. These tests were conducted at the Ballistics/Aerodynamics Research System (BARS) Facility, Air Force Armament Laboratory, Eglin Air Force Base, Florida.

Air Force Armament Laboratory Piranha Project Engineer Mr. Ronald A. Giordano (DLJM) and Mr. Joseph S. Eken also of DLJM, assisted in the preparation of this report. Mr. Jack C. Hopps of the Honeywell Corporation, Government and Aerospace Products Division, Aerodynamics Group, also assisted in conducting the tests and in the report preparation.

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

FOR THE COMMANDER



ALFRED D. BROWN, JR., Colonel, USAF
Chief, Guns, Rockets & Explosives Division

ABSTRACT

This report presents results from wind tunnel tests of several air duct/ turbine wheel designs for the Piranha air-deliverable underwater mine (BLU-94). The tests were conducted to determine the optimum turbine wheel blade angle for maximum rotational speed and acceleration, and to verify that the highest performance obtained would be sufficient to operate a portion of the mine's Safety and Arming mechanism. Maximum rotational speed developed with the optimum blade angle of 40 degrees was 147 revolutions per second at an angle of attack of 10 degrees and a free stream speed of 60.5 meters per second. Safety and Arming mechanism function was obtained twice during the test.

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TABLE OF CONTENTS

Section	Title	Page
I	INTRODUCTION.	5
II	TEST.	7
	Test Article	7
	Test Facility.	12
	Instrumentation.	12
	Procedure.	17
III	RESULTS	19
	Data	19
	Computations	19
	Analysis	19
IV	CONCLUSIONS	25

LIST OF FIGURES

Figure	Title	Page
1	Piranha Mine General Configuration	8
2	T1 Fin Support Ring and F1 Turbine Wheel Design	9
3	T2 Fin Support Ring and F2 - F6 Turbine Wheel Design.	10
4	NBT2F4 Turbine and Duct Assembly Details.	11
5	Piranha Mine Wind Tunnel Mounting	13
6	Turbine Speed Sensor.	14
7	Typical Turbine Wheel with Sensor Trigger Tape.	15
8	Sensor and Model Internal Component Relationships	16
9	S&A Mechanism Turbine Hub with Open Shutter	18
10	Plotter Traces for Tests 52 through 60.	23

LIST OF TABLES

Table	Title	Page
1	Turbine/Duct Selection Testing.	20
2	Optimum Design Verification Testing	21
3	Tabulated Results and Computations.	22

SECTION I

INTRODUCTION

In order to obtain a fuze activation function dependent on time of flight, an air-driven turbine and associated ducting was designed for the Piranha air-deliverable underwater mine (BLU-94). At the request of the Air Force Armament Laboratory's Mines Branch (DLJM), the Laboratory's Ballistics/Aerodynamics Research System (BARS) Facility conducted a series of wind tunnel tests with the turbine equipped mine.

The primary objective of the test program was to select an optimum air turbine/duct design based on the maximum rotational speed obtained and minimum elapsed time to that speed. A secondary objective was to verify that the turbine design selected could provide sufficient speed and acceleration to operate that part of the mine's Safety and Arming (S&A) mechanism involved in the delay function.

The remainder of this report is in three sections: Section II covers the test article and design of the various components from which it was assembled, the facility in which the test was conducted, instrumentation used to collect data, and procedures used to conduct the test. Section III contains a discussion of the data collected, the computations performed with the data, and an analysis of the data relative to the test objectives. Conclusions drawn from the test are presented in Section IV.

SECTION II

TEST

Test Article

Full scale flight test versions of the Piranha mine components required were provided by the manufacturer. Figure 1 shows the assembled test article configuration; components from which it was assembled are identified as follows:

- N - Standard Nose
- B - Standard Body
- T1 - Fin Support Ring as Shown in Figure 2A
- F1 - Turbine Design Shown in Figure 2B
- T2 - Fin Support Ring as Shown in Figure 3A
- F2, F3, F4 - Turbine design shown in Figure 3B, with blade angles of 40, 45, and 50 degrees, respectively.
- F5, F6 - Turbine design shown in Figure 3B, with blade angles of 50 and 35 degrees, respectively, and with approximately 15 percent camber.

Configurations are identified as "NBT1F1" which means that the model was assembled with a standard nose, standard body, type T1 fin support ring, and type F1 turbine wheel. Both styles of fin support ring had the standard stabilization fins attached and permanently set in the fully opened position.

Ducts cut in fin support ring T1 were designed for the blade size of turbine design F1, and the T2 support ring ducts were similarly designed for the F2 through F6 turbine blades. Figure 4 shows details of the NBT2F4 turbine and duct assembly.

Only one S&A mechanism was available for the test, and a possibility existed that one or more components designed for one-time operation might fail. Therefore, the first, or optimum design selection, portion of the test series was conducted with the S&A mechanism replaced by an inertia wheel, a flywheel having approximately twice the moment of inertia of the S&A. An inertia wheel with a higher moment of inertia than that of the operational hardware was used in an attempt to clearly demonstrate that the designed operating conditions for fuze function (27.5 revolutions per second within one second) could be met before starting the S&A phase of the test.

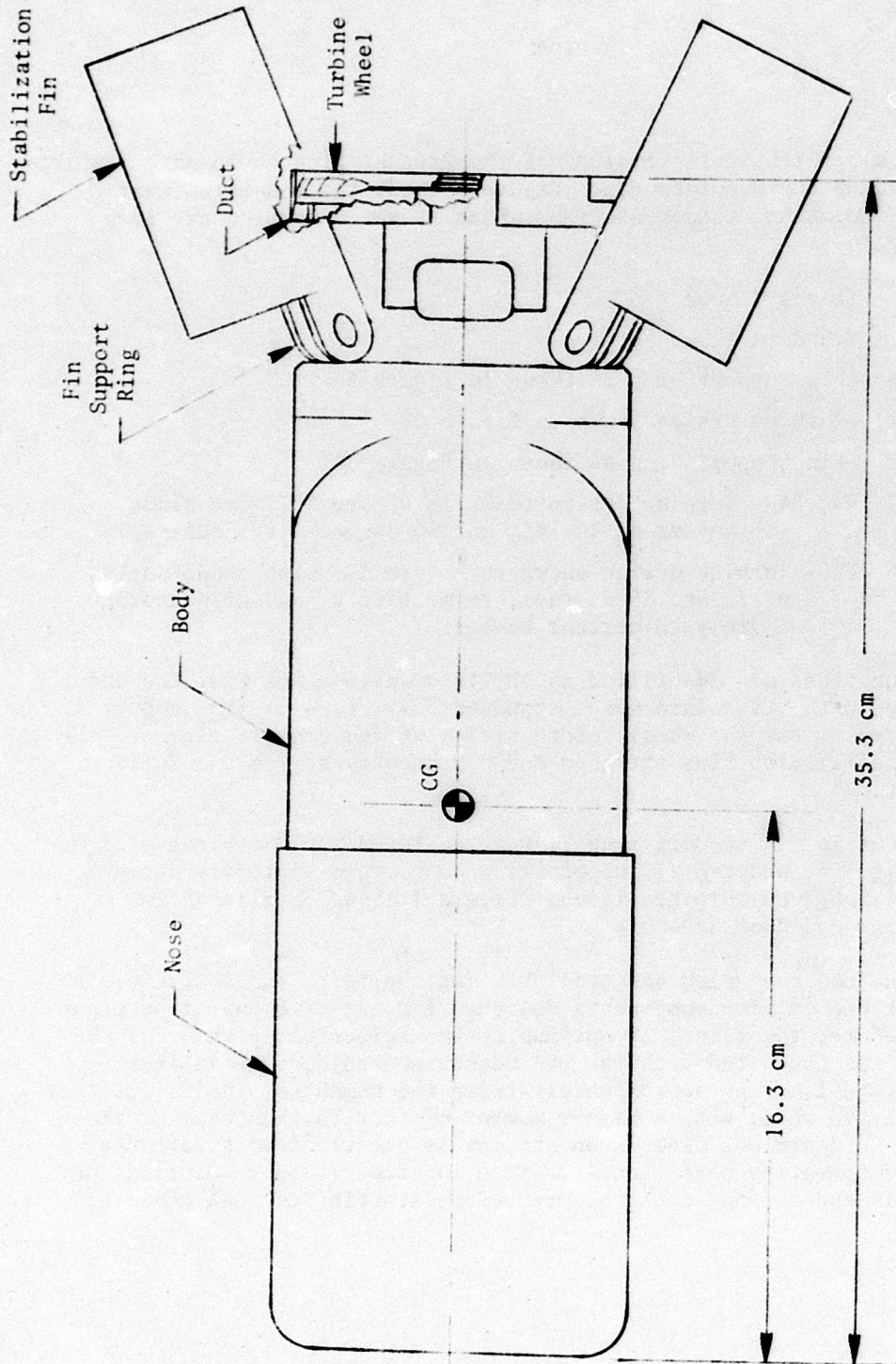
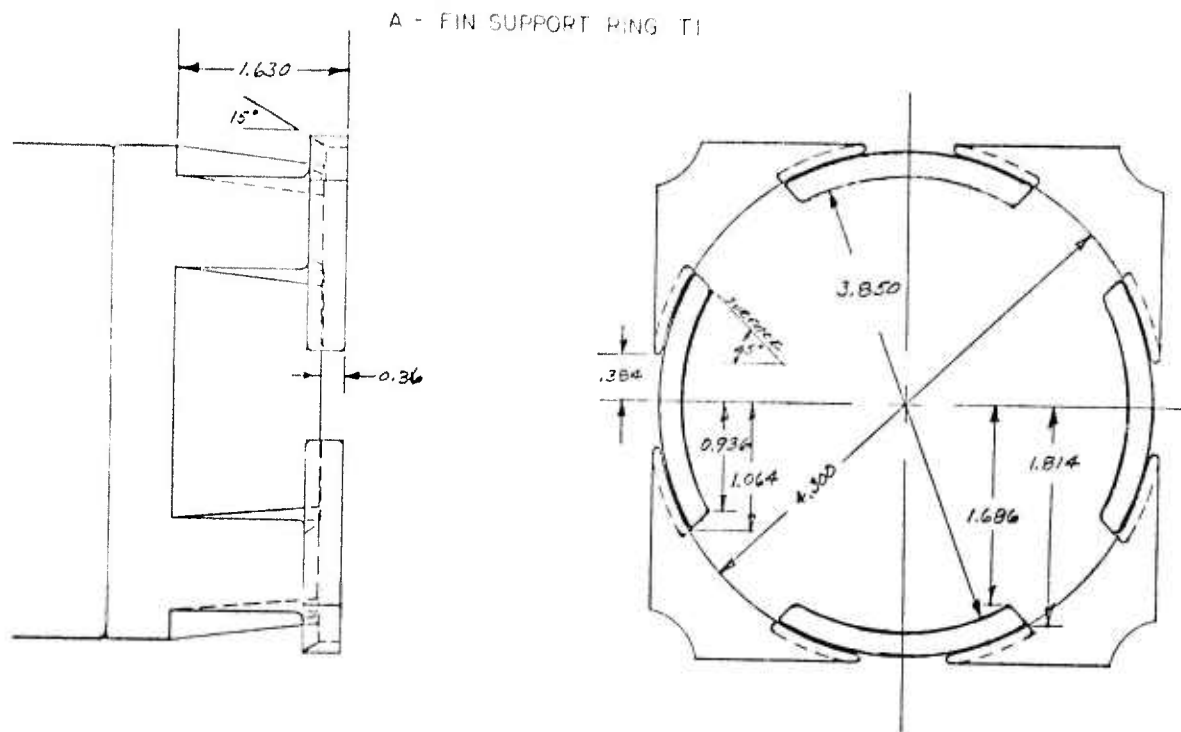


Figure 1. Piranha Mine General Configuration



B - TURBINE DESIGN F1

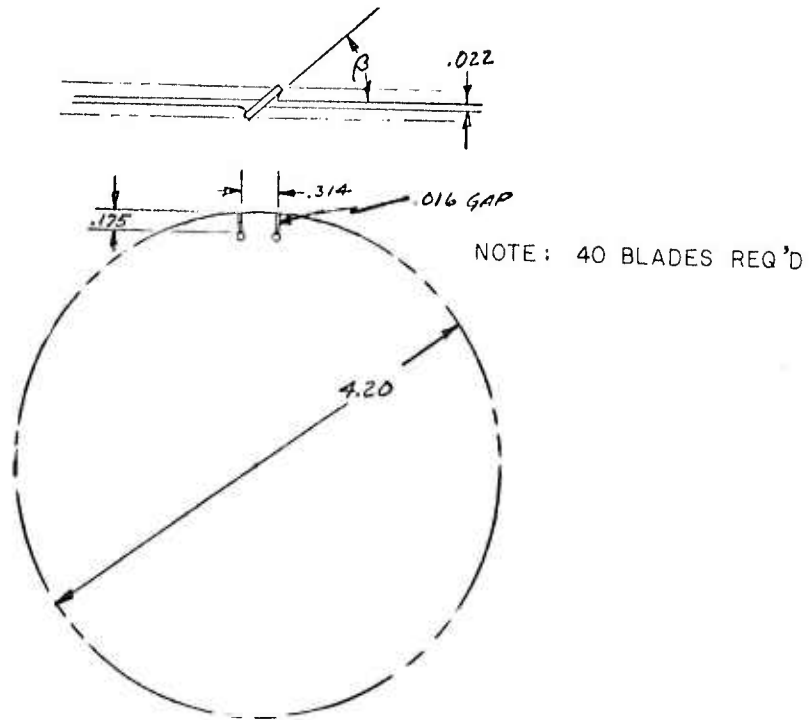
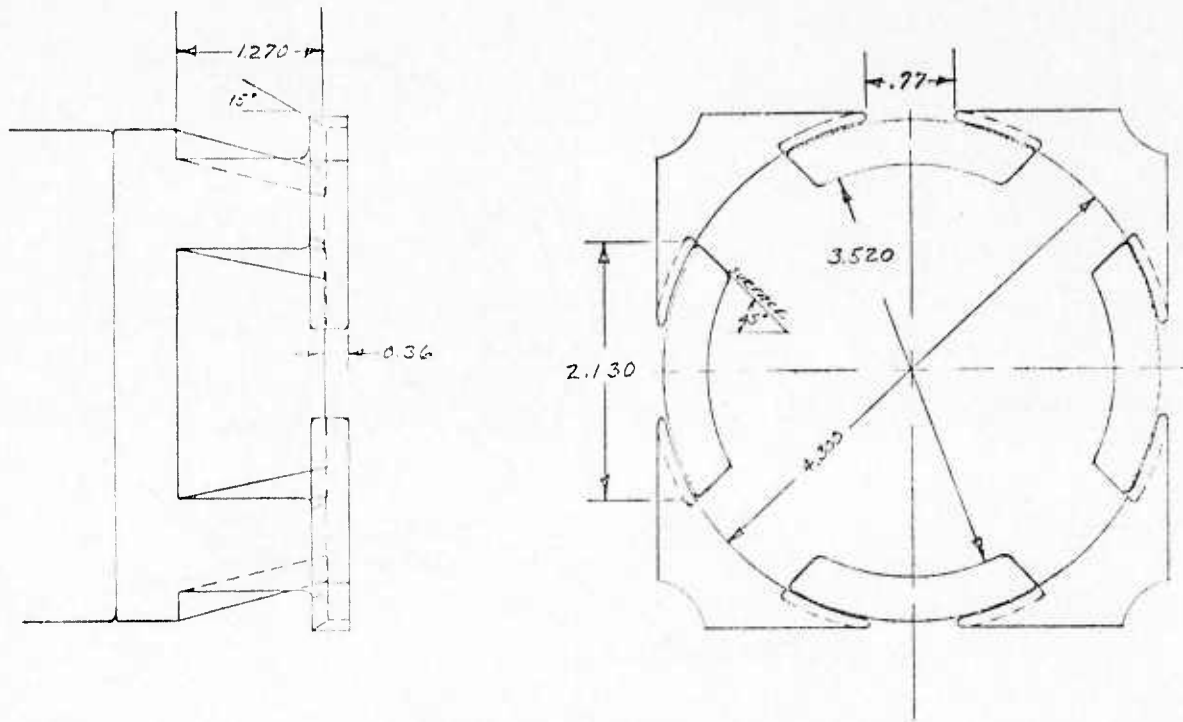


Figure 2. T1 Fin Support Ring and F1 Turbine Wheel Design

A - FIN SUPPORT RING T2



B - TURBINE DESIGN F2

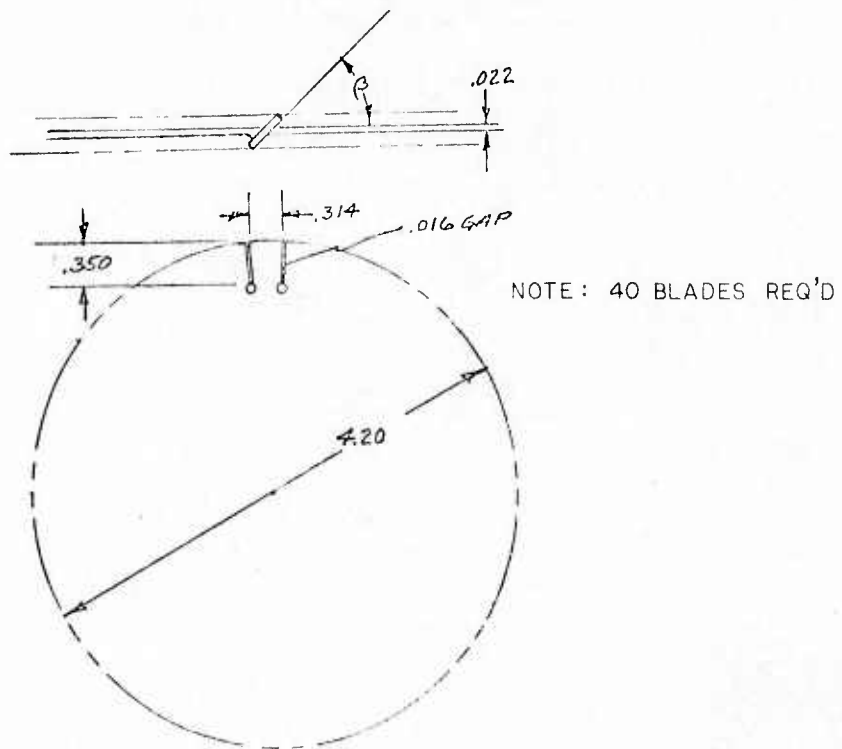


Figure 3. T2 Fin Support Ring and F2 - F6 Turbine Wheel Design

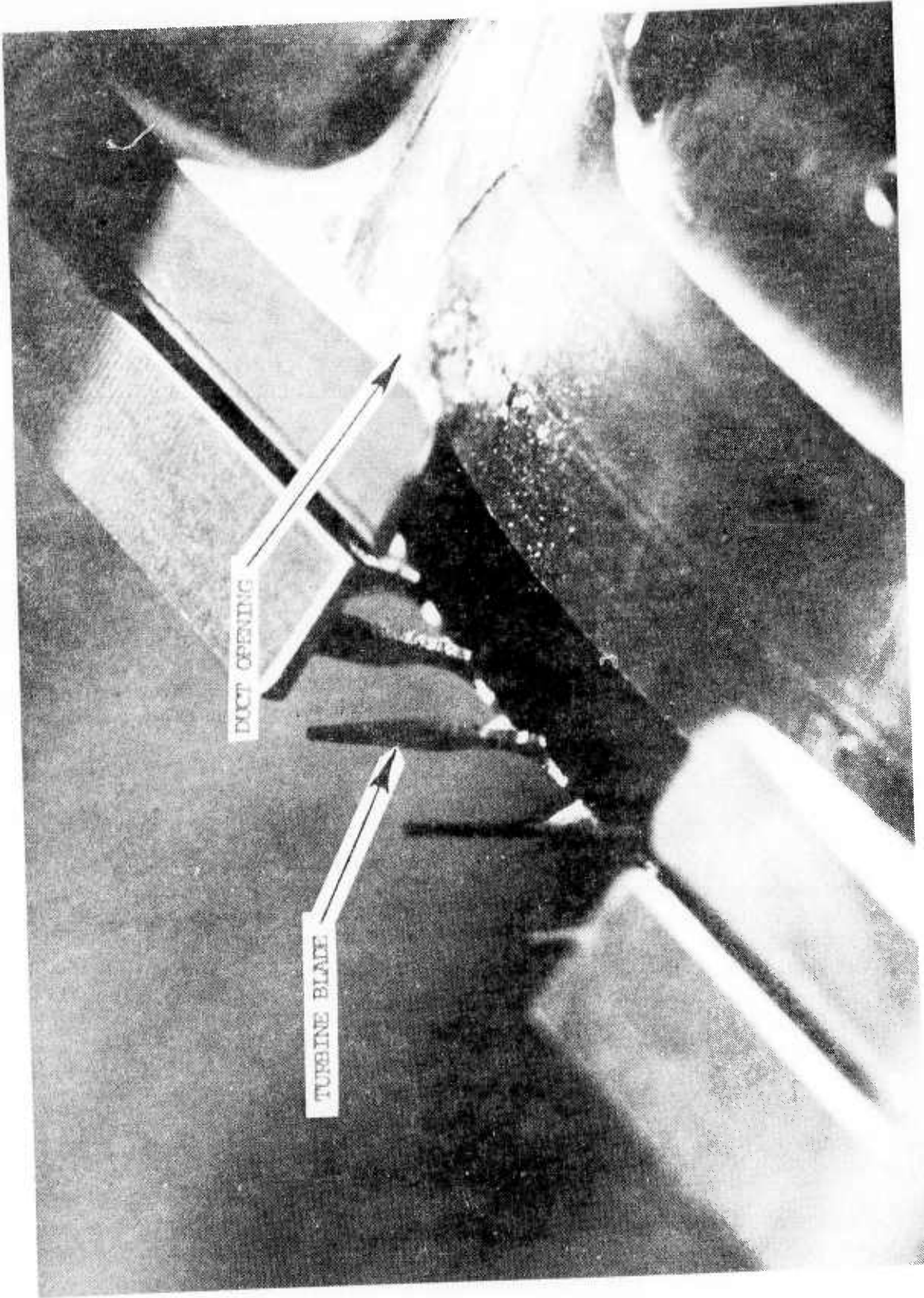


Figure 4. Configuration Duct and Turbine

Moments of inertia measured for the rotating component assemblies were:

Inertia Wheel + Turbine:	$I = 1014.0 \text{ gm-cm}^2$
S&A + Turbine:	$I = 539.3 \text{ gm-cm}^2$

The model was transversely mounted in the wind tunnel at its center of gravity with a pivoting support in the test section roof (Figure 5). The attachment support allowed changes in model angle of attack to be made from outside the test section while the tunnel was running.

Test Facility

Wind tunnel testing was done in the BARS Facility subsonic wind tunnel located in building 419 on Eglin AFB test area A-22. The tunnel is an open circuit design with a test section 71 centimeters by 122 centimeters in cross section and 152 centimeters long. The wind tunnel is described in detail in Reference 1.

Instrumentation

Turbine speed versus time data were collected by means of an optical speed sensor mounted inside the wind tunnel model. A small incandescent lamp mounted beside a silicon photodiode formed the sensor (Figure 6).

The inertia wheel and the various turbines were painted flat black on one surface and four 0.3-cm-wide strips of aluminized Mylar[®] tape, located 90 degrees apart, were applied as sensor triggers (Figure 7). The measured moments of inertia for these components include both paint and tape.

For model configurations with the inertia wheel installed, the sensor was triggered by the tape strips on the inertia wheel. The sensor was remounted to detect the turbine strips when the S&A mechanism was installed. Sensor and model component relationships in the two cases are shown in Figure 8.

The photodiode output signal was passed through two Hewlett-Packard 2471 amplifiers in parallel, both set for unity gain. Output from one amplifier was routed to an oscilloscope and digital counter. The output of the other amplifier was connected to a General Radio Corporation 1142A

REFERENCE:

¹Tymms, David E. & Weber, Paul A., "Wind Tunnel Facility Equipment and Test Capabilities at the Air Force Armament Laboratory", AFATL-TR-74-145, September 1974.

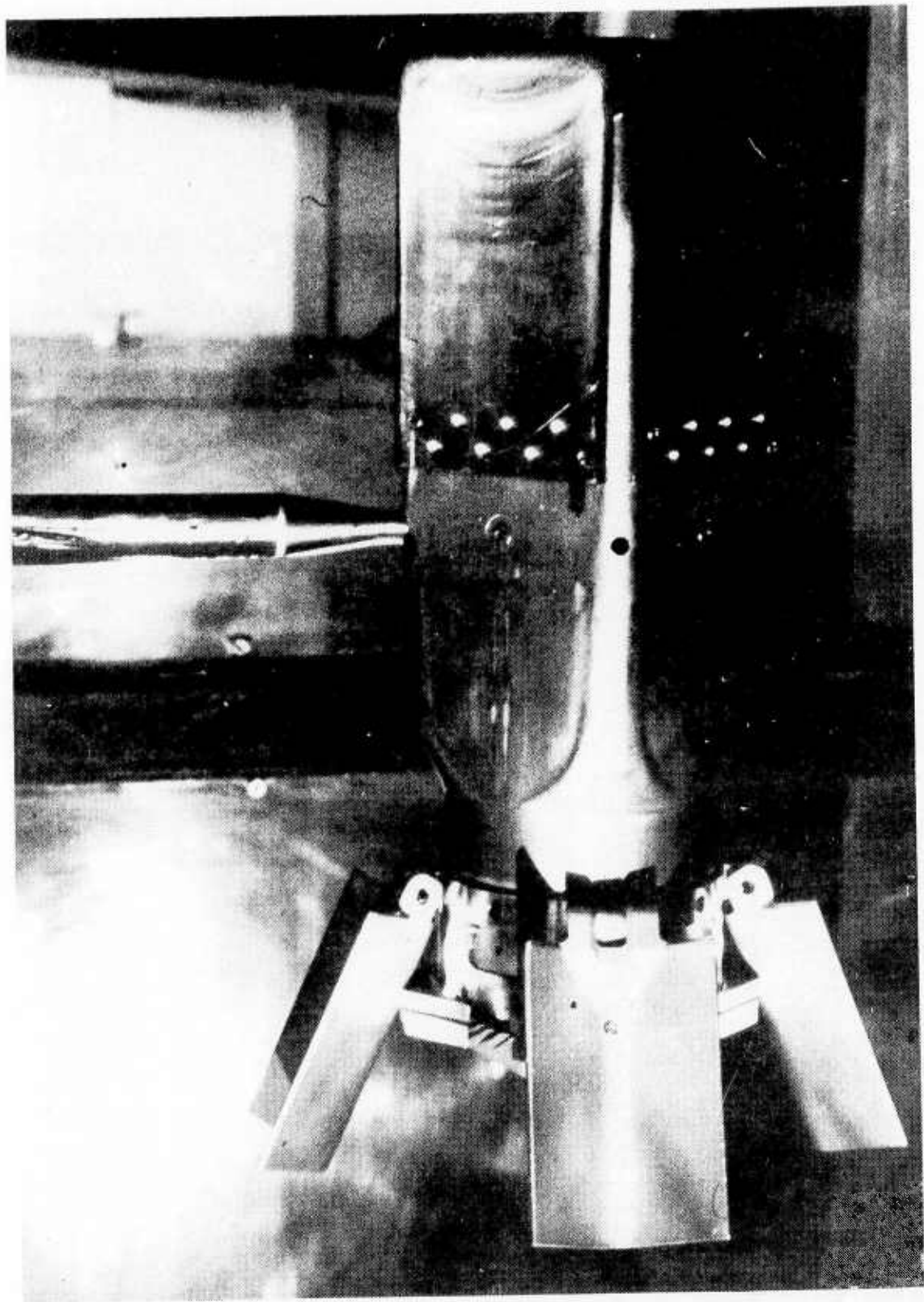


Figure 5. Piranha Mine Test Section Mounting

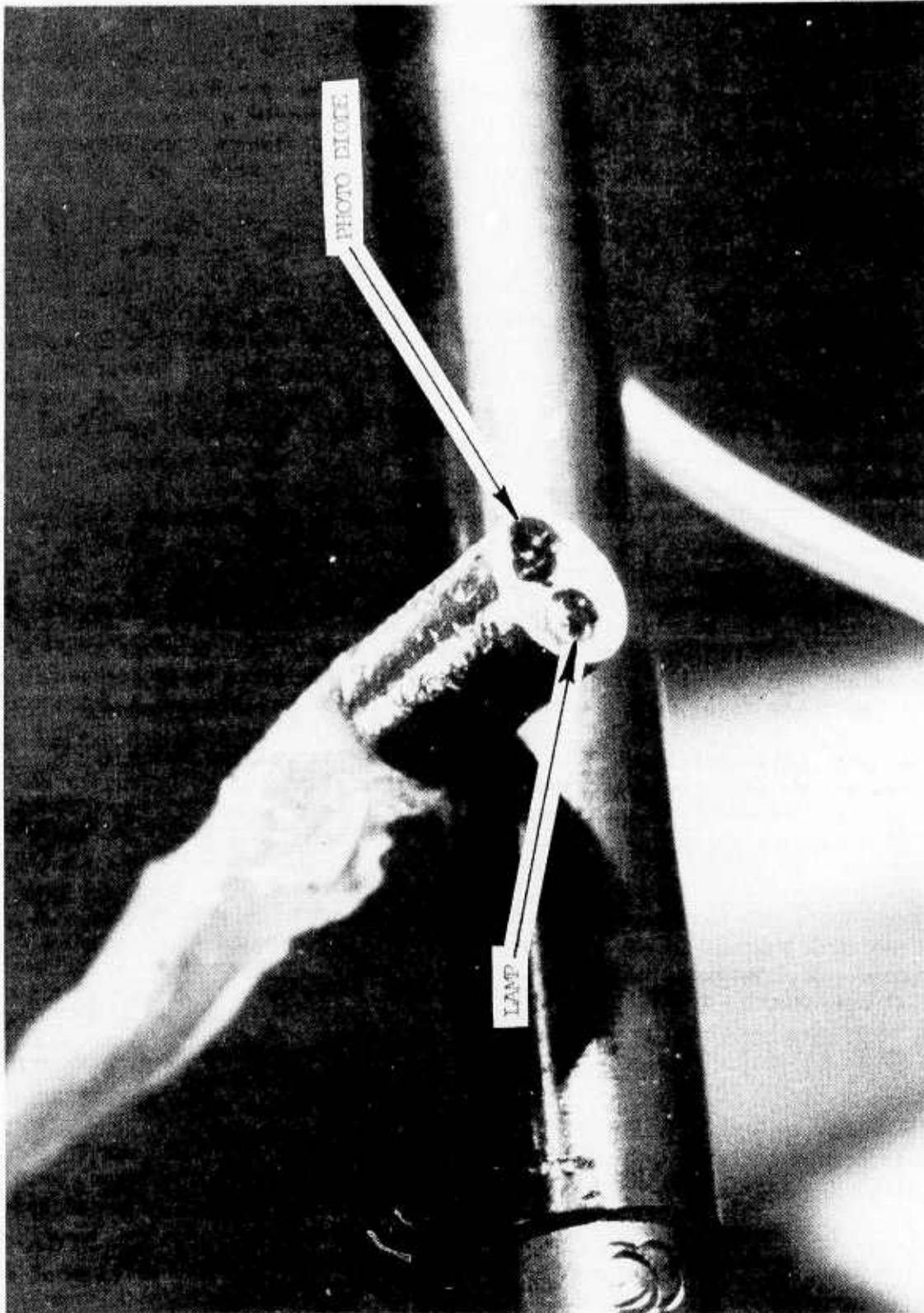


Figure 6. Turbine Speed Sensor

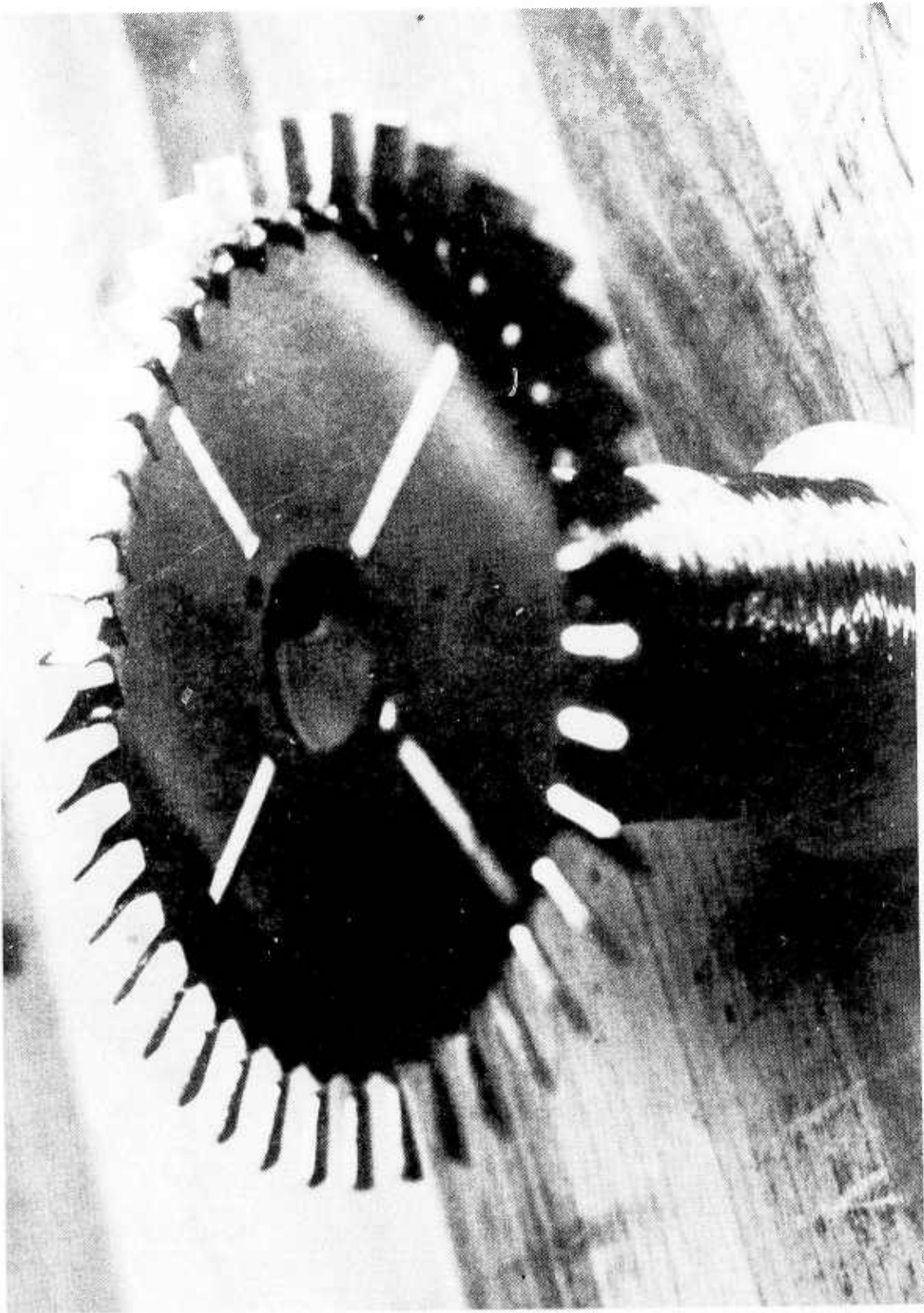
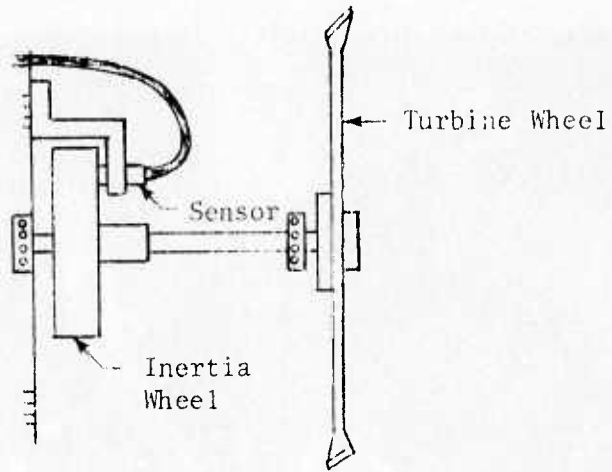


Figure 7. Typical Turbine Wheel With Sensor Trigger Tape

Sensor Location With Inertia Wheel



S&A Mechanism Sensor Location

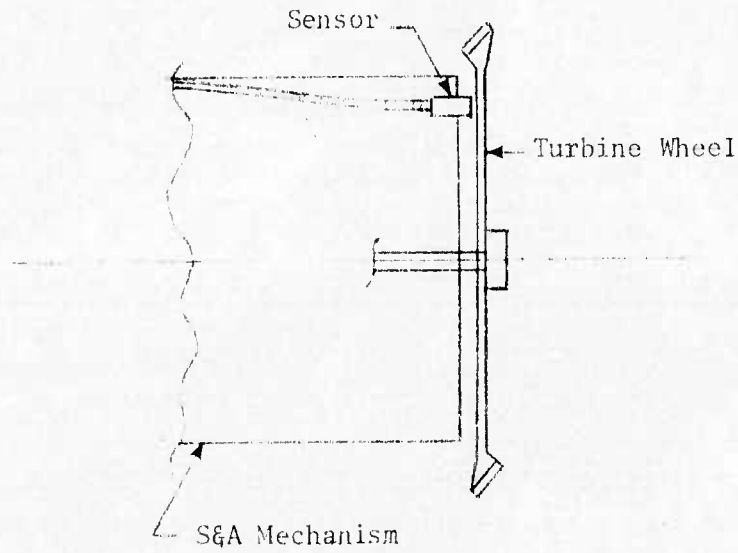


Figure 8. Sensor and Model Internal Component Locations

Frequency Discriminator. This instrument produces an output voltage directly proportional to input signal frequency.

The frequency discriminator provided the input signal for a Hewlett-Packard Model 7004B Analog X-Y plotter which served as the data logging device. The oscilloscope and digital counter functioned as a means of verifying sensor operation and provided a direct check of frequency discriminator and plotter performance.

Procedure

The test was divided into two parts: First, all configurations were tested with the inertia wheel/ second, the optimum configuration selected in the first part was tested with the S&A mechanism in place.

Each model was tested at indicated wind tunnel speeds of 15.4, 25.7, 36.0 and 51.5 meters per second, and at maximum tunnel speed of approximately 60.7 meters per second. Angle of attack was varied from zero to 10 degrees.

In order to determine maximum speed and acceleration of the turbine wheel, an initial condition of zero turbine speed was required. It was obtained by halting the turbine wheel between data collecting runs with a rubber-tipped probe inserted into the test section. The analog plotter was started, and then the probe was withdrawn downstream. The plot trace was continued until a stable turbine speed was indicated.

The S&A mechanism function which was to be tested in the second part of this test is referred to in the Piranha program as rotor/lock number 2. When certain mechanical components are driven into appropriate positions by the turbine rotation, and if the turbine acceleration has been rapid enough to engage other components, the rotor/lock number 2 has prepared the fuze for subsequent arming.

In the second or performance verification part of the test, rotor/lock number 2 function was monitored in three ways: (1) turbine speed was expected to show a sharp decrease at some point in the function cycle and would thus be visible on the plotter; (2) a pair of centrifugal shutters located in the turbine hub (Figure 9) would open to pass and trap a short pin in the extended position (this was watched for during the course of each run); and (3) on indication of at least partial functioning of the rotor/lock, the model was removed from the tunnel and disassembled to check the internal components involved.

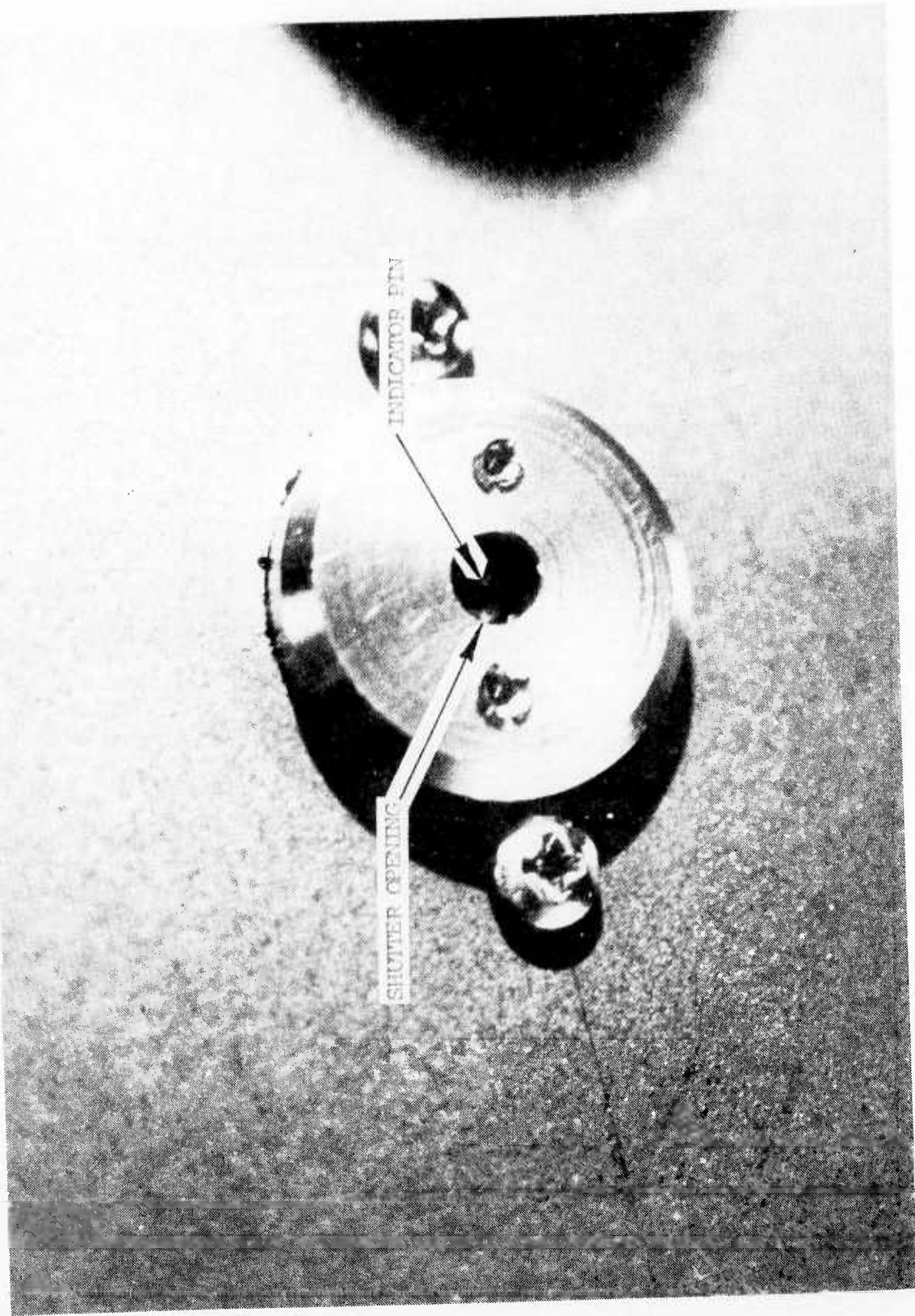


Figure 9. S&A Mechanism Turbine Hub with Shutter Open, Pin Partially Extended

SECTION III

RESULTS

Data

Sixty data collection test runs were made. Table 1 contains a list of the turbine/duct selection part of the test with flow conditions, model configurations, maximum revolutions per second obtained for each configuration, and ratio of maximum speed to time elapsed to maximum speed. This ratio was the basis of selection and the highest ratio of 14.2, obtained from configuration NBT2F2 in test 26, indicated that it was the optimum design under the given conditions.

Table 2 contains a list of test conditions and results obtained during the second, or performance verification, part of the testing of NBT2F2. Tests 42 through 51 were made at intermediate angles of attack (3 and 5 degrees) and tests 57 through 60 were conducted at intermediate tunnel speeds (20.6, 30.9, and 41.2 meters per second). This section of the program was conducted with the S&A mechanism in place.

Computations

Table 3 is a tabulation of best performances by the various configurations and performance of the selected optimum design in the second testing phase. The approximate torques produced by the turbine during highest acceleration were determined from:

$$T = I \ddot{\theta}$$

Where: T = Torque (dyne-centimeters)

I = Moment of inertia of rotating parts (gm-cm²)

"

$\ddot{\theta}$ = Angular acceleration of rotating parts (radians/second²)

Angular accelerations were approximated from the slopes of the plotter traces. Estimated maximum torques were not used in the design selection decision; they were computed for reference purposes only.

Analysis

Figure 10 is a reproduction of the plotter traces for test runs 52 through 60 showing turbine speed versus time elapsed from turbine release. The model configuration tested was NBT2F2, the turbine/duct arrangement selected in part 1 of the testing program. Mine angle of attack was 10 degrees.

TABLE 1. TURBINE/DUCT SELECTION TESTING

Configuration	Test No.	V True (mps)	Angle of Attack (deg)	Blade Angle (deg)	RPS Max	Time to Max RPS (sec)	Ratio of RPS to Time
NBT1F1 (Inertia Wheel)	1	15.6	0	50	15.0	-	-
	2	26.1	0	50	27.5	-	-
	3	36.6	0	50	39.8	-	-
	4	52.1	0	50	57.2	-	-
	5	60.8	0	50	67.0	10.0	6.7
	6	15.6	10	50	21.0	-	-
	7	26.1	10	50	37.1	-	-
	8	36.6	10	50	53.6	-	-
	9	52.1	10	50	75.5	-	-
	10	60.8	10	50	87.0	6.8	12.8
NBT2F4 (Inertia Wheel)	11	15.6	0	50	20.5	-	-
	12	26.1	0	50	35.9	-	-
	13	36.6	0	50	50.5	-	-
	14	36.5	0	50	49.3	-	-
	15	51.9	0	50	71.9	-	-
	16	61.1	0	50	85.0	6.5	13.1
NBT2F3	17	61.1	0	45	103.0	8.7	11.8
	18	51.9	0	45	87.3	-	-
	19	36.5	0	45	59.9	-	-
	20	25.9	0	45	42.0	-	-
	21	15.5	0	45	24.3	-	-
NBT2F2 (Inertia Wheel)	22	15.7	0	40	25.8	-	-
	23	26.2	0	40	46.1	-	-
	24	36.7	0	40	65.9	-	-
	25	52.3	0	40	96.4	-	-
	26	60.4	0	40	113.5	8.0	14.2
NBT2F5 (Inertia Wheel)	27	15.6	0	50	22.5	-	-
	28	25.9	0	50	40.5	-	-
	29	26.5	0	50	57.5	-	-
	30	51.9	0	50	84.9	-	-
	31	61.2	0	50	101.0	9.5	10.6
NBT2F6 (Inertia Wheel)	32	61.0	0	35	126.5	9.9	12.8
	33	51.9	0	35	106.0	-	-
	34	36.5	0	35	71.8	-	-
	35	25.9	0	35	49.6	-	-
	36	15.6	0	35	27.0	-	-

TABLE 2. OPTIMUM DESIGN VERIFICATION

NBT2F2 Configuration; S&A in Place

Test No.	V True (mps)	Angle of Attack (deg)	RPS Max
37	15.6	0	21.0
38	25.9	0	33.0
39	36.5	0	51.5
40	51.9	0	75.3
41	61.2	0	94.0
42	60.5	3	104.0
43	52.2	3	87.0
44	36.6	3	57.0
45	26.1	3	37.5
46	15.6	3	21.0
47	15.6	5	22.0
48	26.1	5	41.5
49	36.6	5	61.5
50	52.2	5	93.5
51	60.5	5	109.0
52	60.5	10	147.0
53	52.2	10	117.3
54	36.2	10	74.7
55	26.1	10	48.5
56	15.6	10	23.0
57	20.8	10	38.9
58	31.3	10	*
59	41.7	10	**
60	31.3	10	76.3

* Note: Component failure produced continuous speed increase; terminal speed not recorded.

** Note: Plotter malfunction; no usable trace obtained.

TABLE 3. TABULATED RESULTS AND COMPUTATIONS

Configuration	Test No.	RPS Max	Time To Max RPS (sec)	Max RPS / Time To Max RPS	" θ (rad) / (sec ²)	T (dyne) (x cm) (x 10 ⁵)*	RPS At T Max	Time To T Max (sec)	
NBT1F1	5	67.0	10.0	6.7	138.2	1.40	18.0	1.10	
NBT1F1	10	87.0	6.8	12.8	212.1	2.15	21.5	0.75	
NBT2F4	16	85.0	6.5	13.1	229.3	2.33	30.0	1.04	
NBT2F3	17	103.0	8.7	11.8	268.3	2.72	28.0	0.80	
NBT2F2	26	113.5	8.0	14.2	245.0	2.48	45.0	1.30	
NBT2F5	31	101.0	9.5	10.6	315.7	3.20	30.0	0.80	
NBT2F6	32	126.5	9.9	12.8	290.6	2.95	36.0	1.00	
(S&A Mechanism Installed)									
NBT2F2	41	94.0	3.6	--	395.8	2.13	37.0	0.62	
NBT2F2	42	104.0	3.2	--	446.1	2.41	35.0	0.60	
NBT2F2	51	109.0	3.3	--	565.5	3.05	37.0	0.60	
NBT2F2	52	147.0	4.8	--	596.9	3.22	45.0	0.60	

* Note: Read the T (Torque) column as in 1.40×10^5 dyne-cm

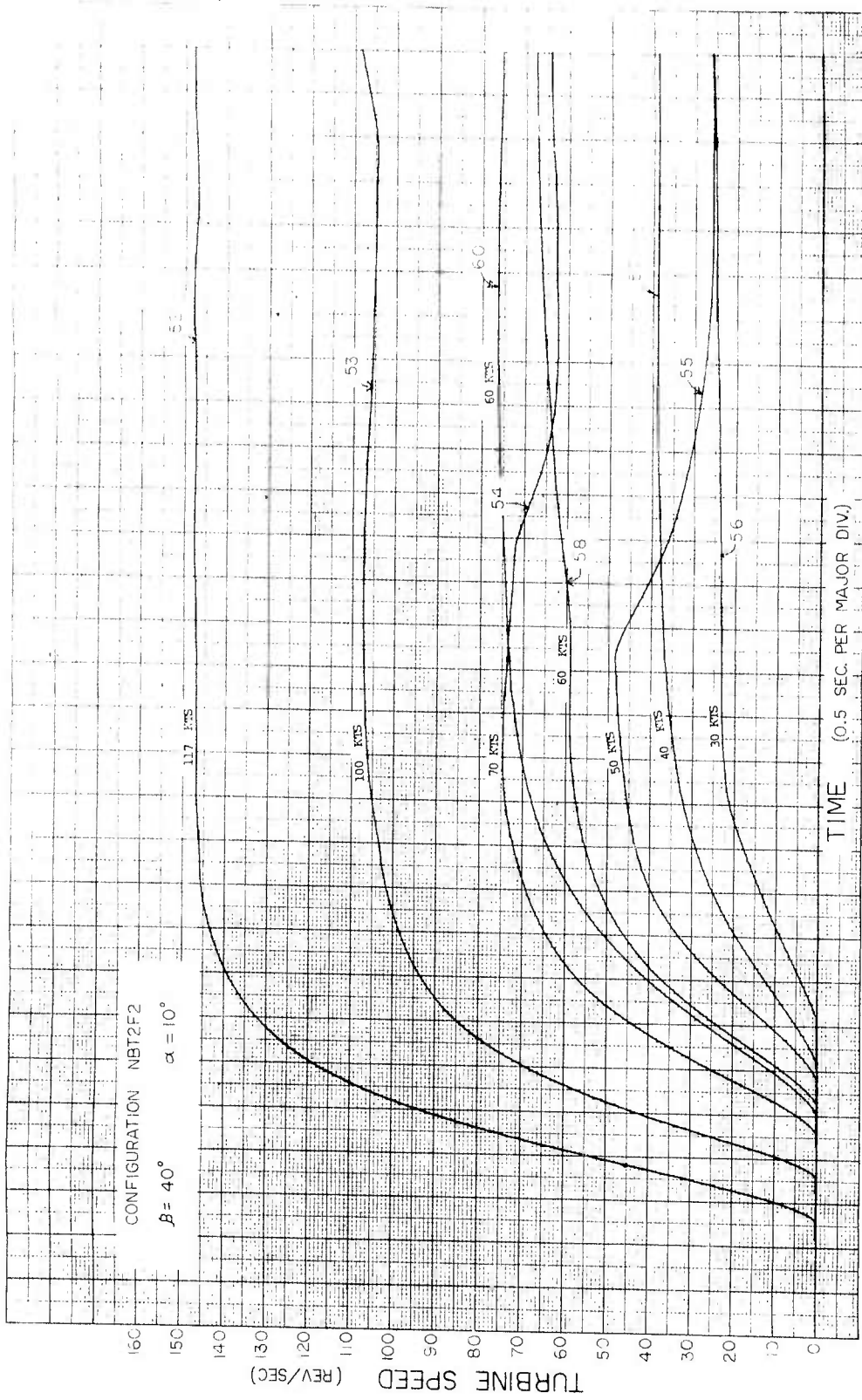


Figure 10. Plotter Traces From Data Collection Runs 52 through 60

There was no indication of rotor/lock number 2 function until test number 54. In that test, after accelerating to 74.6 revolutions per second in 4.4 seconds, turbine speed gradually decreased until 6.9 seconds elapsed. Then it decreased sharply. The turbine hub shutters opened and when the turbine was stopped, the indicator pin was trapped in the extended position. The model was disassembled and S&A functioning verified by the position of internal components. Rotor/lock function was also observed in test number 55, even though the design point speed/time of 27.5 revolutions per second at 1.0 second was not reached. Succeeding tests at lower air velocities show no S&A function.

S&A rotor/lock function was expected in tests 58, 59, and 60, but a turbine speed increase rather than decrease was observed. Disassembly of the model showed failure of a mechanism component designed for one-time operation. Evidence was also found that this component, a rubber coupler also used as a spring, had evidently failed partially very soon after the first run of the S&A testing phase. The failure noted would introduce an erroneously high friction torque.

SECTION IV

CONCLUSIONS

All test objectives were successfully met. Fin support ring duct design T2 with turbine design F2 (uncambered 40-degree blades) was found to develop sufficient speed and acceleration to reach the design condition of 27.5 revolutions per second within 10 seconds.

Further testing of the NBT2F2 configuration developed in this test was conducted by launching the Piranha mine into free flight with a compressed air gun. Free flight testing will be described in a future report.

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