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The High-Spin Tabletop Artillery Simulator (2 in.)

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Adelphi, MD 20783

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The High-Spin Tabletop Artillery Simulator (2 in.) is a device for testing fuze power supplies. The tester was designed to provide in the laboratory the setback, angular acceleration, and centrifugal forces required to activate the M732 fuze power supply (PS115). Setback forces of 5000 g and spin rates of 300 rps are produced. The tester is partially automatic and provides a readout system for monitoring the power-supply output voltage. The tester and its performance characteristics are described.

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FOREWORD

The design, fabrication, and testing of this simulator was sponsored by the U.S. Army Armament Command, Rock Island, IL 61201, under project number 5763095, titled MM&T Mortar and Artillery Simulator Fuze Testing. This project was accomplished as part of the U.S. Army Manufacturing Technology Program. The primary objective of this program is to develop, on a timely basis, manufacturing processes, techniques, and equipment for use in production of Army materiel.

The detailed design was developed by Arthur Ball who also supervised the fabrication of the individual parts and assembled the simulator. Mr. Ball conducted all the system checkouts and early testing.

Forrest Nelson designed and constructed the electronic control circuits and associated electrical wiring.

H. D. Curchack was the overall supervisor on this project and his technical guidance was invaluable.

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FIGURES

FIGURES (Cont'd)

TABLE

1. INTRODUCTION

The High-Spin Tabletop Artillery Simulator (2 in.) (herein called the tester) described in this report fulfills the requirements for a procedure to test the PS115 power supply for the M732 fuze. The tester was designed to provide the proper environment to activate this power supply but (as will be shown) is useful for testing other power supplies as well. Further, the tester incorporates a method for monitoring the voltage characteristics of the power supply under load in a dynamic environment.

Briefly, the tester consists of five major assemblies:

(1) a cylindrical projectile which houses the power supply to be tested,

(2) an air gun which propels the projectile at a sufficient velocity to activate the power supply when the setback force is simulated,

(3) a rotating catch tube (the spinner assembly) in which the setback force is simulated and the power supply is activated,

(4) a second catch tube (the MEM catch tube) into which a momentum exchange mass (MEM) is injected, and

(5) an electronic control console, providing automatic sequencing of many of the steps involved in testing the power supply.

Additional ancillary equipment required to complete the tester is described in section 4.6. Recently, two additional testers have been constructed for use in production-lot testing of the PS115 power supply.

2. OPERATION OF TESTER

Figure 1 shows the completed tester; figure 2 gives a schematic. The power supply is contained in a cylindrical projectile which is placed in the breech end of the air gun. The projectile seals the breech end of the gun by bearing against an O-ring. The projectile is restrained from sliding down the gun tube by a metal dowel (the release pin) projecting through the wall of the tube from the outside. The muzzle end of the gun is sealed with a thin, plastic diaphragm. A vacuum pump removes the air from the gun tube.

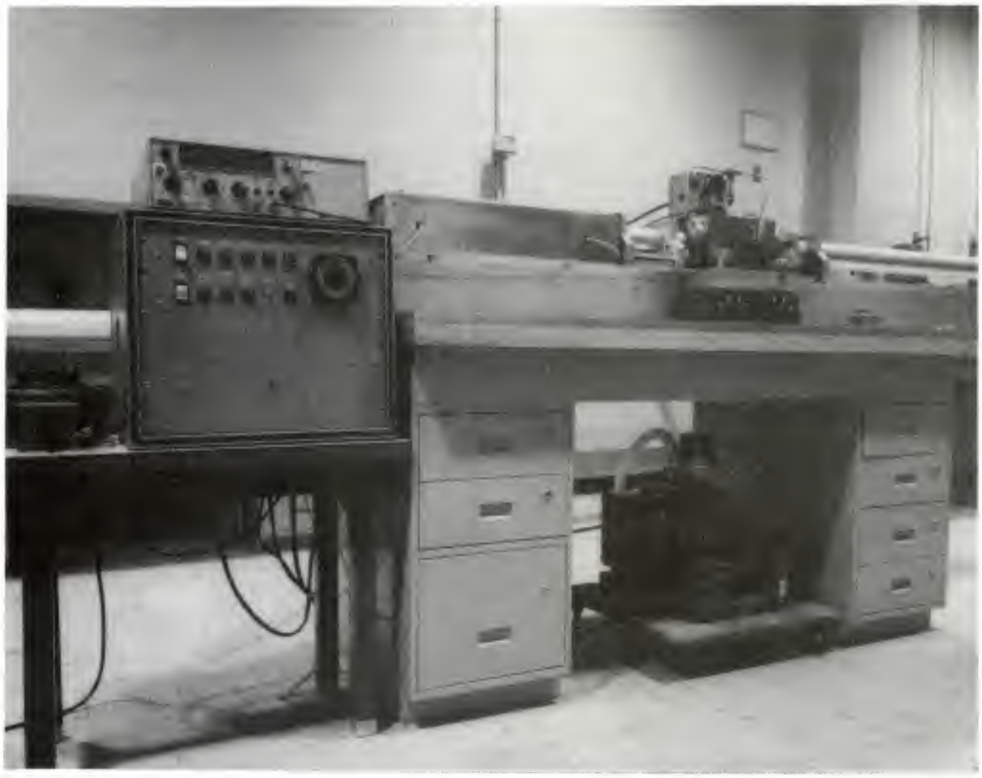


Figure 1. High-Spin Tabletop Artillery Simulator (2 in.)--tester.

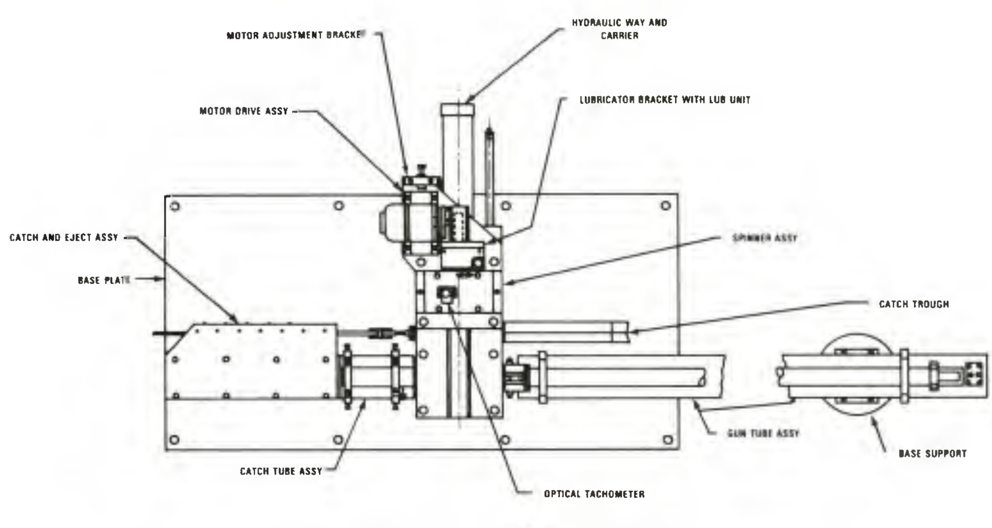


Figure 2. Schematic illustration of tester.

The gun is fired by withdrawing the release pin. This allows ambient room air pressure to accelerate the projectile along the gun tube. Upon reaching the muzzle end of the gun, the projectile ruptures the plastic diaphragm. The projectile emerges from the end of the gun and enters the spinner assembly.

The PS115 power supply requires three distinct forces acting in a specific sequence to cause activation. The first force is called the "setback" force. As a component of a fuze, the power supply experiences this force when fired from an artilley weapon. The setback force is merely the inertial resistance offered by the components of the round, formerly at rest, opposing their acceleration along the gun barrel. The second force is an angular force generated when the ordnance round begins spinning because of the rifling in the barrel. Both forces are required to successfully open the power-supply ampule. The third force, centrifugal force, distributes the electrolyte to the cells. In the tester, these forces are produced by the action that takes place in the spinner assembly.

The orientation in the test projectile is such that the base of the power supply points in the direction of travel; this is contrary to the normal position of the power supply in an ordnance round. The acceleration experienced by the test projectile in the air gun is small and directed away from the base of the power supply; this is in opposition to the direction that the setback force must be applied. As the projectile enters the spinner assembly, it is brought to an abrupt, but controlled, stop. This rapid deceleration of the projectile generates a force on the power supply of the proper magnitude and direction to simulate the setback force.

The spinner assembly contains a tube whose inner diameter is slightly larger than the projectile. This tube--the spinner tube--is positioned with its longitudinal axis coincident with the air gun. Two items, the mitigator and the MEM, are placed inside the spinner tube. When the projectile impacts the mitigator-MEM configuration, it comes to a controlled stop and experiences the setback force and angular acceleration.

Before firing and throughout the test, the spinner tube is made to rotate about its longitudinal axis. When the projectile interacts with the mitigator-MEM configuration, it begins to rotate also. The centrifugal force thus generated completes the activation of the power supply. The MEM, which has absorbed much of the linear momentum of the projectile, is ejected from the spinner assembly. It enters the MEM catch tube where it plays no further part in the test.

Electrical connections are established between the power supply and metal coatings on the inner surface of the spinner tube. This is accomplished by two centrifugally deployed contacts on the outer surface of the test projectile. Slip rings and brushes complete the circuit from the spinner tube to a remote voltage monitor.

The rotation of the spinner tube is maintained for as long as one desires (but usually for only 3 minutes) to monitor the power supply output.

3. ORIGINAL DESIGN CRITERIA

At the beginning of this project, certain design criteria were developed by personnel of the Harry Diamond Laboratories (HDL). These criteria largely governed the mechanical and electrical design of the tester. The extent that these criteria were satisfied is, in a way, a measure of the successful completion of this project. The original design criteria are presented in appendix A. Those features and parameters incorporated in the tester are indicated.

4. DESCRIPTION OF TESTER

4.1 Test Projectile

Figure 3 shows the test projectile, indicating the two-piece construction and the placement of the power supply. The projectile is 2.009 in. (5.103 cm) in diameter and 3.06 in. (7.77 cm) long. It is fabricated from linen-base phenolic and is made of two sections which screw together. The weight, including the power supply to be tested, is 8.96 oz (254 g). The projectile is reusable and, with care, may be fired several hundred times.

Figure 3. Test projectile.

The forward section of the projectile contains all the electrical connections to the power supply. Two spring-loaded electrical contacts are mounted on the outer surface of this section. When the projectile is not rotating, these contacts are retracted. Wires connect the contacts to two miniature receptacles into which the leads on the power supply fit. A 3000-ohm resistor (the value used when testing the PS115 power supply) is connected across the contacts and acts as a load for the power supply. The resistor and all internal wires are laid in a channel forward of the power-supply compartment. They are embedded in a nonhardening putty to prevent movement and provide ruggedness to the resistor during impact and spin.

A metal bar containing two threaded holes is recessed in the front face of the projectile. From these holes two metal studs called "grabber pins" protrude about 0.5 in. (1.3 cm). As the projectile enters the spinner tube, the grabber pins penetrate the surface of the mitigator. The resulting intimate coupling between the projectile and the already spinning mitigator-MEM combination imparts a high angular acceleration to the projectile.

The test projectile is not leakproof. Occasionally, electrolyte seeping from a defective power supply will contaminate the interior of the projectile and the spinner tube. In such occurrences a follow-up swabbing of the spinner tube with a damp rag is required. Also, the interior of the projectile must be cleaned and dried. Any residual electrolyte may cause a short circuit of the internal wiring.

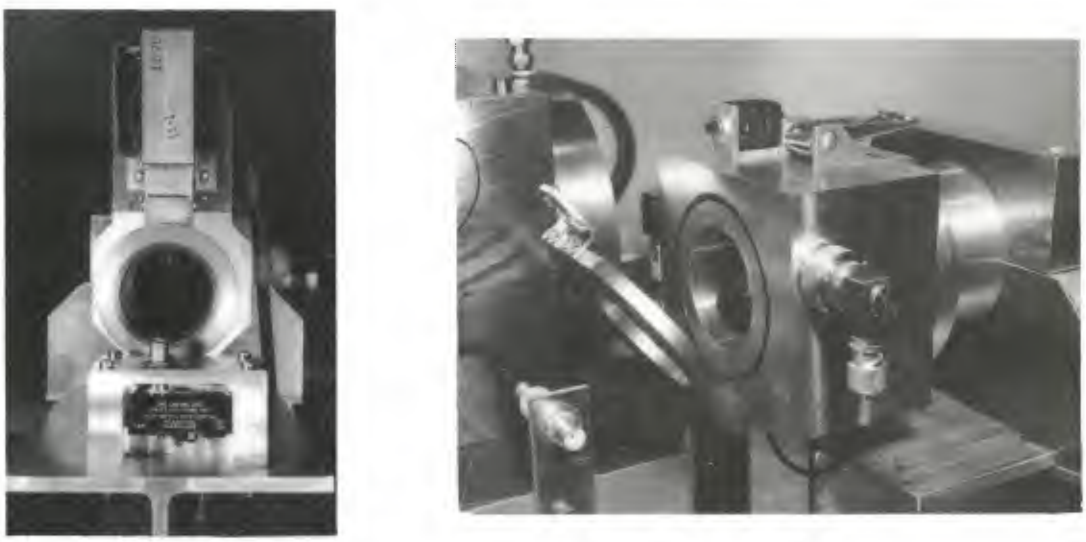
The projectile is assembled for a test by hand, without the use of any tools. However, the setback force and subsequent spinning generally leave the two sections of the projectile locked tightly together after a test. Therefore, a two-piece tool is required to disassemble the projectile. The grabber pins are inserted into a groove milled in a metal plate fastened to the tester. A spanner wrench having two dowel pins is fitted into mating holes provided in the rear face of the projectile. The operator can then easily unscrew the two halves of the test projectile.

4.2 Air Gun

The air gun propels the projectile into the spinner assembly at a sufficient velocity to generate an adequate setback signature on impact. The gun is a smooth-bore aluminum tube 84 in. (213 cm) long. It has an internal diameter of 2.012 in. (5.11 cm) and external diameter of 2.50 in. (6.35 cm).

Mechanically, the air gun is supported on an aluminum I-beam. The gun tube is fastened to this beam by a support bracket at each end. The section of I-beam near the muzzle end is bolted to the baseplate of the tester. The remainder of the gun and support beam, however, overhangs the baseplate. The breech end of the support beam rests on an adjustable pedestal, free-standing on the floor.

As shown in figure 4, the gun tube is fitted with several items required for the proper and safe operation of the air gun. At the breech end is a release pin, which, when relaxed, protrudes into the gun tube. The pin prevents the projectile from sliding forward as the gun tube is evacuated. The pin is retracted by a solenoid when the firing circuit is completed. In the prefire condition, an O-ring mounted in the gun tube forms a vacuum seal between the projectile and the tube.



(a) (b)

Figure 4. Air gun: (a) breech end and (b) muzzle end.

When the tester is operated in the automatic mode, two microswitches near the breech control a vacuum valve in the pipe connecting the gun tube to the vacuum pump. Only when the switch closest to the breech is depressed is the vacuum valve opened. Before loading, a mylar diaphragm is inserted into the adapter assembly, sealing off the muzzle end of the gun tube. Up to this point the vacuum valve has been closed, preventing the pump from drawing air out of the gun tube. Both microswitches are depressed as the projectile is inserted into the breech; the vacuum valve remains closed. When the projectile is pushed forward against the release pin, pressure on the rear microswitch is relieved. This action leaves only the front microswitch depressed. At this moment, after the projectile has been properly seated, the vacuum valve opens and evacuation of the gun tube commences. As the gun is fired, the projectile begins to move forward and releases the front microswitch. The vacuum valve again closes and the external vacuum system returns to the preload state. In the manual mode, a switch operates the vacuum valve on demand.

A photoelectric sensor is mounted near the muzzle end of the gun. Passage of the projectile interrupts a light beam incident on the sensor. The sensor produces an electrical pulse whose duration is directly related to the length and speed of the projectile. The pulse is used to determine projectile speed during the calibration of the tester. At other times, the pulse is used to monitor speed; it also acts as a "T-zero" pulse from which certain actions are initiated.

4.3 Spinner Assembly

The spinner assembly is another major assembly in the tester. It is here that the power supply is activated and remains throughout the test.

Setback, angular, and centrifugal forces necessary to activate the power supply are generated when the projectile enters the spinner tube. As indicated in figure 5, the spinner tube is a hollow fiberglass cylinder 11.7 in. (29.8 cm) long. The maximum outer diameter is 3 in. (7.6 cm), and the inner diameter is equal to that of the gun tube. When properly aligned, the axes of the spinner tube and gun tube are coincident.

The inner surface of the spinner tube is faced with two semicylinders of copper plating. (The configuration of the plating is that of a cylinder sliced down the middle parallel to its axis.) These copper sections are 10.7 in. (27.3 cm) long. They are electrically insulated from each other by two narrow strips of fiberglass material. The semicylinders are electrically connected through the wall of the spinner tube to a pair of slip rings on the outer periphery. Carbon alloy brushes bear against the slip rings and complete the circuit to a remote voltage monitor. It is these metal semicylinders that the centrifugal contacts on the projectile touch during the test.

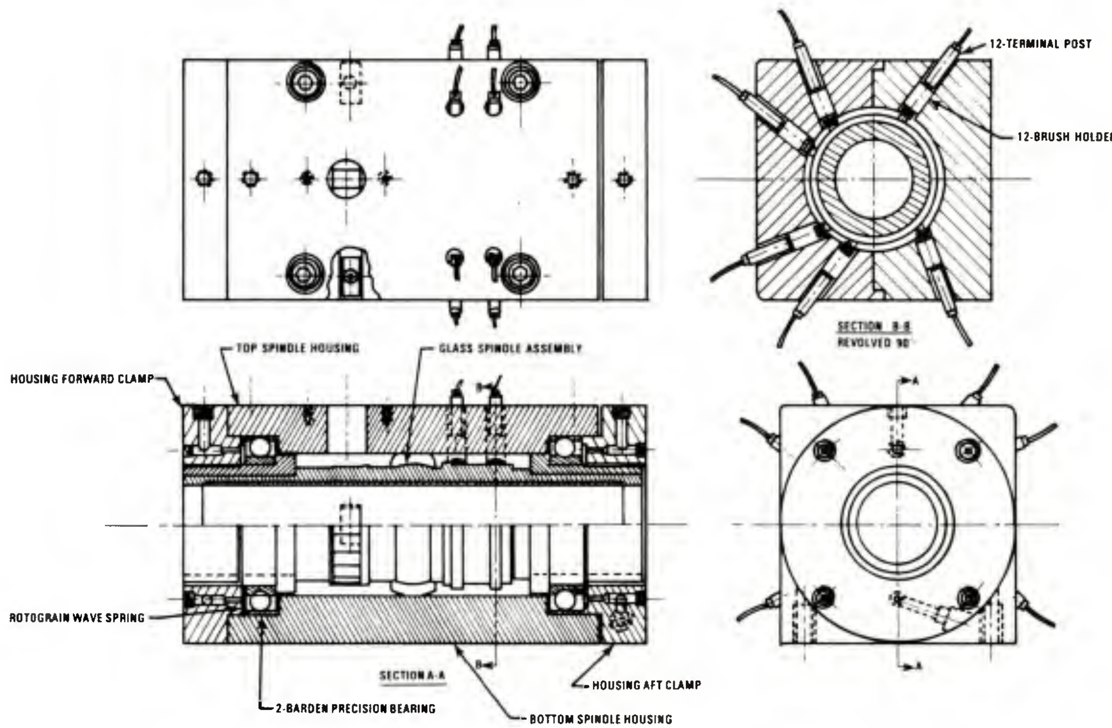


Figure 5. Spinner tube.

Also on the outer surface of the spinner tube is a metal strip called the "scanner band." It features 10 reflective and 10 dull areas of surface finish alternating around the circumference of the band. A photoelectric sensor viewing a light beam reflected from the band generates a series of 10 pulses during each rotation of the spinner tube. An electronic counter connected to the sensor can be set to indicate the speed of the spinner tube in revolutions per second.

The spinner tube is supported by two large ball bearings in the spindle housing. The housing is a large, two-piece, steel block. It is appropriately machined to support the spinner tube bearings, the rotation sensor, and the slip ring brushes. The housing also serves as a safety enclosure in case of a catastrophic failure of some internal component. Thick, metal rings on each end of the housing retain and preload the bearings. The rings are connected to a lubricator, which during operation provides a continuous supply of cooling air and lubricating oil to the bearings. An access slot is cut into the rear of the housing to accommodate a belt from the drive motor. Located just behind the housing, the drive motor turns the spinner tube through a one-to-one pulley ratio. The normal operating speed of the motor is 18,000 rpm (300 rps).

All these components--spindle housing, drive motor, and lubricator--are mounted on a pneumatic transport system. After each test the entire spinner assembly slides out of line relative to the air gun. This facilitates removing the projectile and mitigator from the spinner tube. Control circuits reposition the assembly for the next test.

4.4 MEM Catch Tube

A cylindrical metal slug (the MEM) absorbs the forward momentum of the test projectile and, in turn, is ejected from the spinner tube. To prevent injury to the operator, or damage to the tester or itself, the MEM is captured in the MEM catch tube.

The catch tube construction is shown in figure 6. It is downstream from the spinner assembly. The tube is aluminum, with an internal diameter of 2.012 in. (5.11 cm) and a length of 10 in. (25.4 cm). It is rigidly mounted in two support brackets. The brackets are fastened with a system of push-pull alignment bolts to a length of I-beam. The gun/spinner/catch-tube configuration is carefully aligned for smooth transitions of projectile and MEM from one assembly to the next.

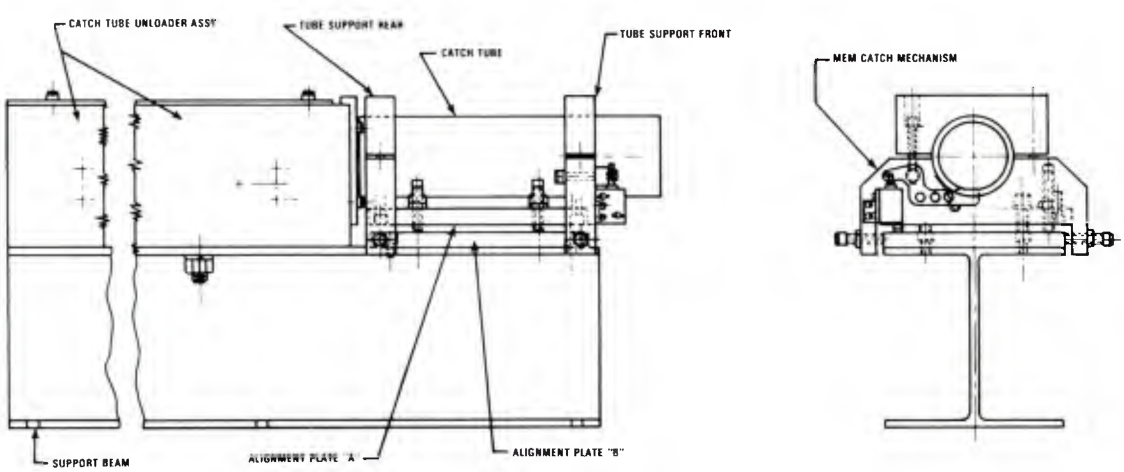


Figure 6. MEM catch tube.

A solenoid-actuated locking blade is located near the entrance of the catch tube. Normally, the blade is retained out of the way by a spring. As such the blade does not obstruct the tube and the MEM is free to pass through the length of the catch tube. At the end of the catch tube are two metal plates, arranged side by side, with a narrow strip of insulating material separating them. A rubber pad is mounted behind the plates; reinforcing the pad is the heavy box enclosing the tube unloader assembly. The box is bolted to the supporting I-beam and forms a rigid backstop for the catch tube assembly. When it enters the catch tube, the MEM strikes the metal plates and electrically shorts them. A circuit to which they are connected energizes the solenoid which lifts the lock blade. The lock blade prevents the MEM from rebounding back into the spinner tube. The blade is reset after the test. Then the MEM is repositioned back into the spinner tube (with a fresh mitigator) for the next test by a pneumatic ram in the tube unloader assembly.

4.5 Control Console

The control console is the final major assembly in the tester. It contains nearly all the electrical controls required to operate the tester. The console is the terminus for all wiring in the tester and supplies all ac and dc power used by the tester. A choice of manual or automatic operation of the tester is provided. In the automatic mode, an electrical timer is used to properly sequence many of the operations during the test. An electronic counter which indicates the rotational speed of the spinner tube is not provided. Another component not included in the console is the instrument which monitors the power-supply output voltage. A counter used to measure projectile velocity is included, but this information is not always required. Figure 7 shows the control console, and figure 8 is the complete wiring diagram of this unit.

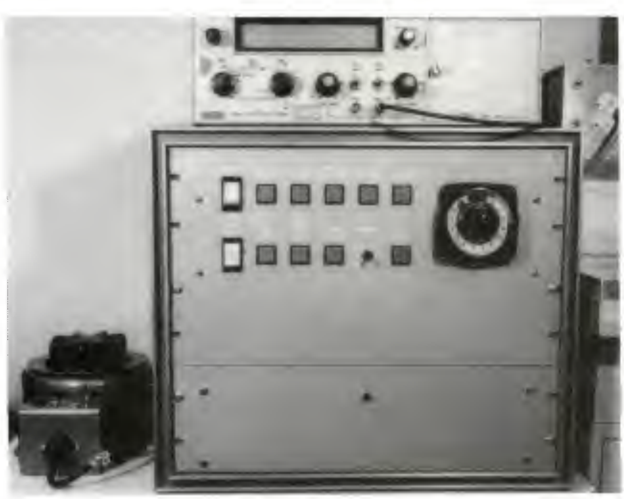


Figure 7. Control console.

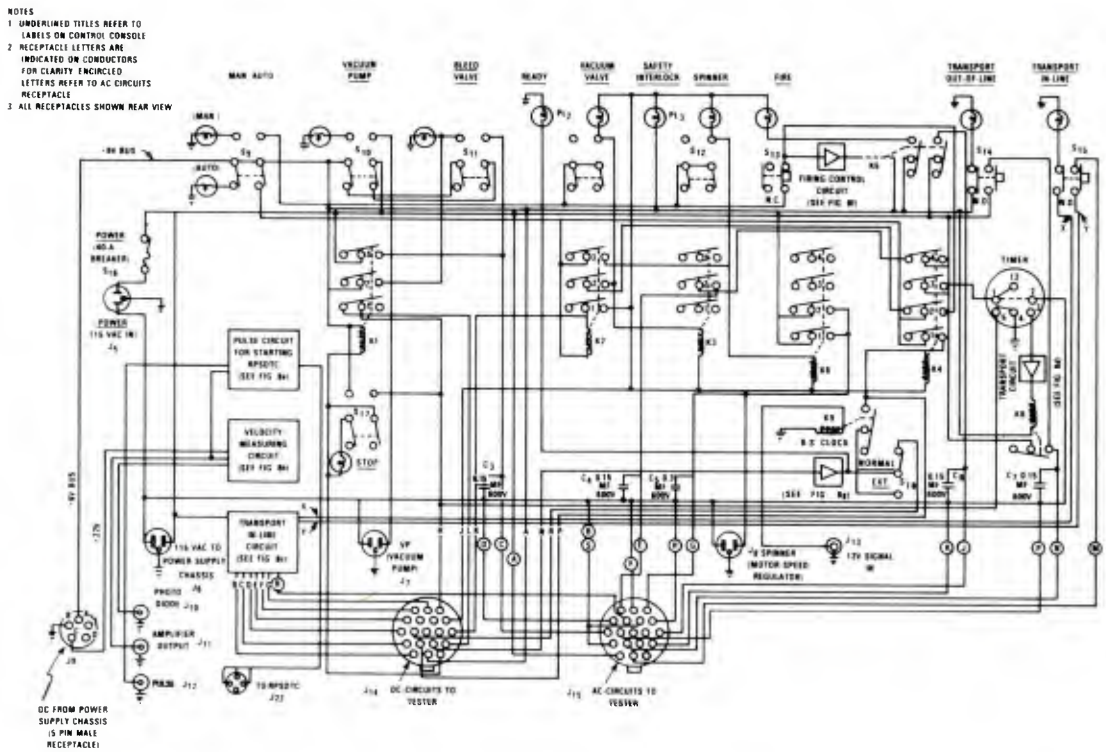


Figure 8. Wiring diagram of control console: (a) control chassis.

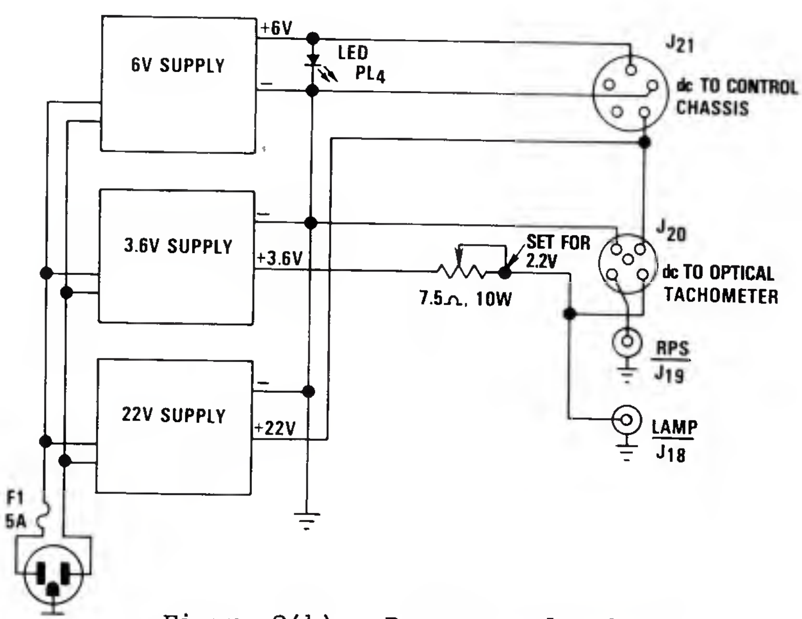


Figure 8(b). Power supply chassis.

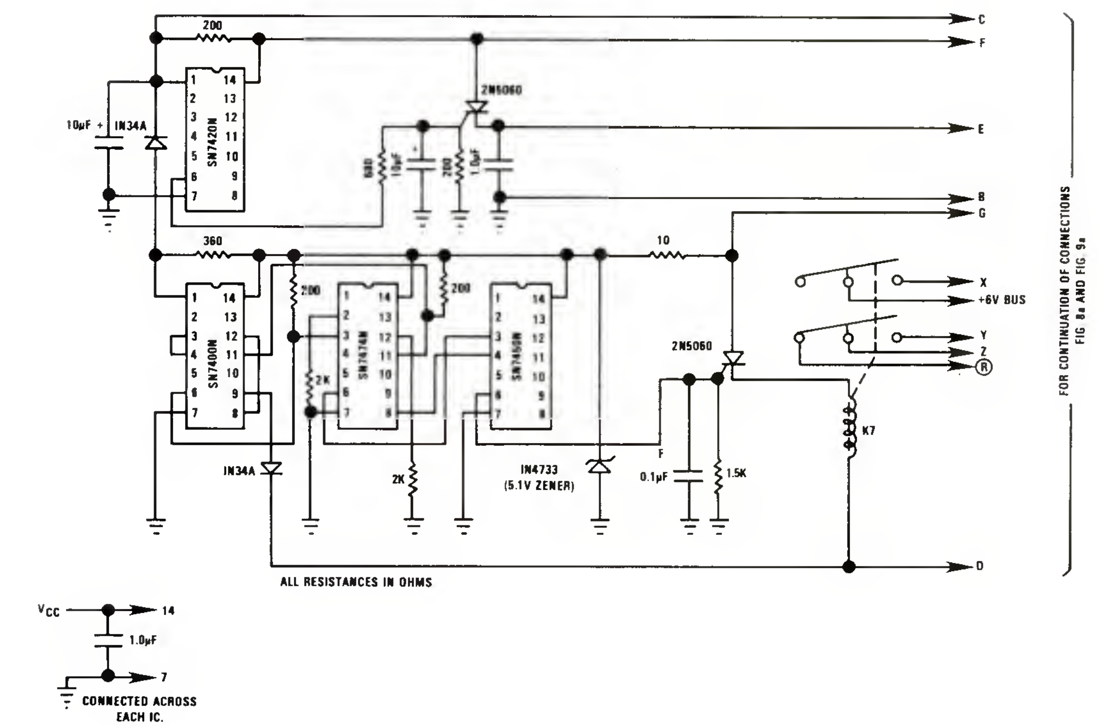


Figure 8(c). Transport in-line circuit.

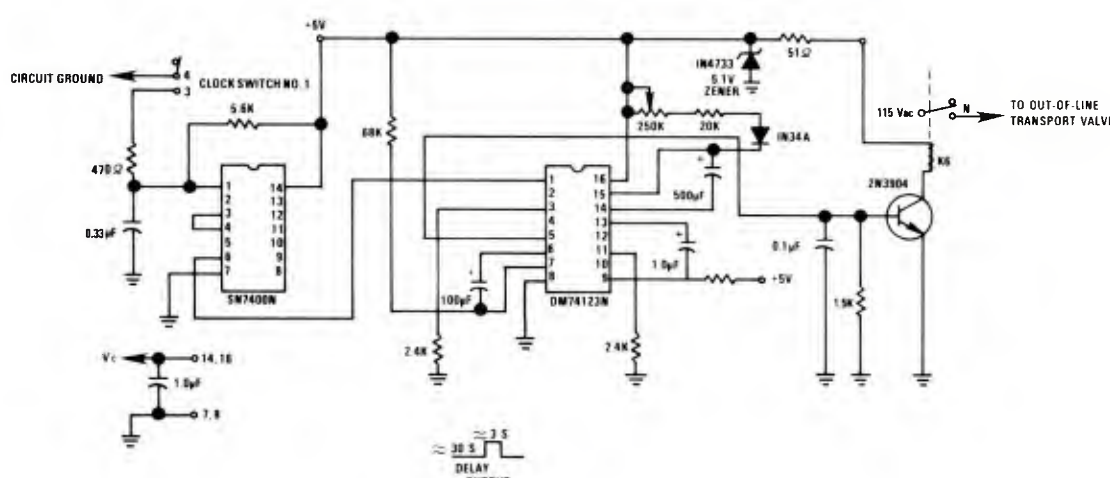


Figure 8(d). Transport time-delay circuit.

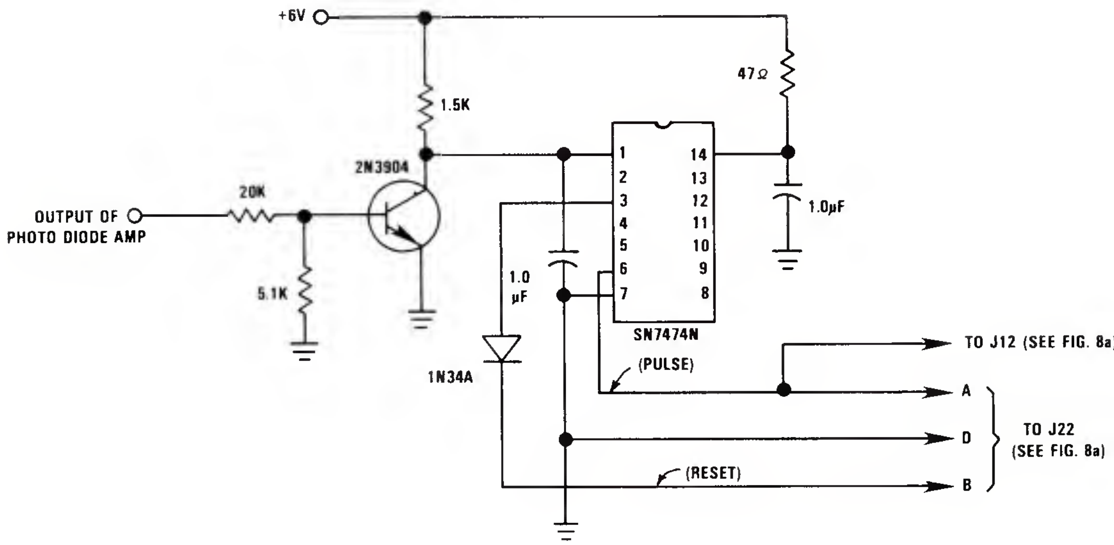


Figure 8(e). Pulse circuit for starting RPSDTC.

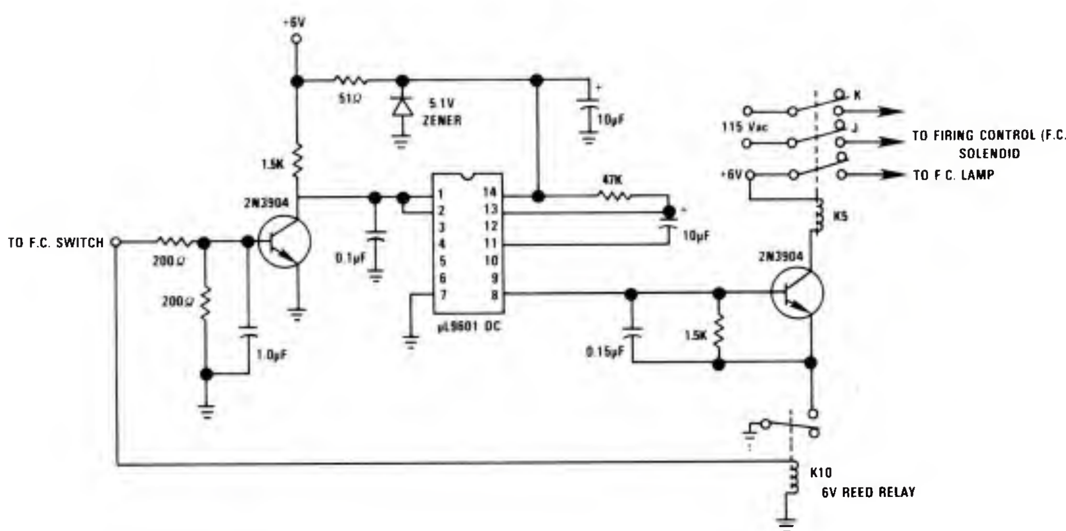


Figure 8(f). Firing control circuit.

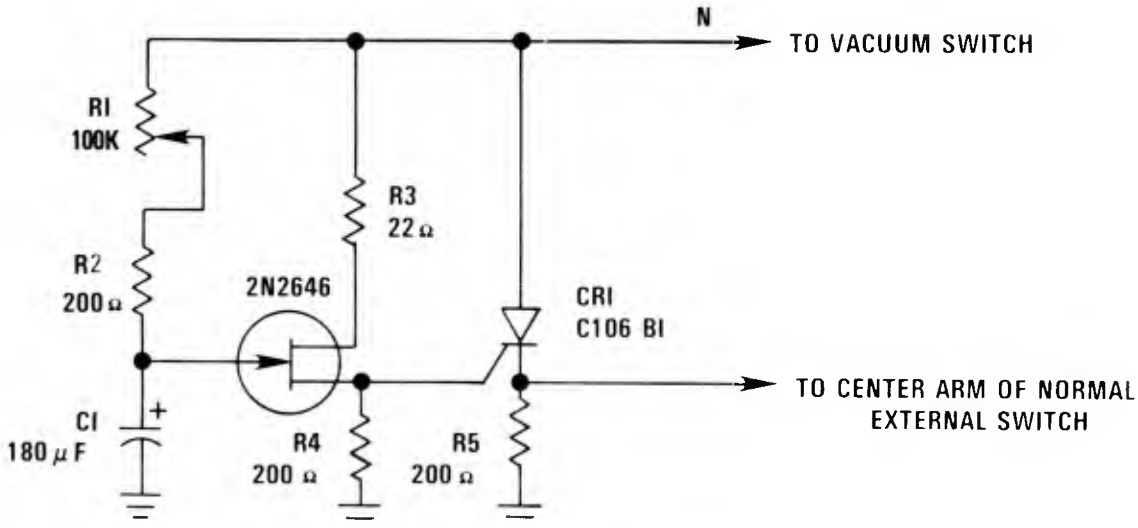


Figure 8(g). Adjustable 8-s clock circuit.

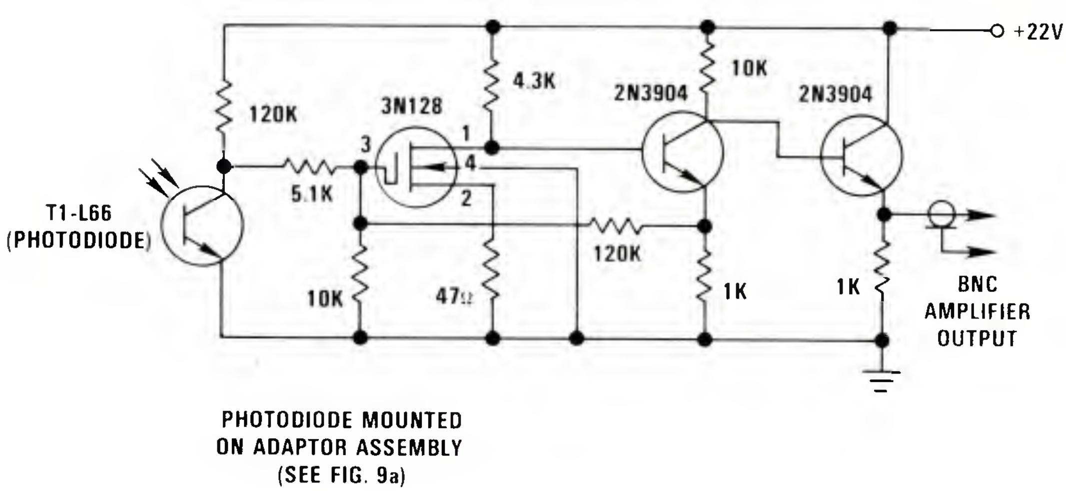


Figure 8(h). Photodiode velocity-measuring circuit.

4.6 Ancillary Equipment

Various ancillary items of equipment complete the tester. These are

(1) electrical limit switches associated with the spinner assembly transport,

(2) electrically operated air valves to pressurize the pneumatic systems,

(3) a projectile ram for removing the mitigator and projectile from the spinner after a test,

(4) an electrically operated bleed valve on the air gun to readmit air to the system if necessary,

(5) various air-pressure regulators,

(6) a dial vacuum gage which indicates the pressure in the air gun,

(7) the vacuum pump, and

(8) the vacuum valve which connects the gun to the pump.

All these items are shown schematically in the electrical wiring diagram and the plumbing diagram (fig. 9 to 11).

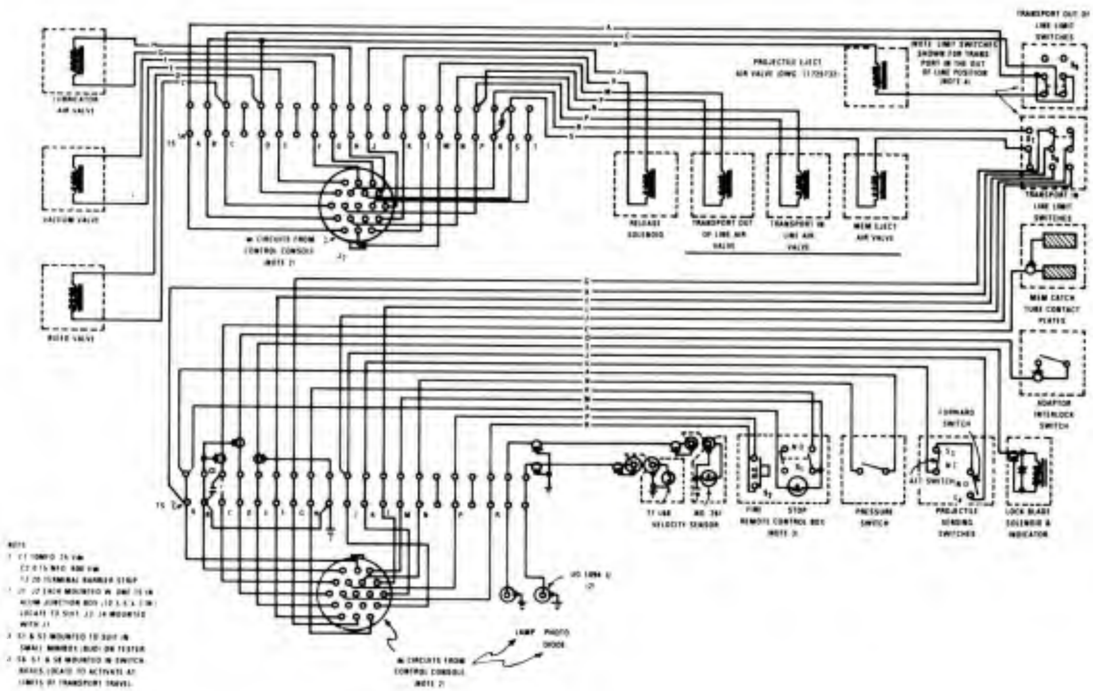


Figure 9(a). Wiring diagrams: tester.

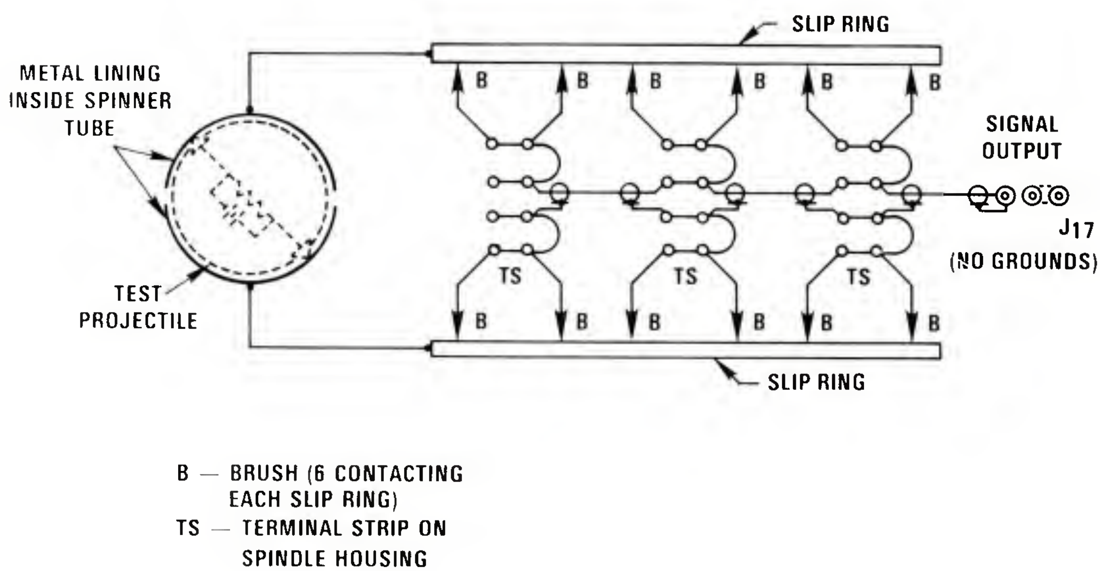


Figure 9(b). Spinner assembly.

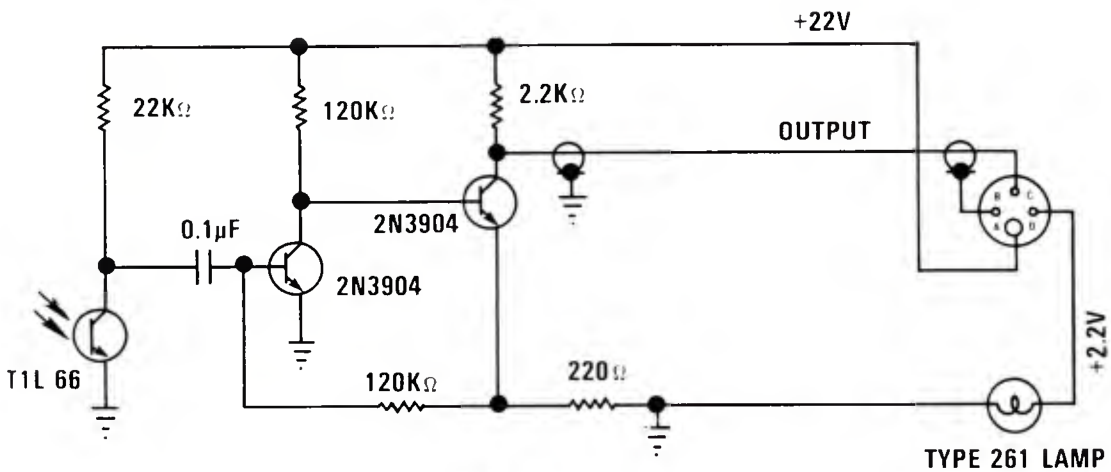
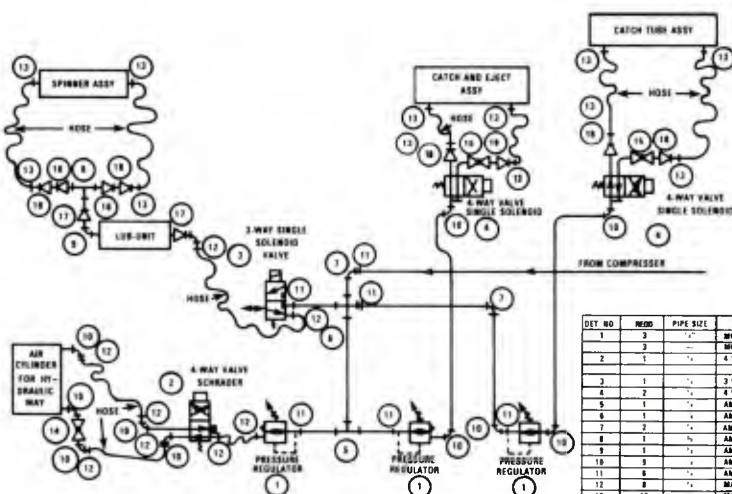
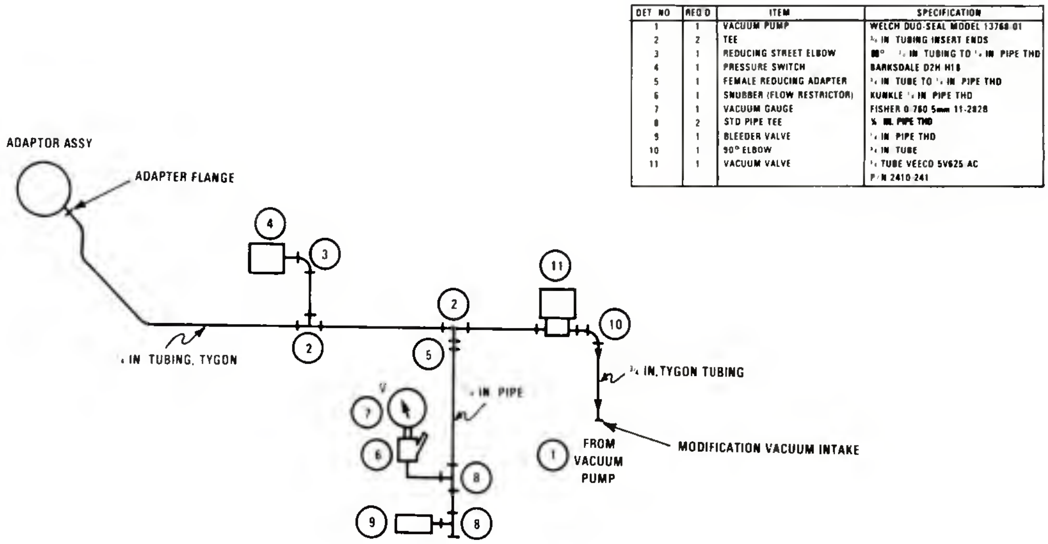


Figure 9(c). Optical tachometer circuit.



DET NO	REQD	PIPE SIZE	ITEM	SPECIFICATIONS
1	3	[illegible]	MINIATURE PRESSURE REGULATOR	SCOVILL WITH GAUGE NO 5420A
	3	—	MOUNTING BRACKET	NO 5420 MB
2	1	[illegible]	4 WAY VALVE	[illegible] PIPE THD 2 POSITION 2 SOLENOID
				SCHRADER 520001
3	1	[illegible]	3 WAY VALVE	1 SOLENOID SCOVILL NO 9725
4	2	[illegible]	4 WAY VALVE	2 POSITION 1 SOLENOID SCOVILL 3455KS
5	1	[illegible]	AM STD PIPE TEE	BRASS SAE CA377 NO 101 B
6	1	[illegible]	AM STD PIPE CROSS	BRASS SAE CA377 NO 102 B
7	2	[illegible]	AM STD PIPE ELBOW	BRASS SAE CA377 NO 100 B
8	1	[illegible]	AM STD PIPE TEE	BRASS SAE CA377 NO 101 B
9	1	[illegible]	AM STD STREET ELBOW	BRASS SAE CA377 NO 116 B
10	9	[illegible]	AM STD STREET ELBOW	BRASS SAE CA377 NO 116 B
11	6	[illegible]	AM STD HEX NIPPLE	BRASS SAE CA377 NO 122 B
12	8	[illegible]	MALE HOSE CONNECTOR	POLY FLO NO 268 P
13	12	[illegible]	MALE HOSE CONNECTOR	POLY FLO NO 268 P
14	1	[illegible]	SHUT OFF VALVE	2 WAY NO 101HD
15	2	[illegible]	SHUT OFF VALVE	2 WAY NO 103HD
16	2	[illegible] TO [illegible]	STD REDUCING NIPPLE	BRASS SAE CA377 NO 123 B
17	2	[illegible] TO [illegible]	STD REDUCING NIPPLE	BRASS SAE CA377 NO 119 B
18	4	[illegible] TO [illegible]	STD REDUCING NIPPLE	BRASS SAE CA377 NO 123 B

Figure 10. Plumbing diagram--air system.



DET NO	REQ'D	ITEM	SPECIFICATION
1	1	VACUUM PUMP	WELCH DUO-SEAL MODEL 13768-01
2	2	TEE	[illegible] IN TUBING INSERT ENDS
3	1	REDUCING STREET ELBOW	[illegible]° [illegible] IN TUBING TO [illegible] IN PIPE THD
4	1	PRESSURE SWITCH	BARKSDALE D2H H18
5	1	FEMALE REDUCING ADAPTER	[illegible] IN TUBE TO [illegible] IN PIPE THD
6	1	SNUBBER (FLOW RESTRICTOR)	KUNKLE [illegible] IN PIPE THD
7	1	VACUUM GAUGE	FISHER 0-760 5mm 11-2828
8	2	STD PIPE TEE	[illegible] IN. PIPE THD
9	1	BLEEDER VALVE	[illegible] IN PIPE THD
10	1	90° ELBOW	[illegible] IN TUBE
11	1	VACUUM VALVE	[illegible] TUBE VEECO SV625 AC P/N 2410-241

Figure 11. Plumbing diagram--vacuum system.

5. MITIGATOR-MEM CONFIGURATION

The use of a crushable mass (mitigator) and a momentum exchange mass (MEM) to stop the test projectile has been discussed in an earlier report.[1] Briefly, the reference points out that an elastic collision between a projectile and a MEM of equal weight would result in the projectile coming to a complete stop within the spinner tube. In this case, all the kinetic energy of the projectile is transferred to the MEM, which is then ejected from the spinner tube. But if the impact were not completely elastic, some of the kinetic energy would not be carried off by the MEM. This energy would be absorbed in crushing and permanent distortion of the projectile, which is very undesirable. To prevent such damage, a third material (the mitigator) is used as an absorber between the projectile and the MEM. The mitigator deforms, and in doing so, limits the peak force on the projectile (setback force). In this tester, the mitigator consists of 7-ply, 0.75-in. (1.91-cm) thick, plywood blocks cut in the shape of equilateral triangles. The sides of the blocks are 1.75 in. (4.45 cm) long; six blocks are used to make a mitigator. The blocks are taped together with fiber-

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[1]*H. D. Curchack, An Artillery Simulator for Fuze Evaluation, Harry Diamond Laboratories, HDL-TR-1330 (November 1966).*

glass-reinforced self-adhesive tape. Marine grade plywood is chosen for its uniformity and general freedom from internal knots and voids. The finished mitigator and one crushed in a test shot are shown in figure 12. The mitigator usually weighs about 1.9 oz (54 g). However, variations up to ±7 percent of this value are not uncommon.

Figure 12. MEM, fresh mitigator, and a crushed mitigator.

The MEM (fig. 12) is a solid brass cylinder 1.75 in. (4.45 cm) in diameter by 4.12 in. (10.46 cm) long. Four phenolic runners are fastened to its outer surface. After assembly, the runners are turned down on a lathe to an overall diameter of 2.009 in. (5.103 cm). (The purpose of the runners on an undersized cylinder is to prevent the MEM from acting as a piston. This action might draw the projectile with it as it leaves the spinner tube.) The weight of the MEM is 45.5 oz (1291 g). The diameter of the MEM is checked occasionally with a ring gauge to detect any wear of the runners. The runners are replaced before the MEM becomes loose in the catch tube. Any excessive wear may cause the MEM to hang up as it enters the catch tube.

The mitigator and MEM are loaded into the spinner tube such that the mitigator is between the projectile and MEM during impact. A specific "set distance," measured from the spinner tube entrance to the face of the mitigator, locates the mitigator in the spinner tube. A set distance of 2.5 in. (6.3 cm) is proper for the dimensions and weights of the elements given in this report. The mitigator and MEM should be in contact.

6. CALIBRATION

The initial calibration of the tester consists primarily in determining the g-force (setback) that the test projectile experiences during impact.

Curchack[1] offers a formula derived from earlier work with plywood mitigators. The formula yields the average g-force when the parameters of the elements involved in the impact are known. This formula is

$$\text{g-force} = \frac{m_2 v^2}{2\left(m_1 + m_2\right) gL_o \left(\sigma_g\right)} ,$$

where

m_1 = combined weight of the mitigator and MEM,

m_2 = weight of test projectile (including power supply),

v = speed of projectile,

L_o = length of mitigator before impact,

g = 980 cm/s^2, and

σ_g = gross strain of the mitigator.

The only factor in the above formula that cannot be readily determined by direct measurement is the gross strain, σ_g. At the end of the impact event, the mitigator has some definite, but unknown, crushed length. This final length is not measured because the wood is spinning in the spinner for a few minutes after impact. The wood exhibits some delayed elasticity (or memory). By the time the wood is measured, it has recovered some of its lost length. At this point, only the net strain, σ_n, can be measured. Some earlier experiments determined the relation between the net strain, σ_n, and the gross strain, σ_g. This relation (derived from fig. 13) is

$$\sigma_g = 1.389\sigma_n + 0.025 \text{ for } \sigma_n > 0.217$$

and

$$\sigma_g = 1.08\sigma_n + 0.92 \text{ for } \sigma_n < 0.217 \quad .$$

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[1] *H. D. Curchack, An Artillery Simulator for Fuze Evaluation, Harry Diamond Laboratories, HDL-TR-1330 (November 1966).*

Also,

$$\sigma_n = \left(L_o - L_n\right)/L_o \quad ,$$

where L_n = the net crushed length of the mitigator (measured several minutes after impact).

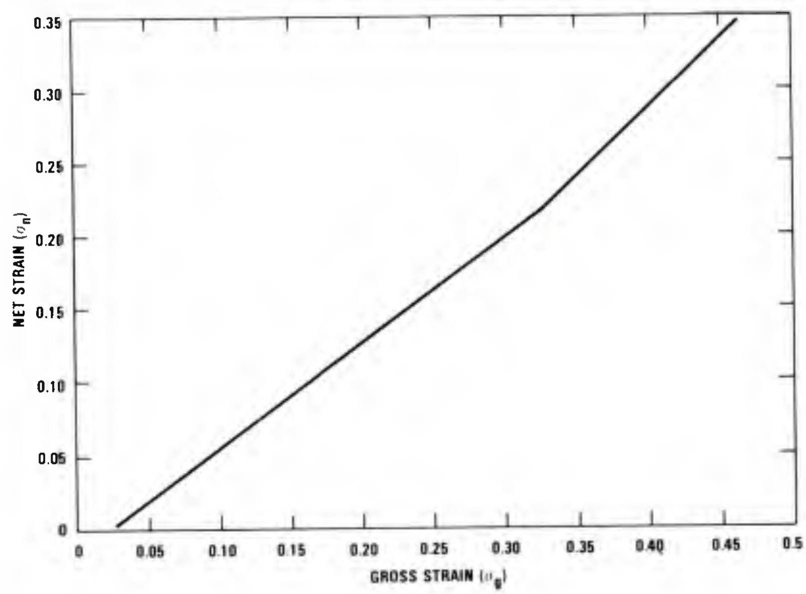

Figure 13. Plot of net strain, σ_n, versus gross strain, σ_g.

Many shots were fired in the tester to initially determine the impact or setback force. The parameters were varied until setback forces matching those specified for reliable power-supply activaton could be obtained repeatedly. The final parameters produce a setback force which almost always lies between 3800 and 5000 g. Corresponding impact duration times range from 1.30 to 0.95 ms. The final parameters adopted are summarized in table 1.

TABLE 1. SUMMARY OF TESTER PARAMETERS

Set distance = 2.5 in. (6.3 cm)

Item	Weight		Length		Material	Shape
	(oz)	(g)	(in.)	(cm)		
Projectile (with power supply)	8.96	254	3.06	7.77	Linen-base phenolic	2.009-in. (5.103-cm) diam cylinder
Mitigator	1.9	54	~4.5	~11.4	7-ply, 0.75-in. thick marine plywood	Equilaterial triangular blocks, 1.75-in. (4.45-cm) sides
MEM	45.5	1291	4.12	10.46	Brass (with phenolic runner)	2.009-in. (5.103-cm) diam cylinder

7. PERFORMANCE

By the end of 1977, a total of 511 shots had been fired in the tester. These shots were tests of both PS115 and PS127 power supplies. Many of the early shots were a "learning process" for the designers and operators. However, most of these shots were actual power-supply tests conducted on a routine basis.

The total running time accumulated on the spinner assembly during this period was 28.4 hours at 300 rps. The average running time per test was 200 s. One power supply was spun for 16.6 minutes.

All these tests were conducted in the manual operating mode. Only near the end of this project was the automatic mode of operation made available.

The list of design criteria in appendix A contains comments following some of the entries. These comments summarize the performance of the tester in a manner which permits the reader to directly compare the accomplishments with the original objectives. Where no comments appear, the design criteria were implemented as originally stated.

In all, about 2 percent (13 out of 511) of the test shots failed because of faulty tester operation. In nearly every case these malfunctions could be traced back to operator error or inadequate maintenance of the tester, projectile, or MEM. The most common cause of tester failure proved to be excessive wear of the MEM runners and misalignment of the spinner assembly and the MEM catch tube.

8. SUMMARY

The High-Spin Tabletop Artillery Simulator (2 in.) has proven to be an adequate device for testing PS115 fuze power supplies. The simulator (tester) provides in the laboratory a dynamic environment which produces setback and centrifugal forces sufficient to activate the power supplies.

So far, 511 power-supply tests have been conducted, 2 percent of which were aborted because of tester malfunctions. Design changes made late in the project should reduce the number of malfunctions, but this has yet to be proven. During this period, no major components (such as bearings, drive motor, etc) had to be replaced because of wear.

APPENDIX A.--DESIGN CRITERIA FOR PBS PROJECT 5763095 300-rps SPIN CATCHER

A-1. BACKGROUND

The system design criteria are based on testing requirements for the PS115 power supply. This system will also be capable of initiating and testing all currently (1976) produced thermal and liquid power supplies used in conventional Army mortar and artillery weapons. Sections A-2 through A-7 list specific design criteria. Basic (A) criteria are those which are funded by this project and are essential to the project's successful completion. Secondary (B) criteria would be required or be useful if this equipment were to be used in a production facility. Criteria for B must be considered so that the design will not preclude their incorporation in the future. Some B criteria may be included in this project immediately (if additional funds are available) since they do not conflict with successful completion of the project. A third category, C, are those criteria which also are important but may impede achievement of project requirements. Category C items will not be included until this project is satisfatorily completed. An (*) indicates that the design criterion has been achieved.

A-2. GENERAL CHARACTERISTICS

*(A) The system diameter will be 2.012 in. (5.11 cm) to permit projectile interchangeability between this tester and existing laboratory testers.

(B) The system will be electrically compatible with the Reserve Power Supply Destructive Test Console (RPSDTC) at the Harry Diamond Laboratories (HDL) both for signal monitoring and test control. [Comment: Although the tester has been so designed, compatibility with the RPSDTC has not yet been proven.]

(B) The system will be designed to test 40 power supplies in four hours at the high-spin speed (see sect. A-5.2). [Comment: This rate of testing has not been verified in the manual or automatic modes of operation.]

(C) The system will be designed to test 40 power supplies in four hours at the low-spin speed (see sect. A-5.2). [Comment: Since low-spin testers are available, this rate of testing has not been investigated at the low spin in either the manual or automatic modes of operation.]

*(A) The duration of each power supply test will be three minutes.

*(B) The duration of each power supply test will be variable at the user's option up to a maximum of five minutes, with a resultant reduction in testing rate.

*(B) The system will be designed to start power-supply initiation within 15 s after the time the projectile is brought to the gun breech.

(B) Any critical tester system subassembly which may go bad is to be changeable by a competent technician within an hour, provided that a spare subassembly is available.

*(B) The system will be self contained and operate from power generally available in commercial production facilities.

*(A) The data package will include a drawing package (from which additonal testers can be built) and a complete set of operating instructions.

A-3. PROJECTILE CHARACTERISTICS

*(A) The projectile body will be constructed of an electrical and thermal insulating material and will contain an electrical link from the housed power supply to external, diametrically opposed contacts on the projectile. The projectile will be used on both the 2-in. HDL artillery simulator and the tester.

*(A) The projectile weight (which affects muzzle velocity and deceleration levels) will be selected to assure proper power-supply initiation in the tester.

*(B) The design will enable power-supply assembly into the projectile that will be simple, quick, and manual and require no tools.

(B) The projectile will be a sealed unit so that in the event of power-supply leakage, acid will not contaminate system parts. [Comment: The current projectile design is not leakproof.]

A-4. CONTROL SYSTEM CHARACTERISTICS

*(A) The controls will operate in a stand-alone manner (i.e., independent of the RPSDTC).

*(B) The controls will operate selectively either stand-alone or with the RPSDTC providing the RPSDTC with a 1-s prefire relay closure ($0.5 < T < 5$ s) to start the chart recorder and a zero time signal to initiate the test. The RPSDTC will provide a steady 12 Vdc to the controls when ready.

*(A) The control system will abort the test in the event of an unsafe condition.

*(A) The control system will terminate the test after the standard test time.

*(B) The operator will manually abort the test when so indicated by the RPSDTC.

*(A) The control system will operate in either an automatic or manual mode.

In the automatic mode, the system will provide signals (or power) in the proper time sequence to

*(A) start lubrication,

*(A) start the spinner,

*(A) open the vacuum valve upon safe entry of the projectile,

*(A) close the vacuum valve and release the projectile,

*(A) stop the spinner and lubricator,

*(B) eject the projectile and spent mitigator from the spinner,

*(B) swab the spinner,

*(B) insert the MEM into the spinner,

*(B) insert a fresh mitigator into the spinner, and

(B) change the diaphragm. [Comment: The diaphragm is manually replaced.]

In the manual mode each of the above functions will be performable-independently (consistent with safe operation).

*(A) A "panic button" will be incorporated to interrupt the test cycle and return the system to a safe condition.

A-5. MOTOR, SPINNER, AND READOUT CHARACTERISTICS

A-5.1 Electrical

*(A) The spinner will electrically accommodate the diametral contacts from the projectile and convey the electrical output from the power supply to the readout system and then to a standard electrical connector.

(A) The system will carry 0.1 A at 30 Vdc. The noise level of the system will not exceed 10 mV at frequencies up to 3000 Hz at the connector. [Comment: The noise level exceeds this criterion by at least a factor of 10. The noise level reaches values of 250 mV rms. This high noise level may be characteristic of this particular tester, caused, perhaps, by an out-of-round spinner, inadequate maintenance of tolerances during fabrication, and the like.]

(B) The noise level of the system will not exceed 10 mV at frequencies between 3000 and 5000 Hz at the connector. [Comment: Refer to second item above. The noise levels in this frequency band are about the same as above.]

A-5.2 Mechanical

*(A) The spinner will operate at one fixed speed in the high-speed range (250 to 350 rps).

*(C) The spinner will work at one fixed speed in the low-speed range (45 to 50 rps).

*(A) Once the test speed is set, it will be maintained between 97 and 103 percent of the level for 3 minutes.

*(A) Spinner rotation will be counterclockwise when viewed from the gun breech.

A-6. GUN CHARACTERISTICS

*(A) The "vacuum" operated gun length will be chosen to impart sufficient velocity to the projectile to activate the power supply.

*(A) The breech design will permit easy insertion of the projectile by a trained operator and will require no manipulation of the release mechanism.

*(B) The breech design will incorporate a safety device to prevent the projectile from backfiring in the event of a diaphragm failure.

(B) The muzzle section will accommodate an automatic diaphragm change mechanism. [Comment: The diaphragm is changed manually.]

*(A) The muzzle section will incorporate a projectile sensor to indicate the start of the test cycle.

A-7. INSTRUMENTATION OF TESTER

System instrumentation will include

*(A) a transducer for measuring spinner rotational velocity, the signal from which can be detected on standard commercial frequency meters, and

*(A) a transducer for measuring the time it takes the projectile to pass near the gun muzzle. This signal when used with an appropriate commercial time-interval meter permits computation of muzzle velocity.

*(A) A visual or mechanical inspection of the mitigator before and after a test will determine conformity to established length criteria.

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