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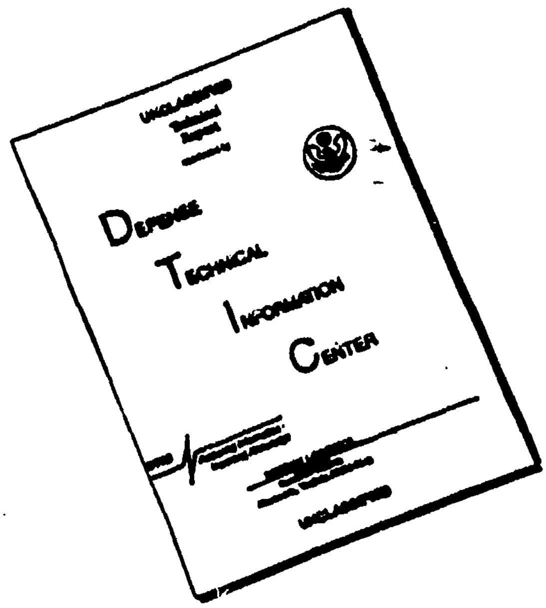

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CIGARETTE FUZE FIELD TEST (U)

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ABSTRACT (C)

Twenty-three "Cigarette" fuzes were mounted in 81-mm mortar shell and tested by field firing at two increments. The score was:

16 – proper function

3 – indeterminate

2 – early

2 – no fuze test

Function height varied from 1 to 6 inches above ground. These tests showed that Cigarette fuzes are suitable for use with projectiles.

1. INTRODUCTION

The original Cigarette fuze was developed for a hand grenade. The entire fuze, including power supply and safety and arming mechanism, was fabricated in a package similar in size and shape to a king-sized cigarette. However, this fuze was not carried beyond prototype stage. Other demonstration models of this type of fuze had also been built (refs 2 and 3) prior to the test described in this report, but these models were not designed for firing.

The Cigarette fuze is an a-c cap[illegible]ce fuze. The principle of operation is described in reference 1. Essentially, the fuze consists of a body with two electrodes. The capacitive coupling between the electrodes changes when the body approaches some object closely. The fuze measures the change in capacitance, and this signal is used to fire a detonator. Design details are discussed in the appendix.

The tests described herein were designed to demonstrate that Cigarette fuzes could be built to survive the conditions of projectile firing and to function properly when approaching targets at projectile speeds.

2. CONCLUSIONS

The test showed that Cigarette fuzes are suitable for use in projectiles.

3. RECOMMENDATIONS

Several factors should be investigated in the further development of a-c capacitance fuzes. One is the possibility of eliminating neutralization of the free-space signal. Another is the effect on function height and free-space signal of the shape, position, and size of the antennas. Other forms of firing circuits should be considered, such as the use of cold-cathode thyratrons or solid-state switches.

To increase the signal-to noise ratio and for additional protection against interference, features such as tuned input circuit and synchronous detection can be considered. Magnetic shielding between oscillator and amplifier may not be necessary, but additional experimental work is required to determine actual shield requirements.

4. SUMMARY OF FIRING TESTS

Twenty-three rounds were fired and the following score was obtained:

16 - proper function

3 - indeterminate

2 - early

2 - no fuze test

The details of the tests are summarized in table 1.

5. DETAILS OF FIRING TESTS

The test vehicle selected was the 81-mm mortar shell fired with two increments. The M527 fuze nose cone, thermal power supply, and safety and arming mechanism were used to expedite fabrication of the necessary hardware. The assembly is shown in figures 1 through 4. Holes in the side of the shell were closed with plugs intended to blow out at detonation so that the flash would be visible.

Photographic coverage was used to obtain function heights. High-speed motion pictures were taken at the time the shell approached the ground, and low-speed pictures were taken with a background scale, marked off in feet from ground, at the spot where the shell landed. When the two pictures were compared, the height of the flash above the ground was obtained. The distance from nose to flash hole was subtracted to obtain the distance between the nose and the ground at the time of the flash. Actual functioning could have been somewhat higher than the measured flash (about one inch) because of the motion between fram[illegible] results were rounded to the next higher full inch. The function height varied fro[illegible] to six inches.

Firing of the 23 rounds was begun on 5 November 1958. Of two rounds fired, the first round showed a flash near the ground, and the second showed no flash. After recovery, it was determined that the second fuze had functioned. Similar troubles at a later date are discussed below.

Three more rounds were fired on 9 January 1959. The first round flashed above ground, the second had a propellant failure and did not reach arming velocity, and the third flashed above ground.

On 23 February 1959, seven rounds were fired: four were successful and three showed no flash. Firing was then stopped until the rounds could be recovered

TABLE 1

ROUNDS FIRED

Date	Round-Amplifier	Tetryl	Proper Function	Function Height Inches	Remarks
11-5-58	A	No	Yes		One increment
	A	No	*		One increment
1-9-59	B	No	Yes		Not Neutralized
	B	No	No		Propellant failure--fuze did not arm
	B	No	Yes		
2-25-59	3-B	No	No		Battery circuit was open
	5-B	No	Yes	4	Blowout plugs intact
	6-B	No	Yes		
	7-B	No	*		Blowout plugs intact
	8-B	No	Yes	4	
	10-B	No	Yes	3	Blowout plugs intact
	11-B	No	*		Three blowout plugs intact
3-20-59	12-B	Yes	Yes	4	
	13-B	Yes	Yes	6	
	14-B	Yes	Yes		
	20-B	Yes	Yes	1	
	21-B	Yes	Yes	5	
	22-B	Yes	Yes	1	
	23-B	Yes	Yes	2	
	24-B	Yes	No		15-sec function
	25-B	Yes	Yes	2	
4-1-59	9-B	Yes	Yes		Light to moderate rain
	15-B	Yes	No		Moderate to heavy rain; 12-sec function

* Indeterminate — no flash was observed but recovered fuze had functioned. Believed to be proper function but wrong orientation to see flash when no tetryl was used.

for examination. Two of the nonflashing rounds had functioned. However, on one the plugs were intact, and on the other only one plug had been blown out. It was decided that the flash powder was not sufficiently powerful to give definite indication unless the orientation of the round happened to be suitable, and that a piece of tetryl should be substituted for one of the flash powder discs in future rounds. The test vehicle had been designed and tested initially in this manner, but flash powder was substituted for the tetryl to permit recovery if necessary. The third nonflashing round had the detonator in line but the detonator had not fired. It was fired successfully in a laboratory test. However, the 6.4-volt battery was still good days after it should have been run down and the battery connection to ground was open. Hence, the amplifier had not been energized. Therefore, this round was not considered a fuze test. A connection between a screw and a soldering lug in the potted amplifier had not been soldered, and was believed to have opened from the shock of firing.

On 20 March 1959, nine more rounds were fired. All functioned, but one exploded in mid-air after 18 seconds. Firing was at 30° elevation and flight time was about 24 seconds.

On April 1, 1959, two more rounds were fired. The first was fired in light to moderate rain and functioned satisfactorily. The second was fired in moderate to heavy rain and functioned in mid-air after 12 seconds. The two earliest are attributed to the same unsoldered connection mentioned above. It is assumed that this connection opened from vibration during flight and removed the bias from the thyratron, thus causing the detonation.

6. ACKNOWLEDGMENTS

John J. Furlani and James Miscampbell conducted the mechanical phases of this project. Lloyd R. Crump developed the electronic circuitry. The Model Shop fabricated the electronic equipment used in the firing tests.

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(4) Lloyd R. Crump, "A Transistor Sine Wave Oscillator," DOFL Report TR-599, June 1958. (referenced in appendix)

(5) Lloyd R. Crump, "Electronic Circuitry For Electrostatic Capacity Fuze For Mortar Firing," (U); DOFL Report R-100-59-1, Confidential, February 1959. (referenced in appendix)

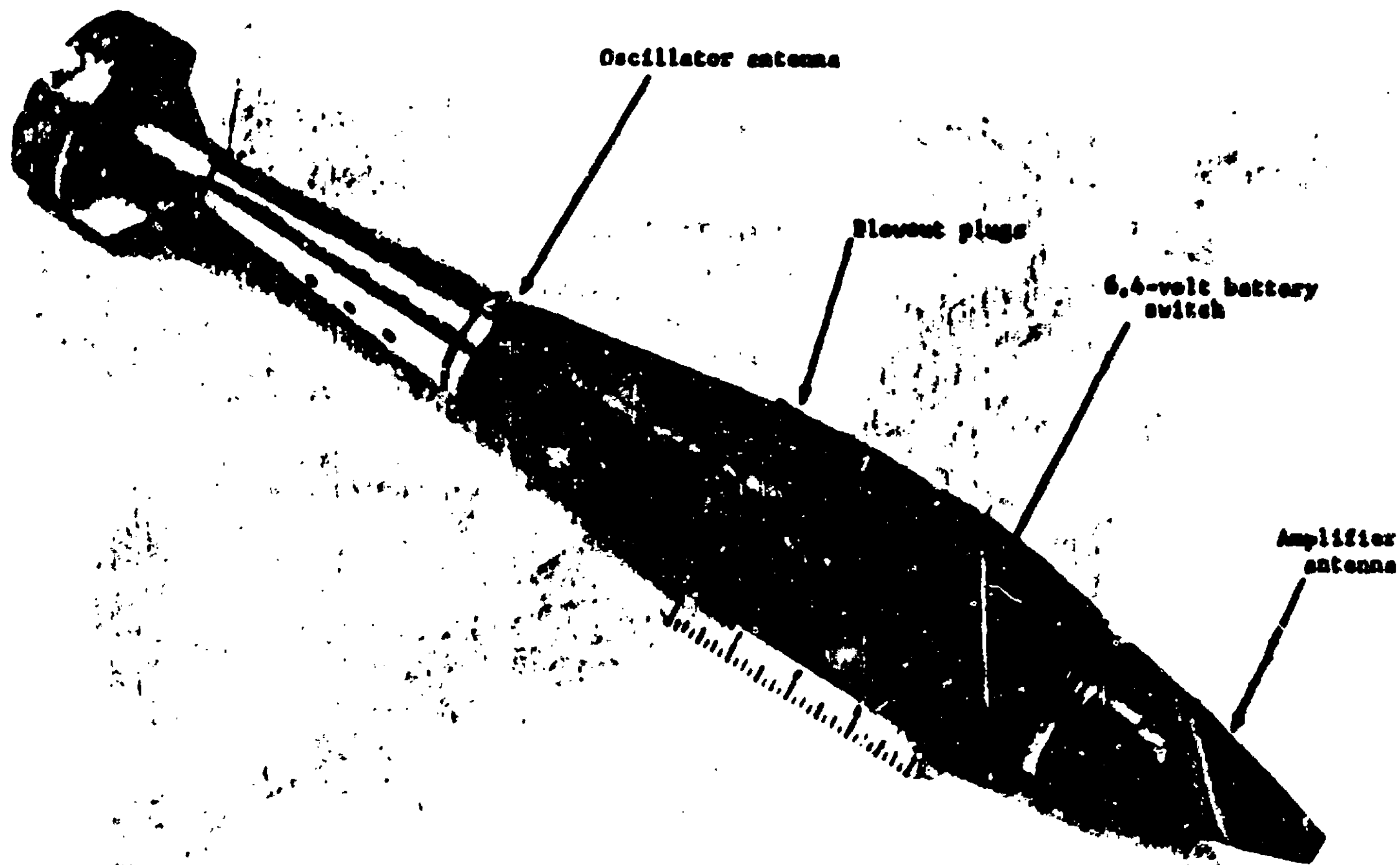

Figure 1. 81-mm test vehicle—assembled for firing.

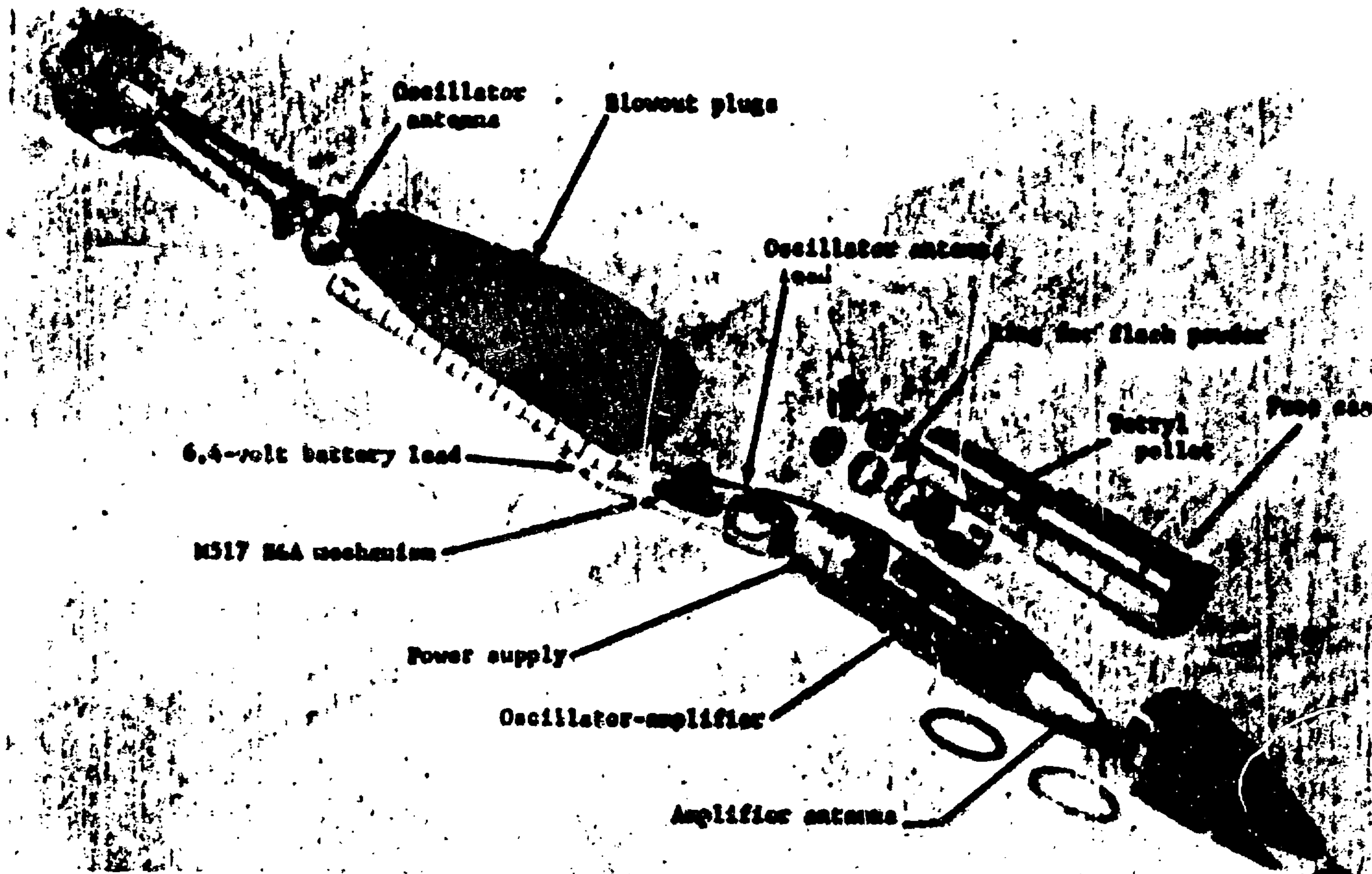

Figure 2. 81-mm test vehicle—exploded view.

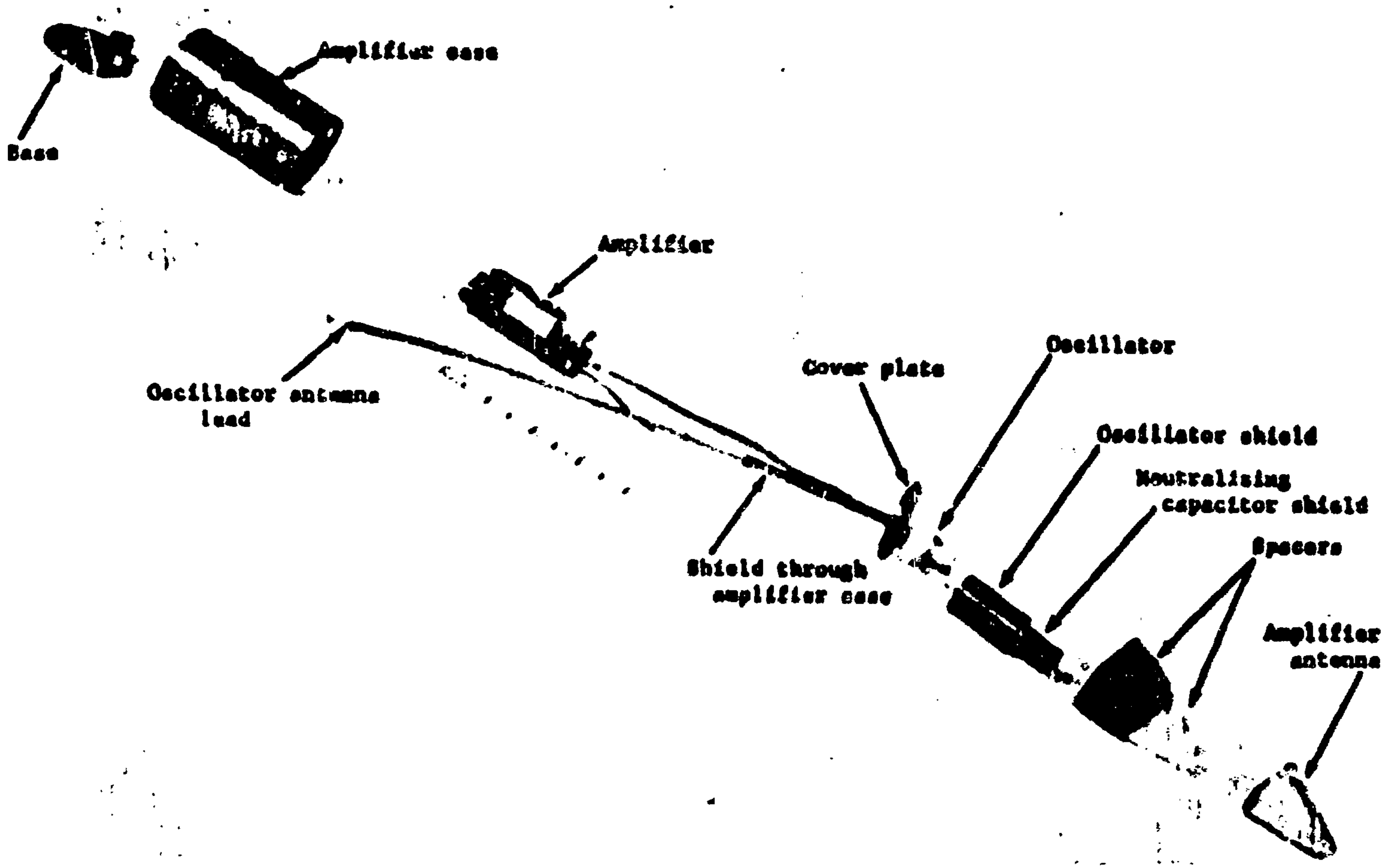

Figure 3. Amplifier and oscillator—exploded view.

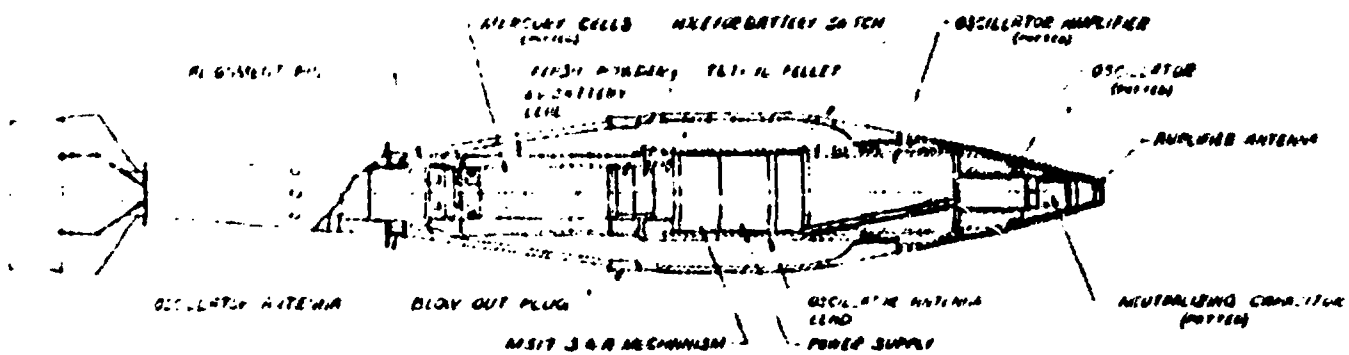

Figure 4. 81-mm test vehicle assembly.

APPENDIX - Design Details

MECHANICAL FEATURES

Several configurations were considered for the electronic packages. The arrangement used was more difficult to achieve but it was selected to simulate proposed use of the fuze. In this proposed use, the oscillator and amplifier were adjacent to each other, and a long shielded lead was used on the oscillator output. This arrangement required the oscillator output lead to pass through the amplifier space. Since there was no time to determine the amount and type of shielding necessary between oscillator and amplifier, fairly heavy magnetic and electrostatic shielding was used. The nose antenna of the M517 fuze was used as the amplifier antenna [illegible] an insulated ring was inserted between the shell and the tail boom for the [illegible] antenna.

A switch for the mercury battery (in the form of a grounding screw) was added on the later models so that assembly of the package for firing could be made without having the amplifier energized. Without the switch, the round had to be fired within two hours of assembly to insure that the battery voltage had not fallen off.

The M48 detonator was tested with an electronic breadboard simulating the proposed firing circuit of the fuze. This detonator was selected because of its short functioning time (about 5 microseconds). However, this detonator did not appear to be sufficiently reliable when used with the proposed circuit. (One dud was obtained and, when used with a tetryl lead, the dent in the test block varied from 0.030 to 0.050 inch). Then the M52 detonator, which is more sensitive and more directional in its explosive output, was tested. Its functioning time varied up to 64 microseconds when tested at 100 volts. This delay in function was considered acceptable, and the M52 detonator was selected for the field tests.

ELECTRONIC FEATURES

The oscillator was based on the circuit of reference 4. The amplifier was based on the circuit of reference 2, with output modified to use a thyratron for firing a detonator, and the bandwidth reduced for improved signal-to-noise ratio (ref 3). The firing circuit was developed to suit the application.

The oscillator was constructed in accordance with the schematic of figure 5. The first oscillator coils were wound with Ceroc wire. This wire was found to be too hard to work with because of its small size (44) and the difficulty of stripping the insulation. Wire with insulation of the Formex-Formvar-Nyclad type was substituted, and was satisfactory; sizes 36 and 42 were used. The iron core was of the shape shown in figure 6.

These oscillators had a resonant frequency of over 40 kc. When the shielded output lead was added, the frequency dropped to about 25 kc. Therefore, amplifiers were designed to peak near 25 kc. Later, with a different lot of cores the frequency of the oscillators with leads fell as low as 13 kc. The frequency was brought up to the 25 kc region by grinding the center of the core a few thousandths of an inch below the outside face, leaving a small airspace in the center leg.

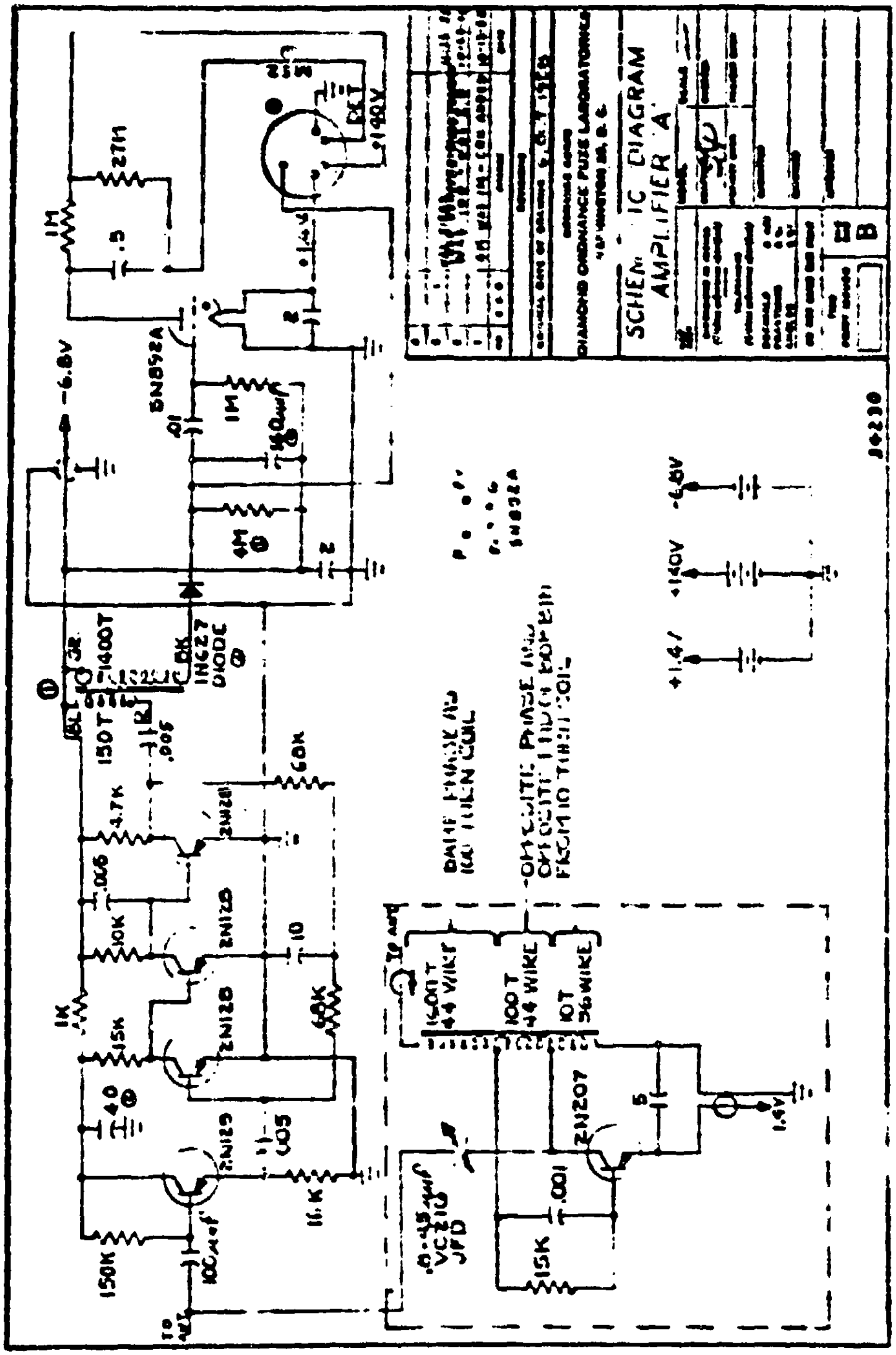

Figure 5. Schematic diagram—amplifier A.

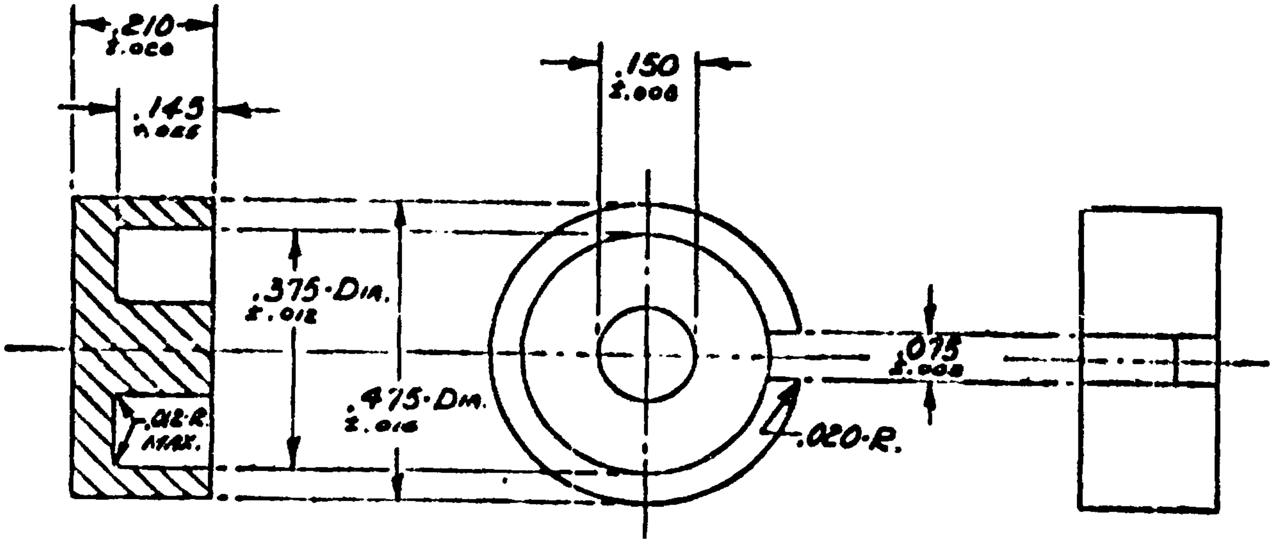

Figure 6. Pot core.

The amplifier was also constructed in accordance with figure 5. First attempts at building the amplifier gave unsatisfactory results. Finally a working model was built by providing copper shields between the first and second stages and between the third and fourth stages. The transformer was fabricated using the core of figure 6.

The system was checked by installing it in a shell with the intended external configuration and without the neutralizing capacitor. Oscillator and amplifier were energized with batteries contained within the shell, and a d-c voltmeter with 1-megohm resistance was inserted in the output circuit at the test lead. This voltmeter was also mounted within the shell. The shell was hung in the air with insulating cords. The "free space" signal input to the amplifier was observed to saturate the amplifier. The gain of the amplifier was lowered until the amplifier was not saturated, and then the voltage output was observed. Next, a low impedance signal source at the oscillator frequency was applied to the amplifier input. A 4-millivolt signal was required to give the amplifier output obtained in free space.

The original amplifier saturated at 15 volts dc with 1.5 mv rms input. The free space signal was thus approximately three times the signal range of the amplifier. Decreasing the amplifier gain would decrease the function height. For example, if the gain were decreased so that 8-mv input would give 15 volts output, the free space output would be about 10 volts, and the function height for 15-volts output would be about 1 inch.

To increase the function height it was decided to retain the full amplifier gain, and to neutralize the free space signal with a 4-mv signal. The phase of the 4-mv signal was reversed with respect to the space signal. This neutralization was provided with a tap on the oscillator and an adjustable capacitor voltage divider to feed a signal to the amplifier antenna. With use of the adjustable capacitor the free space signal could be neutralized readily to within 0.2 mv.

A shell with free space neutralization was hung on an insulating cord with nose end down, and the voltage output of the amplifier was recorded as a function of the distance from the shell to a ground plate. Typical results are shown in figure 7. The straight-line result is caused by the nonlinearity of the amplifier. A hyperbolic type of curve would result from a linear amplifier.

A differentiating network was used on the output of the amplifier so that firing of the detonator would occur on a change of signal rather than on the magnitude of the signal. The hold-off bias on the thyratron grid is -6.4 volts and the thyratron fires with a bias of about -3.0 volts. Thus a rapid 4-volt change in amplifier output is necessary to fire the round. From the curve in figure 7 it is seen that the round should fire about 4 inches above the ground. Five rounds of this type were fabricated but only two checked out suitably for firing.

At about this time it was learned that the 2N128 transistors used in the amplifier had a high failure rate when fired at 10 increments (11,000 g). Tests were conducted with these transistors to determine if they would be suitable for use at lower accelerations. Twenty transistors were fired in the 81-mm mortar with a charge of three increments (2300 g). Fifteen units were oriented so that the accelerating force was normal to the surface of the germanium wafer. Four units failed. Five units were oriented with the accelerating force parallel to the wafer, and one of these failed. To reduce the shock on the transistors, the two rounds were fired at one increment (1000 g).

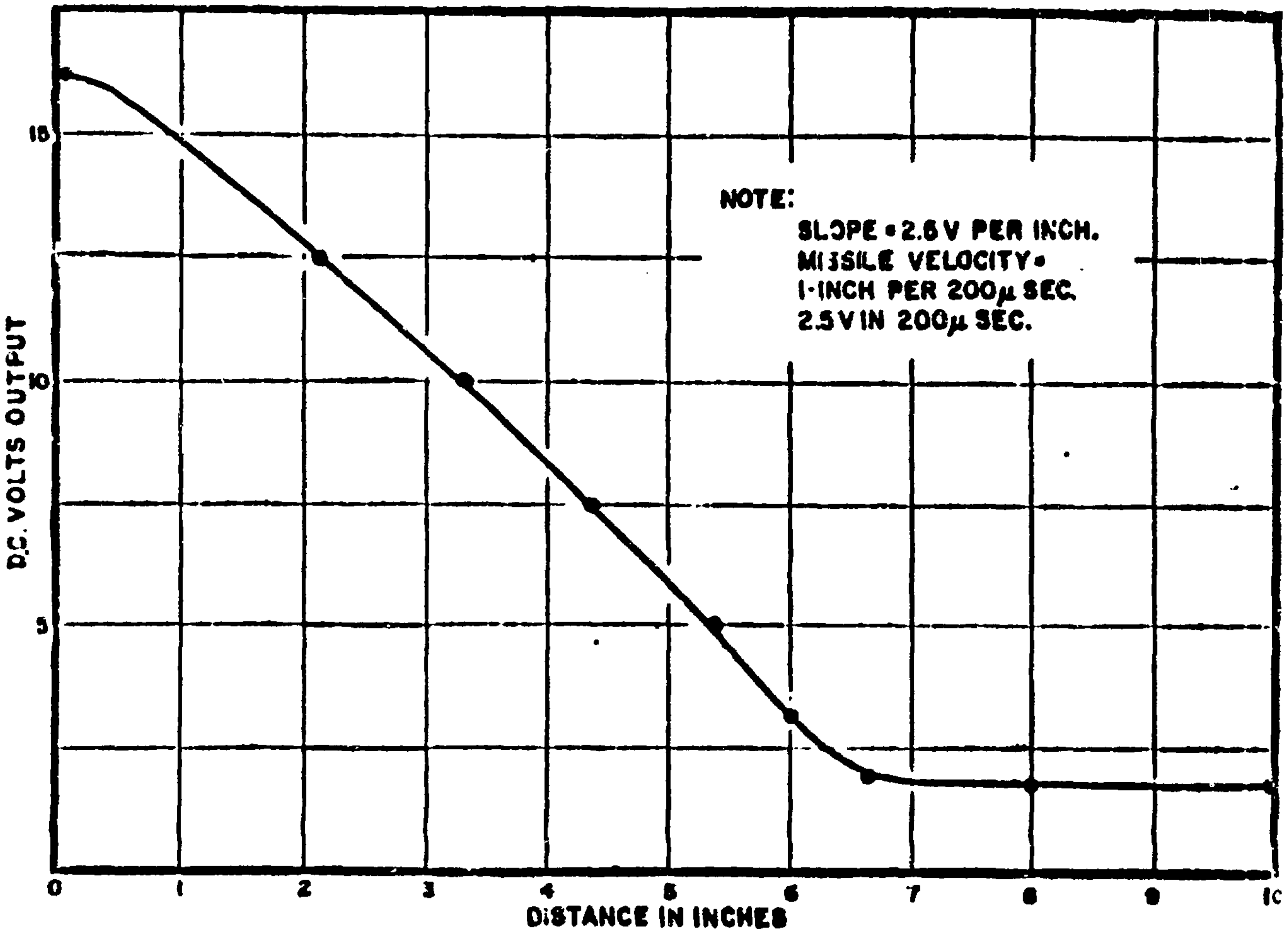

Figure 7. Output voltage vs distance from ground (Amplifier A).

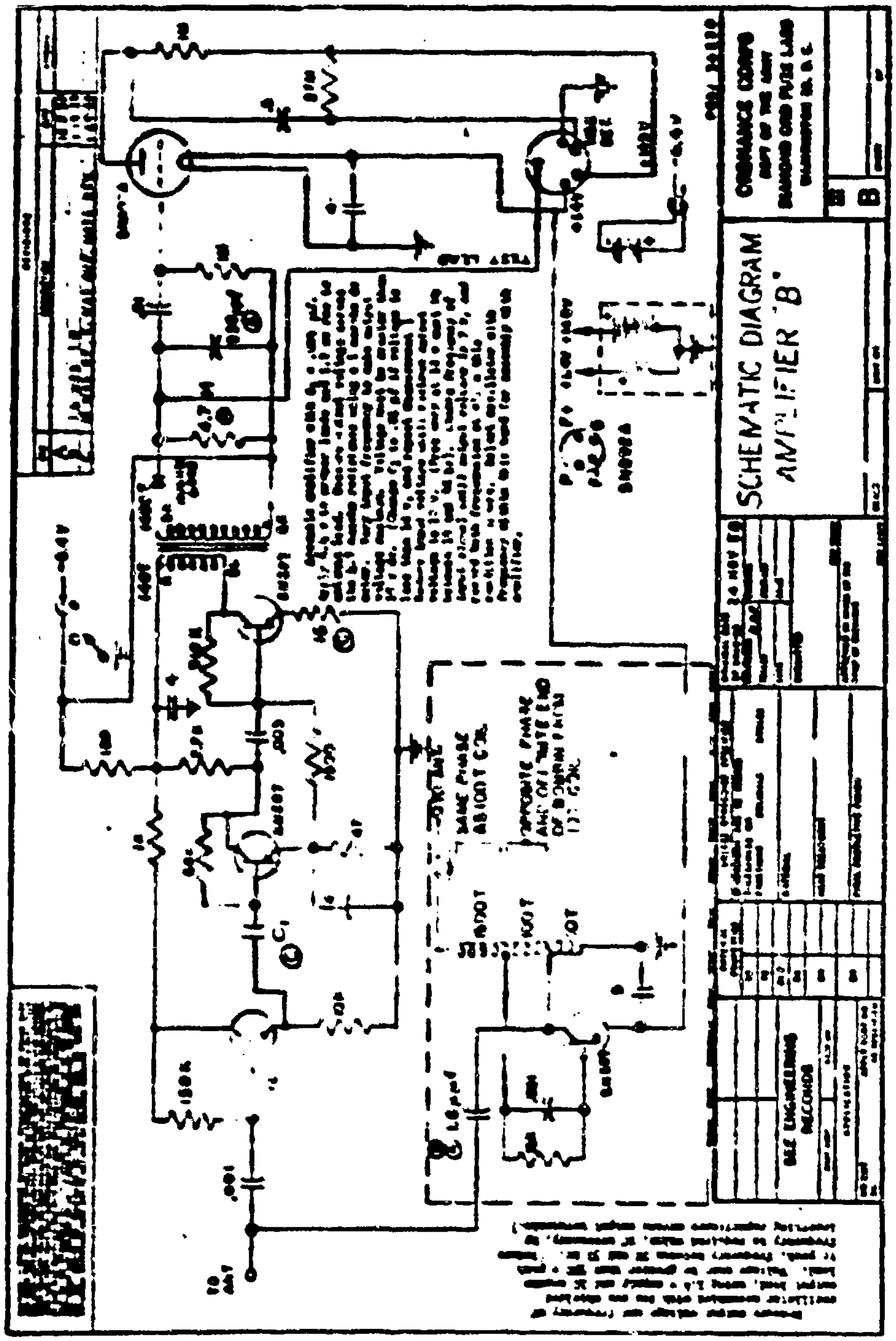

Figure 6. Schematic diagram—amplifier B.

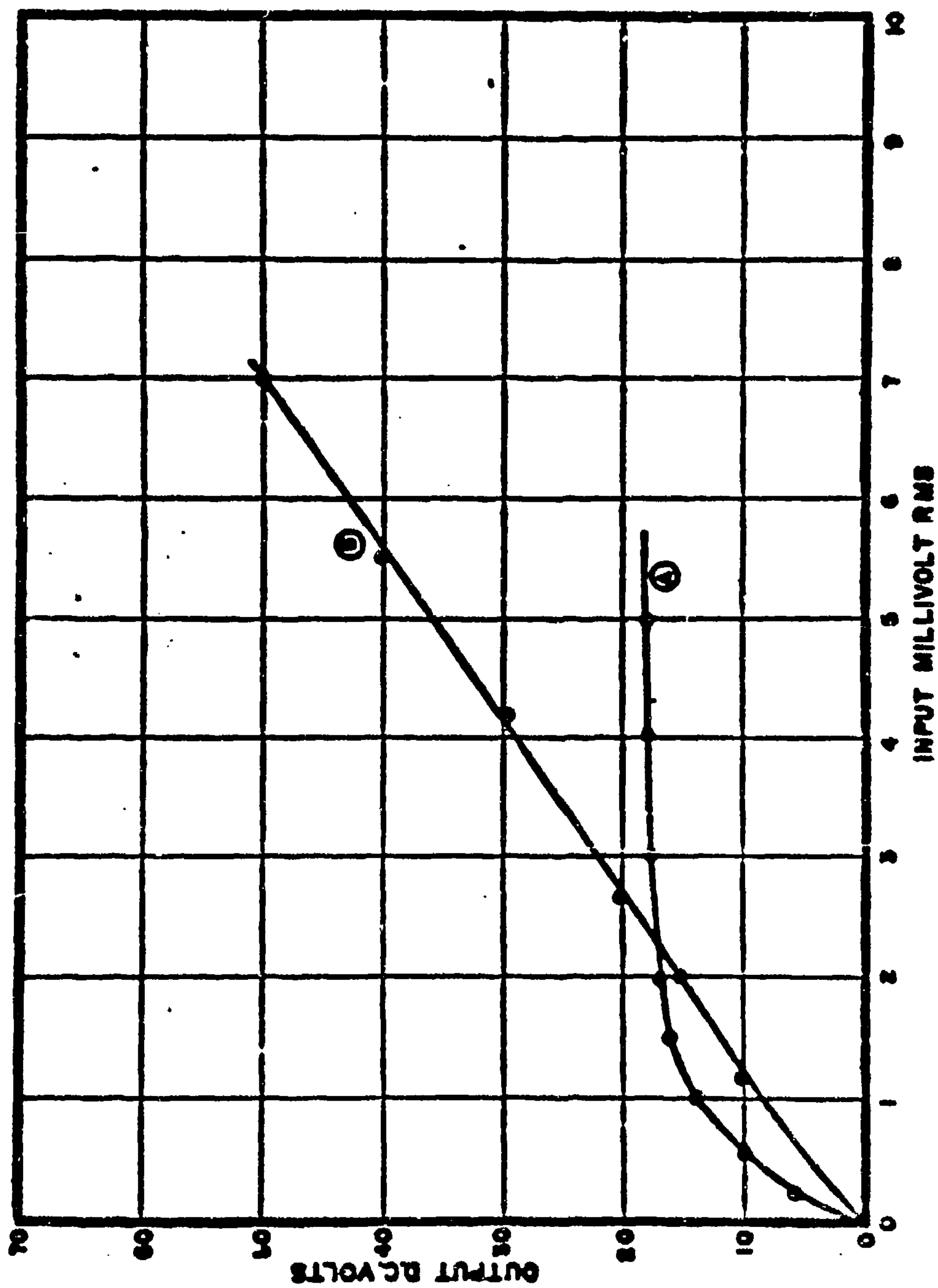

Figure 9. Output voltage vs input voltage (Amplifiers A and B).

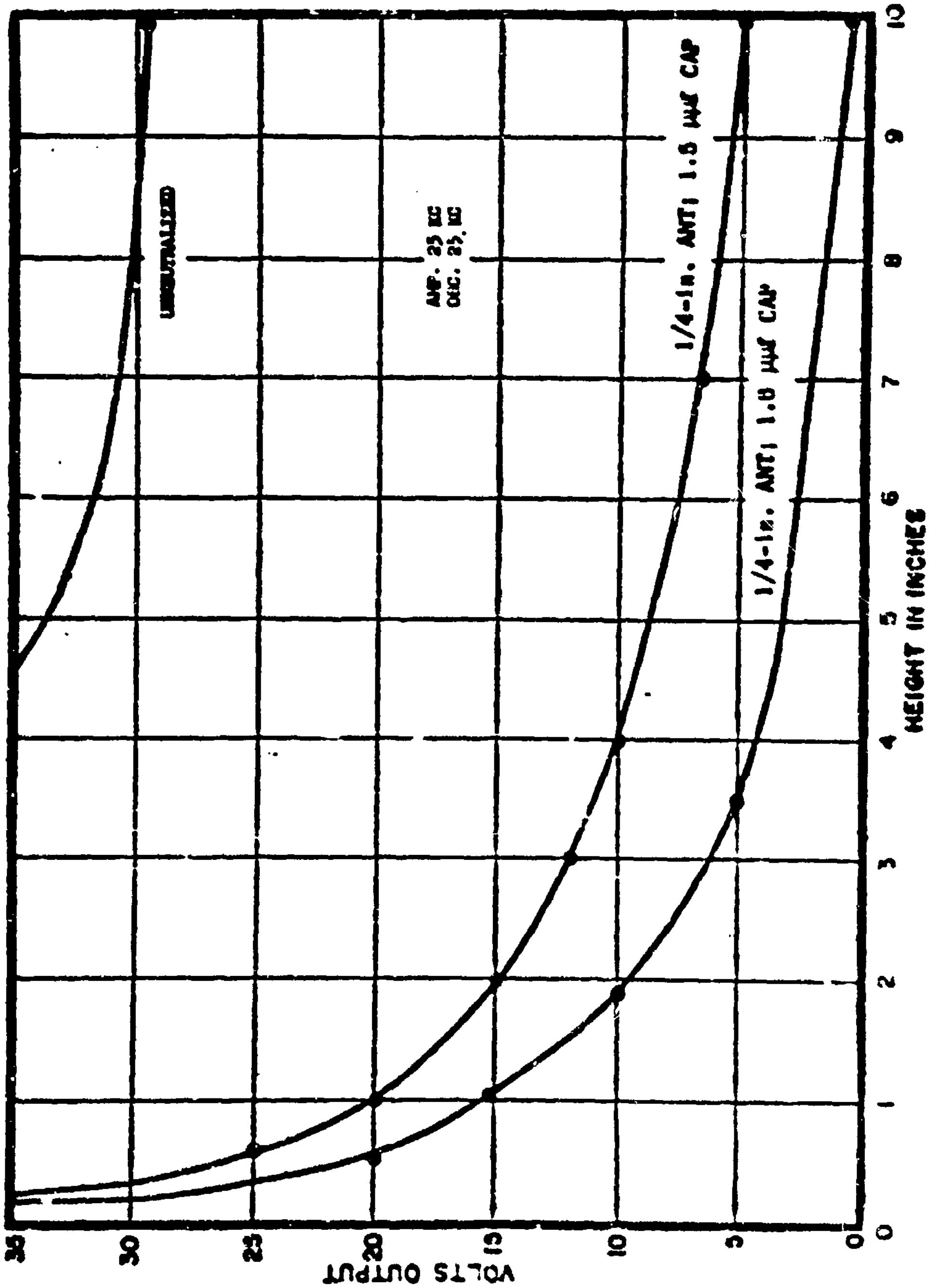

Figure 10. Output voltage vs distance from ground (Amplifier B).

Since the [illegible] transistor was not sufficiently [illegible], it was decided to build an amplifier around the [illegible] transistor. [illegible] others had shown this transistor to have a very [illegible] failure rate at [illegible]. The resulting amplifier circuit is shown in figure 8. Because of difficulties in obtaining enough cores in time for the program, the cores of figure [illegible] were used only for the oscillator, and commercial [illegible] pot cores [illegible] were used for the amplifier. A typical output vs input curve for this amplifier is shown in figure 9. This amplifier does not saturate at the 4-[illegible] signal, whereas, the first amplifier does. The length of the cylindrical [illegible] increased from [illegible] inch to [illegible] inch so that lower amplifier [illegible] could be [illegible].

Curves of output vs input for the amplifier are shown in figure 10 for no neutralization, and with two different values of neutralization. It is clear that neutralization is not critical and that a fixed capacitor can be used.

After the [illegible] checked out, [illegible] rounds were [illegible]. [illegible] were completed, but two did not [illegible] after [illegible] had an open filament; the other had a short between plate and filament. [illegible] of the three remaining rounds did not have neutralization after [illegible] considered satisfactory [illegible]. These were the three rounds [illegible], 1959.

Components were available to complete [illegible] rounds. These were made up like the [illegible]. However, [illegible] amplifiers had too low a gain, and some of the amplifiers and oscillators [illegible] close enough to each other in frequency. The amplifier [illegible] increased by changing one of the capacitors [illegible] in figure [illegible]. The oscillator frequency [illegible] reduced to the desired value by adding a capacitive load. Amplifiers and oscillators were matched so that the frequency of the oscillator was close to the [illegible] frequency of the amplifier. [illegible] of these rounds were used in [illegible] firing tests