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REPORT NO. 269

THE SOLENOID-ELECTROSTATIC ABERDEEN CHRONOGRAPH

by

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THE SOLENOID-ELECTROSTATIC ABERDEEN CHRONOGRAPH

Abstract

This report deals with an equipment for measuring projectile velocities by means of which either solenoid coils or electrostatic antennas are used in conjunction with a newly developed master amplifier and power unit together with a standard Aberdeen Chronograph. The report covers in detail the principle of operation of the various elements of the master amplifier and power unit, the description of the entire apparatus, a complete circuit diagram, a list of all the parts comprising the amplifier and power unit, operating instructions for the entire equipment, and several photographs of the apparatus.

CONTENTS

1. PURPOSE

This apparatus makes possible the use of the Aberdeen Chronograph with either solenoid coils or electrostatic antennas in the measurement of projectile velocities.

2. PRINCIPLES OF OPERATION

2.1 Introduction. The basic functions to be performed by the apparatus are as follows: (a) The production of an electrical transient by each of two or three pickup devices located along the trajectory as the projectile passes through them; (b) the transmission of the pulses to the chronograph position; (c) amplification; (d) the selection of that portion of the pulse occurring at the transit of the bullet; and (e) the discharging successively of the recording sparks of the chronograph by means of this part of the pulses.

The important stages and their functions are represented diagrammatically in Figure 1. The nature of the transient after each operation is also indicated.

2.2 Production of the Transit Pulses. (a) Solenoid Pickups. When a magnetised projectile (the magnetic axis being parallel to the axis of the bullet) passes through a solenoid coil, an electromotive force similar in shape to that of Figure 2 is induced in the coil. The current which flows in the solenoid circuit lags the electromotive force by a slight amount. It has been shown* that the difference in time between the passing of the electromotive force through zero and the passing of the current through zero varies for bullets passing through different portions of the coil, but that it is always less than L/R, where L is the inductance and R the resistance in the solenoid circuit. Accordingly, in solenoid chronographs, in which the instant of zero current is considered to be the instant of passage of the bullet through the central plane of the solenoid coil, L/R should be made less than the maximum permissable uncertainty in time measurement.

* R. H. Kent, Ordnance Technical Notes No. 8.

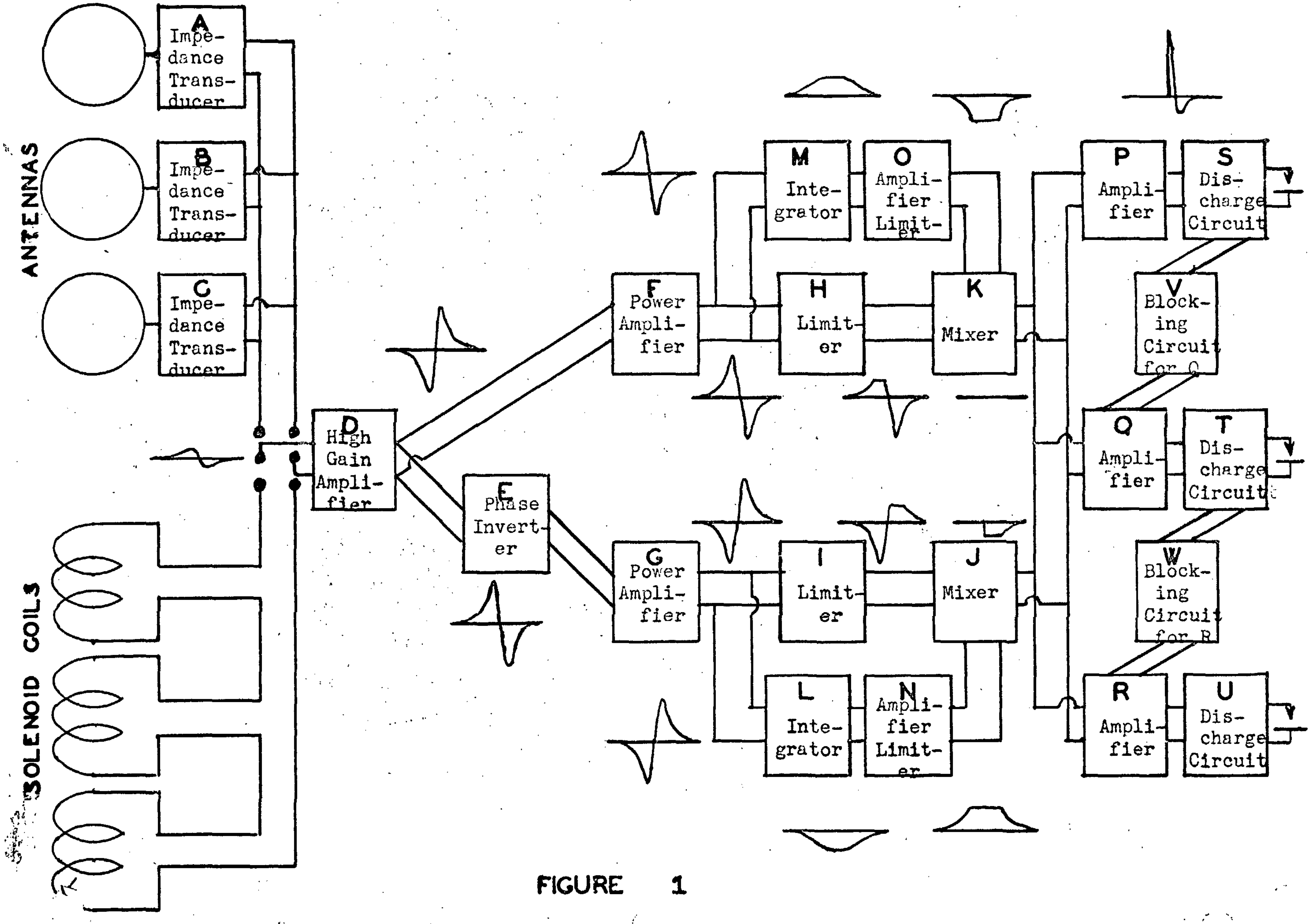
ANTENNAS
SOLENOID COILS
A Impe-dance Trans-ducer
B Impe-dance Trans-ducer
C Impe-dance Trans-ducer
D High Gain Ampli-fier
E Phase Invert-er
F Power Ampli-fier
G Power Ampli-fier
H Limit-er
I Limit-er
K Mixer
J Mixer
M Inte-grator
L Inte-grator
O Ampli-fier Limit-er
N Ampli-fier Limit-er
P Ampli-fier
Q Ampli-fier
R Ampli-fier
S Dis-charge Circuit
T Dis-charge Circuit
U Dis-charge Circuit
V Block-ing Circuit for Q
W Block-ing Circuit for R

FIGURE 1

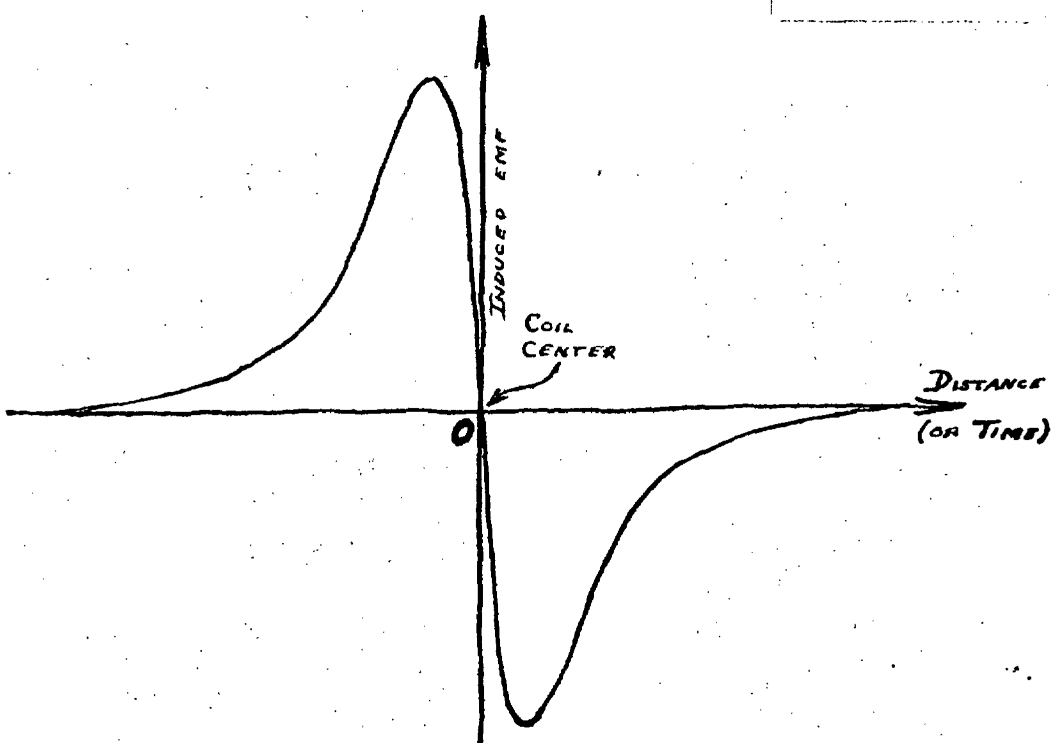

FIG. 2

(b) Electrostatic Pickups. Electrostatic pickups depend for their operation upon the electric charge normally present on projectiles in flight. The production of this charge depends on a number of factors.* The charge may be either positive or negative and varies considerably in magnitude.

The pickup consists of a loop of wire grounded through a high resistance. The loop is connected to the grid of a vacuum tube, which amplifies changes in potential of the loop as the bullet passes through it. If the antenna time constant (RC; resistance to ground x capacity of loop) were infinitesimally small compared with the interval of time during which the antenna is in the effective field of the bullet charge, the current (flow of charge) between ground and antenna would be in one direction as the bullet approaches and in the opposite (returning to the initial equilibrium charge distribution) as the bullet recedes, passing through zero current at the instant the bullet is in the plane of the loop. This current corresponds to a potential of the antenna (i.e., IR drop) which varies in the general manner illustrated in Figure 2. Had the bullet charge been of opposite sign, the ordinates of the curve of Figure 2 would have been reversed.

Actually RC is by no means infinitesimal. A change in the electric field at the loop results in a current change through R which occurs not instantaneously, but lags by an interval dependent upon RC. It has been demonstrated that the interval of time occurring beteen the passage of the

* For a discussion of these factors see "Electrical Phenomena in Small Arms Ballistics", by E. R. Rechel and J. V. Dunham, Frankford Arsenal Report No. 19; 1936. A more thorough investigation of the subject is contemplated by this Laboratory. See also "The Use of the Bullet Charge for Laboratory Velocity Measurements", by James V. Dunham, Frankford Arsenal Report No. 35-A; 1940.

bullet through the plane of the loop and the passage of the potential of the loop through zero is less than RC. Errors in time measurement due to unequal delays for two successive antennas cannot exceed RC, and probably are considerably less than RC. The maximum uncertainty which can be tolerated in the time measurement is taken as the upper limit for RC. In practice a lower limit also exists because of the fact that the amplitude of the transient potential is approximately proportional to RC.

2.3 Transmission. The pickup devices along the trajectory must be connected with the chronograph and auxiliary circuits by means of a transmission line. In order to minimize disturbances picked up by the line, it is terminated with low impedances. In some instances it must also be shielded.

The solenoid coils are connected in series and through the transmission line to the master circuit.

The transients developed by the electrostatic antennas appear initially across a high resistance. In order that approximately the same transient potentials be produced across the low resistances necessary to terminate the lines, an impedance matching stage is used in each pickup. (Figure 1; A, B, and C.)

In both pickup systems all the transients (two or three) are transmitted through a common line to a single amplifier.

2.4 Amplification. The amplifier consists of a stage of high gain (Figure 1; D), a phase inverter (e), and a pair of power amplifier tubes in push-pull. (F, G.) Thus the signal voltage, in addition to being amplified, is sent into two parallel channels in which the amplitudes are numerically equal but are of opposite sign.

2.5 Selection of Instant of Transit. As stated above, the pulse actuating the chronograph must be derived from the steep portion of the transit pulse, as near as possible to the cross-over point. This condition must be fulfilled for either of the two possible polarities. It is accomplished in the following manner:

Each side of the push-pull circuit (from F and G) divides into two channels. Of these, the inner pair in Figure 1 passes through diode limiters (H and I), the purpose of which is to prevent the grids of following stages from being driven positive. Beyond the limiters these two inner channels lead to the control grids of a pair of pentodes, the "Mixers" (J and K). The mixers normally conduct no current because no voltage is applied to the screen grids. Each of the outer push-pull channels passes first into the "Integrator" (L and M). This consists of a resistance and condenser in series across the channel. The time constant of the integrator is several times larger than the duration of the transit pulse; consequently the potential difference across the condenser varies approximately as the time integral of the transit pulse. This integrated transient will always be a positive pulse in one channel and a negative one in the other; the numerical maximum of each occurs at the crossover of the transit pulse. Beyond the integrator the pulse in each outer channel passes through an amplifier (N,O), in which it suffers inversion and is limited in amplitude, to the screen grid of the mixer (J,K). The screen grid of one of the mixers is driven negative; this tube remains nonconducting. The other mixer, however, becomes temporarily sensitive as its screen grid is raised to the normal positive operating voltage. The control grid of this tube is at this instant far negative, past cutoff. At some point on the upswing of the transient curve, not far from crossover, the tube cuts on and amplifies the remainder of the transient, until the screen grid potential returns to zero.

The outputs of the two mixers unite into a common channel. Had the transit pulse polarity been the reverse, a similar pulse would have arrived at this junction point from the opposite channel. This pulse is always negative.

2.6 <u>Distribution and Discharge.</u> The three impulses initiated successively at the three pickup units arrive in the same chronological order at a common point. A method is provided for distributing them in such a way that the first, second and third impulses discharge the first, second and third recording sparks of the chronograph, respectively.

The control grids of three amplifier tubes (P, Q, R) are coupled to the junction point of the two mixers. The output of each of these amplifiers is coupled to a thyratron, the discharge of which produces a spark in the chronograph. Normally, only amplifier P is sensitive. Q and R are biased past cutoff due to the blocking action of V and W. Thus the first pulse, amplified by P, discharges only S. However, the discharge of S acts upon V, which causes Q to assume its normal bias (after a delay, purposely introduced, of a millisecond or two). After S discharges, it remains insensitive for a relatively long time; thus the second pulse is amplified by Q and fires only T. A similar sequence of events enables U to be fired by the third pulse.

3. DESCRIPTION OF THE APPARATUS

3.1 <u>Accuracy</u>. The overall accuracy of the apparatus has been determined by comparison of velocities obtained in a number of firings with corresponding velocities obtained with a standard solenoid chronograph. The results indicated that the overall uncertainty in time measurements is not over

0.4% of the total time interval for time intervals larger than approximately five milliseconds.

The main source of inaccuracy is the variation of the angular velocity of the drum of the Aberdeen Chronograph due to hunting. The supply frequency, it is assumed, is kept at a known and constant value.

The other sources of uncertainty, such as variation in crossover lag, variation in thyratron firing time and wandering of the Aberdeen spark apparently contribute less to the overall error than does hunting.

3.2 List of Units.

Three Electrostatic Pickups, with cable.
*Three Solenoid Coils, with line.
Master Unit.
*Aberdeen Chronograph (two for special applications).
*Source of 60 c/s standard frequency for driving chronograph drum.

3.3 Power Requirements. All power is obtained from the 60 c/s - 115 volt mains. The power consumed, exclusive of that used to operate the chronograph motor, is approximately 100 watts.

3.4 Solenoids. Standard solenoid chronograph coils may be used. For small arms projectiles they should contain at least 200 turns, and be of diameter not exceeding 40 calibers.

3.5 Electrostatic Pickups. The electrostatic antenna consists of a single loop of wire insulated from ground and designed for the minimum capacity to ground consistent with ruggedness and compactness of mounting. The wire is easily replaceable. It is kept under constant tension by means of an adjustable spring located inside the supporting frame.

The vacuum tube (T_{25}, T_{26}, T_{27}, Figure 3) and accompanying circuit are located in a watertight iron box attached to the antenna frame. The tube and circuit may be removed from the box by taking off the plate containing the cable sockets. In two of the units there are two cable sockets; in the third there is but one. Power is supplied the pickup tubes from the master unit. The heaters are operated in series in such a way that the direct current from the high voltage power supply (which fortuitously is approximately equal to the rated heater current for T_{25}, T_{26}, and T_{27}) passes through them. The current is practically the same whether two or three tubes are in series. However, in order that the heater circuit be complete, the pickup unit with the single cable socket must always be operated at the position farthest from the amplifier unit.

* Not supplied.

3.6 Connecting Lines. Ordinary weatherproofed twisted wire may usually be used for interconnecting solenoids and amplifier. However, in locations where there is excessive electrical interference, or whenever the amplifier is set for highest gain, the line should be shielded. The shield should be continuous and grounded to the chassis of the main control circuit.

Three 60-foot lengths and one 120-foot length of cable are provided for interconnecting electrostatic pickups and amplifier. The cable contains four conductors, about one of which is a shield, forming the fifth. On each length there is a male plug on one end and a female plug on the other. The shorter lengths are interchangeable and two may be connected together when longer distances between pickup units are desired.

3.7 Master Unit.

Content. The master unit contains amplifier, selector, distributing and discharge circuits on the upper chassis, and the power supply, and a solenoid coil for magnetising projectiles of diameter up to 40mm on the lower.

Panel. On the panel are the following:

(a) Power Switch. For applying power.
(b) Red Pilot Light. Indication that power is on.
(c) Green Pilot Light. Indication that the time delay has applied the plate voltage.
(d) Fuse. Five-ampere capacity.
(e) Ground Terminal. For connection to a water pipe or other good ground.
(f) Sensitivity Control. A three-position switch which governs the amplification of input signals. At the "High" position the full amplifier gain is obtained.
(g) Magnetising Port. An opening into which projectiles are inserted for magnetisation.
(h) Magnetising Switch. A push-button switch for applying the projectile magnetising current.

Sockets. The various cable sockets located on the master unit are all different. This eliminates the possibility of error in connecting them. They are as follows:

(a) Pickups. For cable from solenoid or electrostatic pickups.
(b) Aberdeen Chronograph. For cable to chronograph.
(c) Power Cable. Upper Chassis. } Interconnected.
(d) Power Cable. Lower Chassis. }

(e) Oscillograph. (Pin jacks) Normally not used. They are for convenience in special applications where velocities are measured by the oscillographic method. The peak voltages of the transients which may be expected here (the red terminal; the black one is grounded) are 0.03 to 1.0 volt above and below the constant bias of +3 volts. They are developed across a resistance of about 500 ohms. An external resistance (the input of the oscillograph) of not less than 1000 ohms may be connected directly across them.

(f) 115 volts 60 cycles. For connection with power mains.

3.8 Aberdeen Chronograph.

Description. See Leeds and Northrup, Operating Instructions for Aberdeen Chronograph. In order to use the Aberdeen Chronograph with the master unit described here it is necessary to make the following alteration in the Aberdeen Chronograph circuit.

Necessary Alteration. The Aberdeen Chronograph was originally designed to receive direct current from the 110 or 220-volt d.c. mains. However, all d.c. voltages necessary for the operation of this apparatus are obtained from the master unit. The d.c. socket on the chronograph must not be used. The three discharge circuits in the Aberdeen are normally connected to the d.c. socket through three pairs of 5000-ohm resistors. In order that the three circuits be isolated from each other, the resistors must be disconnected from the condenser circuits. This is accomplished by removing the wooden panel from the side of the chronograph, and with a soldering iron disconnecting one end of each of the six resistors. All other connections must be left intact.

Frequency of Power Source for Driving Chronograph Motor. The chronograph motor may be operated from the 60 c/s, 115-volt a.c. mains, in which case a frequency meter is necessary, or it may be driven by a source of accurately controlled 60 c/s alternating current, such as a crystal oscillator-multivibrator circuit or a tuning fork controlled supply. An accurately controlled frequency is recommended.

4. OPERATING INSTRUCTIONS

4.1 Use of the Two Types of Pickups. Whenever the projectiles contain steel and can therefore be magnetised, it is perhaps advisable to employ the solenoid pickup system. For nonmagnetic projectiles the electrostatic pickups must be used. The electrostatic system has two limitations--it is of no value when one of the pickups must be located so close to the muzzle of the gun that the charged gases from the blast strike the antenna (about 12' for cal. .30 where no blast baffles are used), and it cannot be used with tracers.

4.2 Installation.

Pickups.

(a) Mounting: Mount the pickups securely at the proper positions. The plane of each solenoid or antenna should be perpendicular to the trajectory. The bullet should pass through the central portion of the coil or loop.

(b) Solenoid connections: Connect the solenoids in series, and attach to the line. The other end of the line must be connected to terminals 1 and 2 of the master unit plug, and terminals 8 and 10 of the plug must be connected together.

(c) Electrostatic Pickup connections: Mount unit having the single cable socket at end farthest from master unit. If two units are used connect one cable between the two and another cable from near unit to master unit. If three units are used, connect farthest with center one, center one with nearest, and nearest with master unit. Do not ground the pickups. This is done through the master unit.

Master Unit.

(a) Locations: The master unit should be located some distance to the rear of the gun (at least 15' for cal. .30) or shielded from blast waves. If it is near the gun, it should rest on wood or some resilient material in order to minimize shock.

(b) Grounding: The binding post on the panel should be connected to a good ground, such as a water pipe, or a rod driven into the ground deep enough to reach moist earth. Improper grounding may cause spurious sparks on the chronograph.

(c) Other connections: Insert all plugs into the proper sockets.

Aberdeen Chronograph. Be sure the alteration to the chronograph described in section 3.8 has been made. Connect the three pairs in the cable from the master unit to the corresponding terminals on the chronograph.

4.3 Operation

(a) Applying power. Connect to the power mains and apply power by means of the switch. The green light should light immediately, then after two minutes the red light. It is best to allow about five minutes for the apparatus to heat.

(b) Sensitivity control. With electrostatic pickups, the sensitivity control should always be on position "High." With solenoids, the control should be at the highest position for which outside electrical disturbances do not produce sparking.

(c) Chronograph. Operation of the Aberdeen Chronograph is described in the Leeds and Northrup instruction sheet accompanying the instrument. The three sparks may be tested by means of the three push-buttons on the chronograph. When any one of the buttons is pressed, only the spark corresponding to that button should occur.

(d) Recovery after firing. An interval of about 6 seconds is necessary for the recharging of the chronograph condensers after a spark is discharged. Consequently, at least 6 seconds should elapse between the firing of consecutive rounds as well as between the testing of a spark and the firing of a round.

(e) Magnetising. If solenoids are used, projectiles must be magnetised. Insert into the magnetising port the bushing which most nearly fits the projectile. Then magnetise by inserting projectile and holding the push-button down for at least 5 seconds. Do not attempt to take a velocity while magnetising is in progress.

4.4 Servicing. If sparks occur due to disturbances from other electrical apparatus, or if two or three sparks occur simultaneously, check the ground connection. If necessary use another ground. If solenoids are used, switch sensitivity control to "Low", or use shielded line. If apparatus fails to function at all, check all connections. Observe whether the regulator tubes (VR 150 and VR 105) glow. The color should be light purple. If not, there is no plate current. If failure occurs with electrostatic pickups, try solenoids. If this corrects the trouble, one of the pickup tubes is probably burned out.

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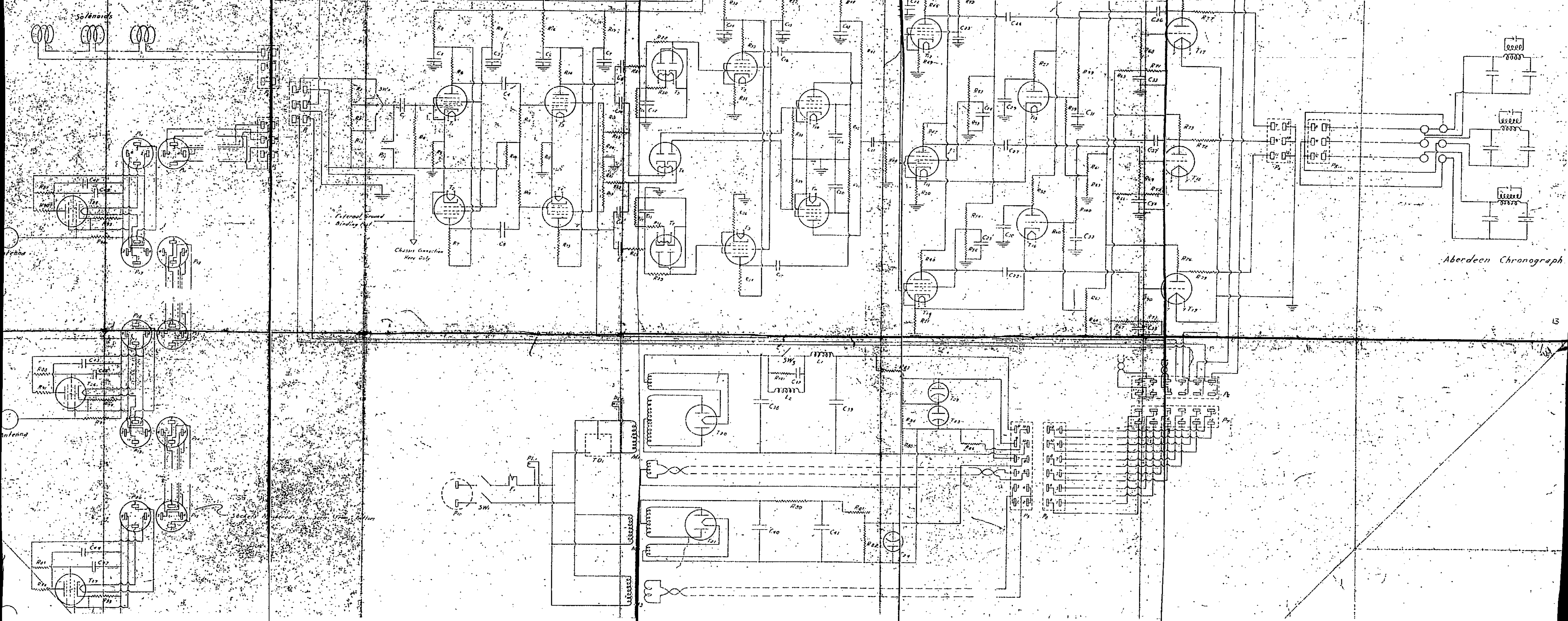


Solenoids
Antenna
External Ground Binding Post
Chassis Connection Here Only
Aberdeen Chronograph

6. LIST OF PARTS

Letters with subscripts refer to circuit diagram.

TUBES

T_1	6SJ7	T_{15}	6J5
T_2	"	T_{16}	"
T_3	6F6	T_{17}	FG27-A
T_4	"	T_{18}	"
T_5	6H6	T_{19}	"
T_6	"	T_{20}	5U4-G
T_7	"	T_{21}	"
T_8	6SJ7	T_{22}	VR150
T_9	"	T_{23}	"
T_{10}	"	T_{24}	VR105
T_{11}	"	T_{25}	12SJ7
T_{12}	"	T_{26}	"
T_{13}	"	T_{27}	"
T_{14}	"		

RESISTORS

Abbreviations: ω = ohms; M = thousand ohms; Ω = megohms; w = watts, power rating.

R_1	100ω	1/2w	R_{26}	1.0 Ω	1/2w
R_2	200ω	1/2w	R_{27}	"	"
R_3	650ω	1/2w	R_{28}	0.5 Ω	1/2w
R_4	0.1 Ω	1/2w	R_{29}	"	"
R_5	500ω	1/2w	R_{30}	0.5 Ω	1/2w
R_6	0.1 Ω	2 w	R_{31}	"	"
R_7	"	"	R_{32}	10M	2 w
R_8	20M	2 w	R_{33}	20M	2 w
R_9	0.25 Ω	2 w	R_{34}	20M	2 w
R_{10}	10M	1/2w	R_{35}	100ω	1/2w
R_{11}	0.25 Ω	1/2w	R_{36}	"	"
R_{12}	"	"	R_{37}	50M	2 w
R_{13}	750ω	20w	R_{38}	0.5 Ω	1/2w
R_{14}	15M	40w	R_{39}	"	"
R_{15}	"	"	R_{40}	25M	1 w
R_{16}	2500ω	40w	R_{41}	2M	1/2w
R_{17}	10M	20w	R_{42}	0.1 Ω	1/2w
R_{18}	25M	1 w	R_{43}	"	"
R_{19}	"	"	R_{44}	0.1 Ω	1/2w
R_{20}	2M	1/2w	R_{45}	15M	2 w
R_{21}	"	"	R_{46}	25M	2 w
R_{22}	0.5 Ω	1/2w	R_{47}	"	"
R_{23}	"	"	R_{48}	"	"
R_{24}	0.25 Ω	1/2w	R_{49}	600ω	1/2w
R_{25}	"	"	R_{50}	"	"

RESISTORS(CONT'D)

Abbreviations: ω = ohms; M = thousand ohms; Ω = megohms; w = watts, power rating.

R_{51}	600ω	1/2w		R_{76}	0.2Ω	1 w
R_{52}	0.2 Ω	1 w		R_{77}	11ω	2 w
R_{53}	0.2 Ω	1 w		R_{78}	"	"
R_{54}	"	"		R_{79}	"	"
R_{55}	0.1 Ω	1 w		R_{80}	3M	20w
R_{56}	"	"		R_{81}	5M	25w, Ohmite "Dividohm"
R_{57}	10M	2 w		R_{82}	0.1Ω	2 w
R_{58}	"	"		R_{83}	5M	50w, Ohmite "Dividohm"
R_{59}	0.5 Ω	1/2w		R_{84}	25M	25w, Ohmite "Dividohm"
R_{60}	"	"		R_{85}	2M	20w
R_{61}	0.1 Ω	2 w		R_{86}	250ω	20w
R_{62}	"	"		R_{87}	0.2Ω	1 w
R_{63}	1M	1/2w		R_{88}	"	"
R_{64}	"	"		R_{89}	"	"
R_{65}	20M	1 w		R_{90}	50M	2 w
R_{66}	"	"		R_{91}	"	"
R_{67}	"	"		R_{92}	"	"
R_{68}	0.1 Ω	1/2w		R_{93}	1M	1 w
R_{69}	"	"		R_{94}	"	"
R_{70}	"	"		R_{95}	"	"
R_{71}	5M	1/2w		R_{96}	5.0 Ω	1/2w
R_{72}	"	"		R_{97}	"	"
R_{73}	"	"		R_{98}	"	"
R_{74}	0.2 Ω	1 w		R_{99}	0.15 Ω	1/2w
R_{75}	"	"		R_{100}	"	"
				R_{101}	500ω	1/2w

CONDENSERS

Abbreviations: µf = microfarad; P = paper condenser, tubular form, rated at 600 volts d.c.; EL = dry electrolytic condenser, tubular form, rated at 450 volts d.c. working voltage unless specified otherwise.

C_1	0.5µf	P	C_{25}	16 µf	EL
C_2	8 µf	EL	C_{26}	0.005µf	P
C_3	4 µf	EL	C_{27}	0.005µf	P
C_4	0.5µf	P	C_{28}	0.005µf	P
C_5	0.5µf	P	C_{29}	16 µf	EL
C_6	16 µf	EL	C_{30}	16 µf	EL
C_7	8 µf	EL	C_{31}	0.05µf	P
C_8	0.25µf	P	C_{32}	0.05µf	P
C_9	0.25µf	P	C_{33}	8 µf	EL, 250 volts d.c.
C_{10}	0.5µf	P	C_{34}	8 µf	EL, 250 volts d.c.
C_{11}	0.5µf	P	C_{35}	8 µf	EL, 250 volts d.c.
C_{12}	0.001µf	P	C_{36}	0.5µf	P
C_{13}	0.001µf	P	C_{37}	0.5µf	P
C_{14}	16 µf	EL	C_{38}	16 µf	EL, 600 volts d.c.
C_{15}	4 µf	EL	C_{39}	16 µf	EL, 600 volts d.c.
C_{16}	0.5µf	P	C_{40}	16 µf	EL, 250 volts d.c.
C_{17}	0.5µf	P	C_{41}	32 µf	EL, 250 volts d.c.
C_{18}	8 µf	EL	C_{42}	8 µf	EL
C_{19}	0.001µf	P	C_{43}	8 µf	EL
C_{20}	0.001µf	P	C_{44}	8 µf	EL
C_{21}	0.5µf	P	C_{45}	8 µf	EL
C_{22}	16 µf	EL	C_{46}	8 µf	EL
C_{23}	8 µf	EL	C_{47}	8 µf	EL
C_{24}	16 µf	EL	C_{48}	0.1µf	P

PLUGS AND SOCKETS

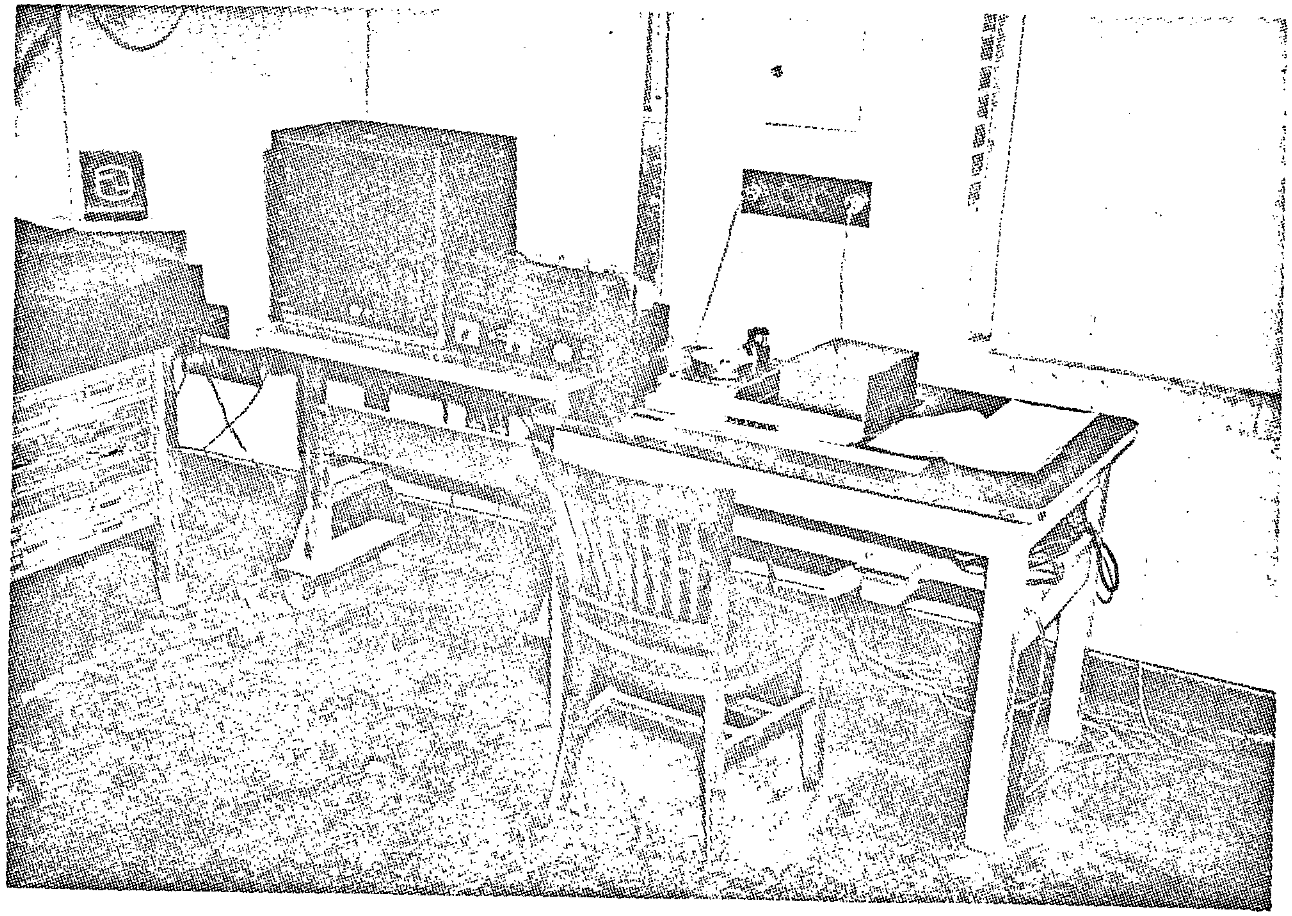
P_1	Socket,	6 contact.	H. B. Jones Co.,		heavy duty
P_2	Plug	"	"		"
P_3	"	"	"		"
P_4	Plug	"	"		"
P_5	Socket	"	"		"
P_6	Plug	12 contact	"		"
P_7	Socket	"	"		"
P_8	Plug	"	"		"
P_9	Socket	"	"		"
P_{10}	Recessed 110v power plug				
P_{11}	Cable connector		Female	Amphenol	92F1
P_{12}	"	"	Male	"	92M
P_{13}	"	"	Female	"	92F1
P_{14}	"	"	Male	"	92M
P_{15}	"	"	Female	"	92F1
P_{16}	Panel receptacle		Male	"	92C1
P_{17}	"	"	Female	"	92C
P_{18}	"	"	Male	"	92C1
P_{19}	"	"	Female	"	92C
P_{20}	"	"	Male	"	92C1
P_{21}	Phone tip jacks, pair, red and black				

MISCELLANEOUS

M_1	Power Transformer 5v. at 3A; 6.3v. at 6A	520-0-520 v.a.c. at 250 ma; Kenyon T-216
M_2	Bias Transformer	250-0-250v., 50ma; 5v. at 2A Kenyon T-222
M_3	Filament Transformer	5v. at 15A Kenyon T-391
L_1	Filter Reactor	12h. at 250 ma. Kenyon T-168
TD_1	Time Delay Relay	Dunco TD 97
SW_1	Power Switch	D. P. S. T., toggle
SW_2	Gain Switch	S. P. -3 Throw, toggle
PL_1	Pilot Light, Green	110v.; Trutest No. 14174
PL_2	Pilot Light, Red	110v.; Trutest No. 14174
F_1	Fuse and Holder, 5 amp.	
L_2	Solenoid coil for magnetising projectiles (40mm capacity)	
SW_3	Push-button switch (Breaks contact on push)	

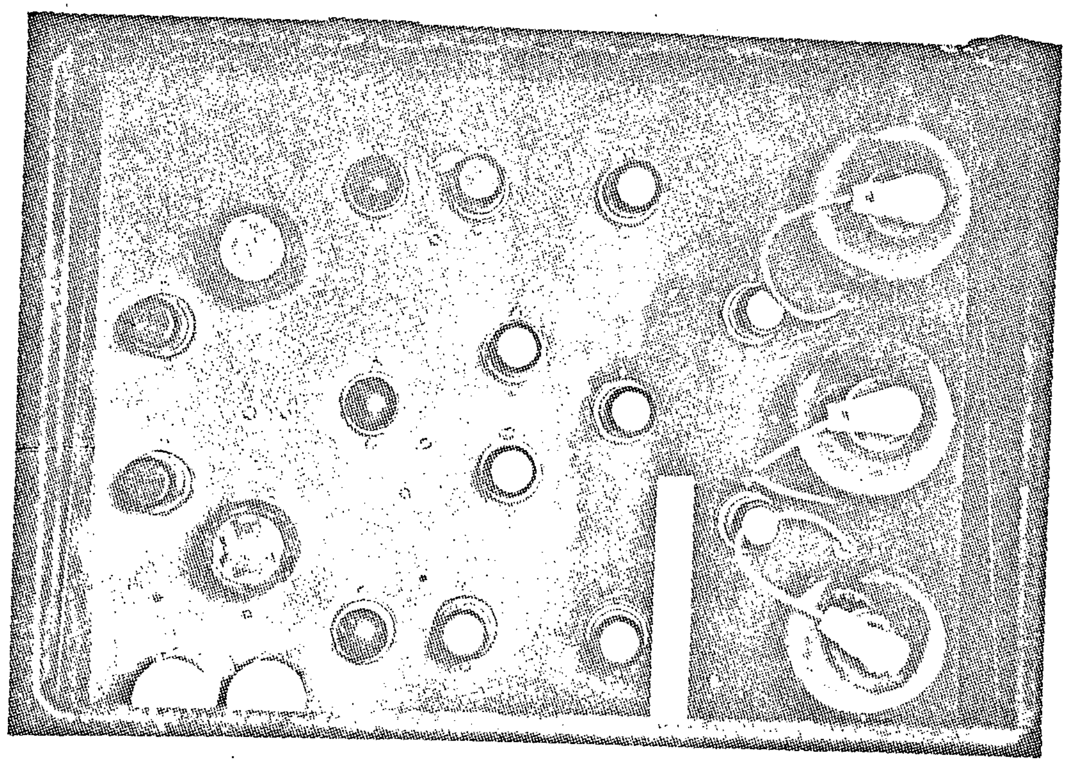
7. PHOTOGRAPHS OF APPARATUS

Note: The photographs which follow are of the pilot model of the apparatus. This model differs from the description in the text in a few minor details.



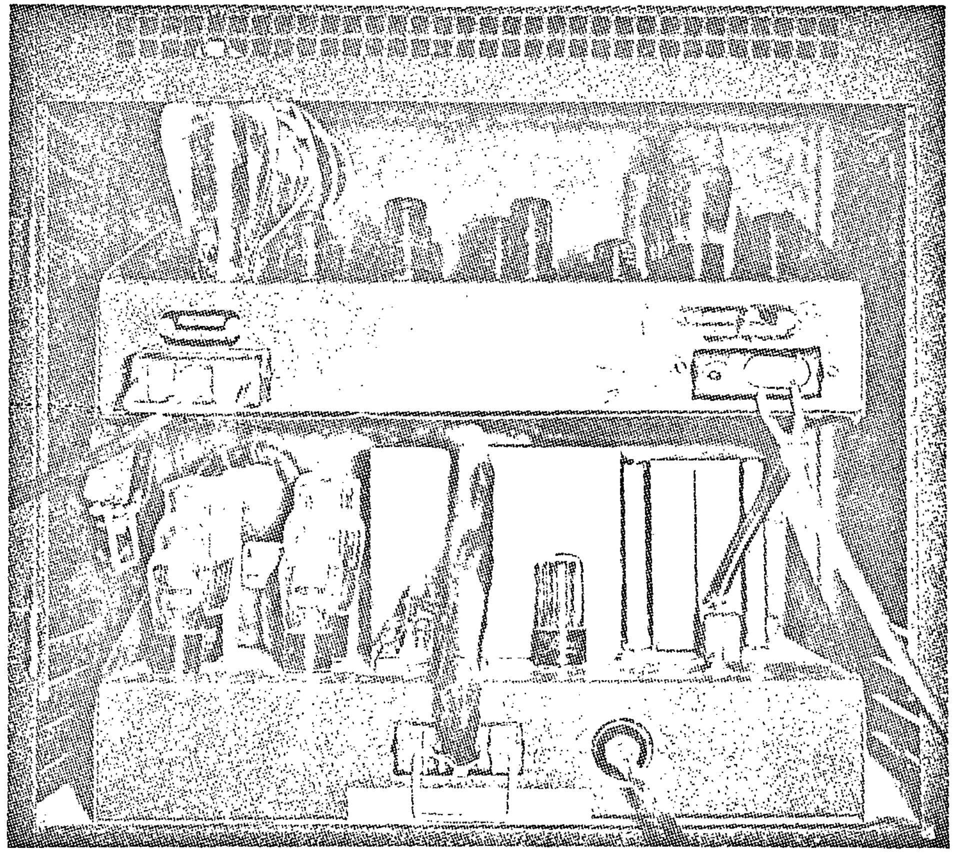
57392 2-12-42 ABERDEEN PROVING GROUND ORDNANCE DEPT.

Complete Chronograph Set-up at Michaelsville Small Arms Range. Left to right: Master Unit, Crystal Controlled Frequency Standard, and Aberdeen Chronograph.



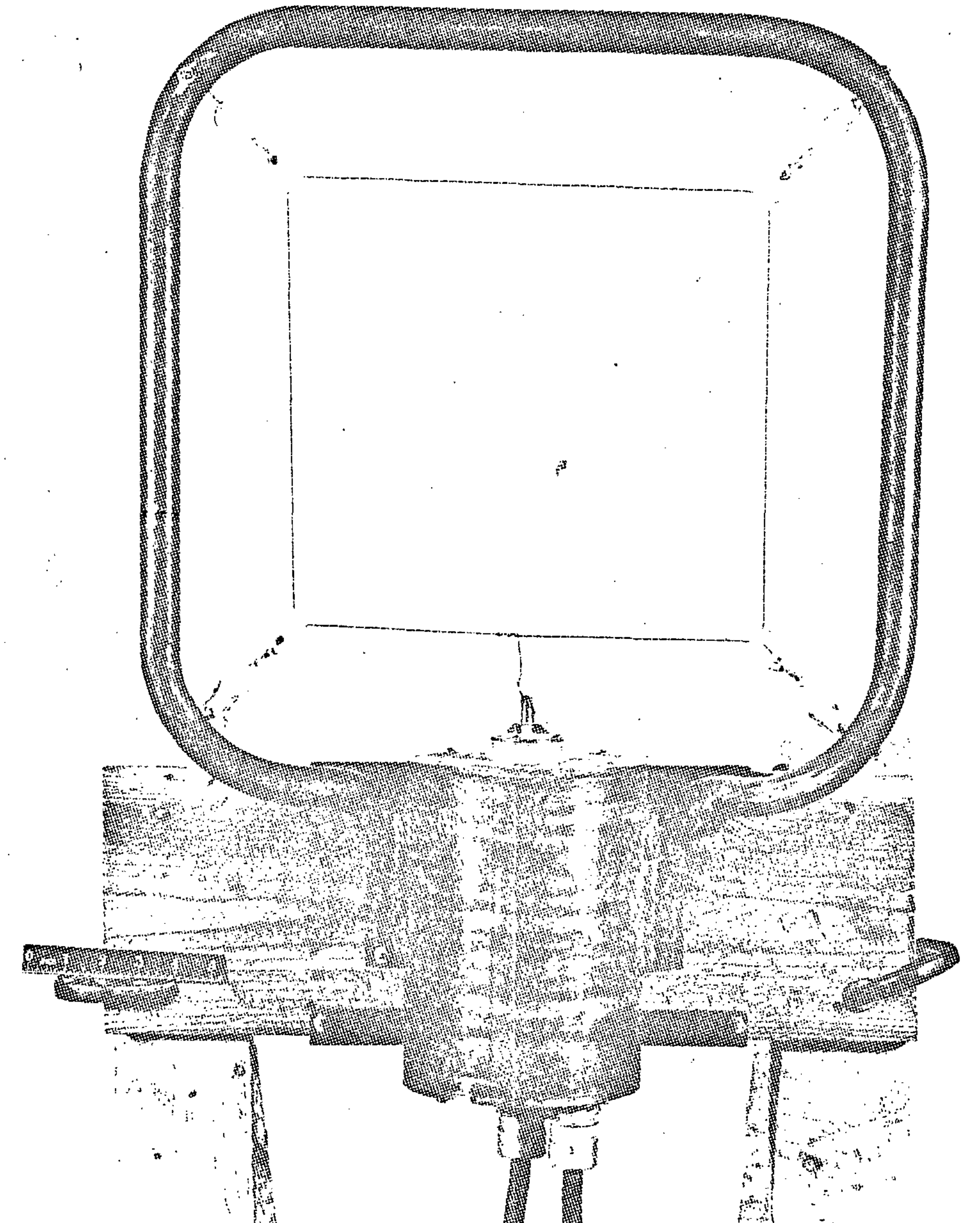
57393 2-12-42 ABERDEEN PROVING GROUND ORDNANCE DEPT.

Chronograph Set-up at Michaelsville Small Arms Range. Top view of Master Unit, showing tubes of the amplifying, selecting, and discharge circuits.



57394 2-12-42 [illegible] PROVING GROUND ORDNANCE DEPT

Chronograph Set-up at Michaelsville Small Arms Range. Rear view of Master Unit. Lower Chassis contains the power supply.



57395 2-12-42 ABERDEEN PROVING GROUND ORDNANCE DEPT

Single Electrostatic Pick-up Unit for Electrostatic Chronograph.

[redacted]

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ABSTRACT:

Report deals with an equipment for measuring projectile velocities by means of which either solenoid coils or electrostatic antennas are used in conjunction with a newly developed master amplifier and power unit and a standard Aberdeen chronograph. The report covers in detail the operating principles of the various elements of the master amplifier and power unit, a description of the entire apparatus, a complete circuit diagram, a list of all the parts comprising the amplifier and power unit, operating instructions for the entire equipment, and several photographs of the apparatus.

Limited Approval must be obtained from CRDTX Wash.DC.

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