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AN EXPLORATORY INVESTIGATION INTO THE POLARITY STABILITY OF THE ELECTROSTATIC CHARGE ON AN IN-FLIGHT PROJECTILE

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ABSTRACT

This paper describes exploratory experiments performed to determine the effects of gun barrel temperature on the stability of an in-flight bullet's natural electrostatic charge.

The data derived from these exploratory experiments indicate that (1) there is a correlation between the polarity (negative-positive-zero) stability of the projectile's electrostatic charge and the thermal inertia effects in the rifle; (2)discrete mobile signal phenomena exist as a function of the thermal conditions in the launcher; and (3) it is possible to predict and/or control specified characteristics of the electrostatic charge on an in-flight projectile.

FOREWORD

The existence of electrostatic charges on in-flight projectiles has been described by several investigators. The problem of controlling the polarity and amplitude of such charges has given rise to a number of theories regarding the genesis of the phenomena. Experiments performed in the Electrophysical Laboratory of the U.S. Naval Training Device Center have indicated that there is a possible correlation between the projectile-launcher temperature characteristics and the electrostatic-charge polarity and amplitude on the projectile.

This paper describes a series of experiments designed to test the correlation, using an M-2 Carbine. (It is planned, at some later date, to further test the correlation by the Method of Statistical Inference.)

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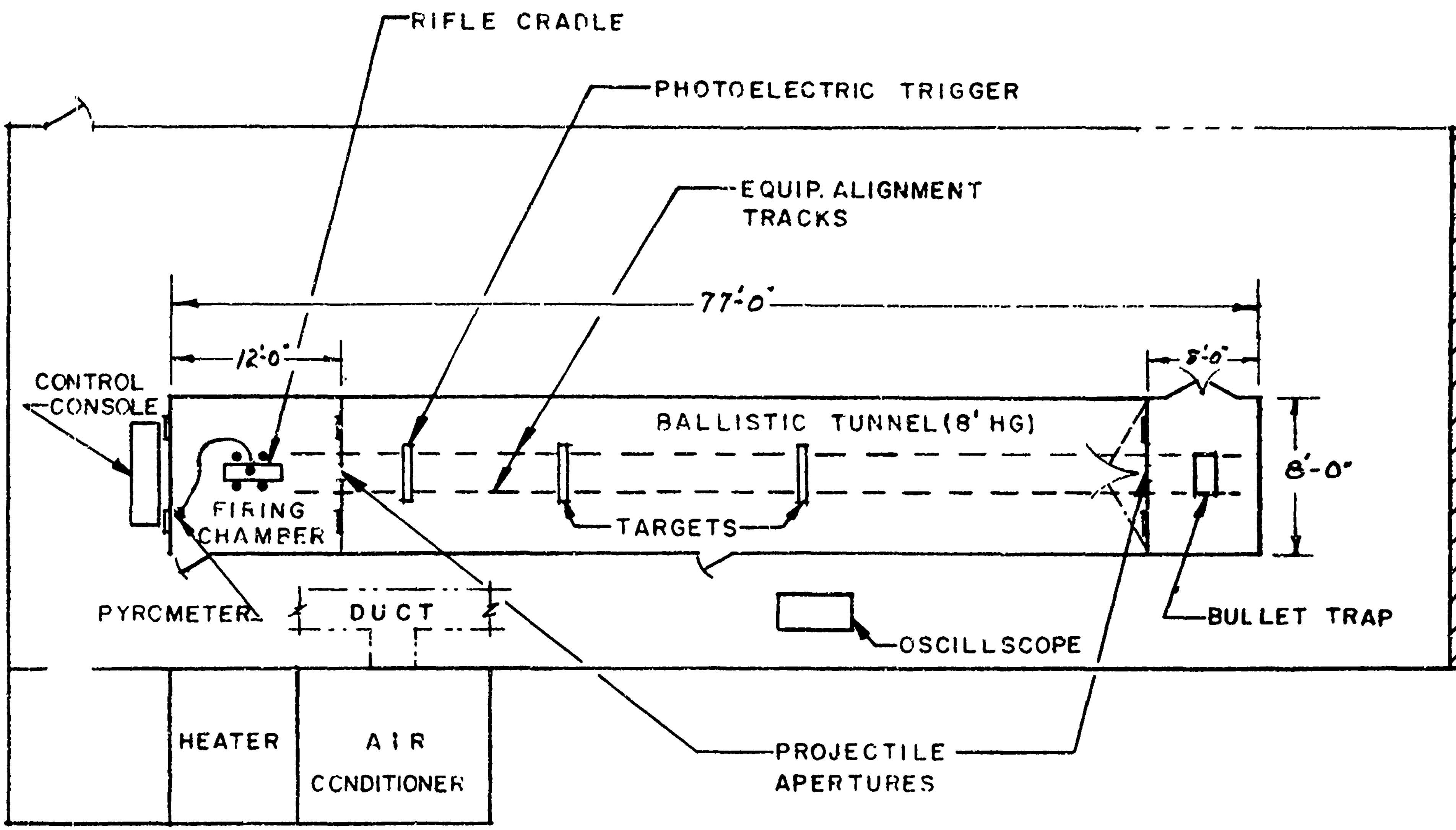


Figure 1. Electrophysical Laboratory

AN EXPLORATORY INVESTIGATION INTO THE POLATIRY STABILITY OF THE ELECTROSTATIC CHARGE ON AN IN-FLIGHT PROJECTILE

INTRODUCTION

Background. During the course of investigating non-material targets for application to gunnery training, use of the natural electrostatic charge on in-flight projectiles was studied as a possible means of solving the problem.

During the investigation, polarity and amplitude variations of the signal induced on the target from the projectile were studied.

While technical literature discusses the phenomena of natural electrostatic charges existing on in-flight bullets, etc., (as listed in the Appendix), a search of the literature did not reveal any techniques for overcoming undesired signal variations.

To resolve the problem, tests were performed to ascertain the parameter(s) affecting these signal variations. Experiments involving the signal-polarity variation as a function of gun barrel temperature are described in this paper. The experiments were performed with relatively short muzzle-to-target spacings. The front target was located ten feet from the gun muzzle, and the second target thirty feet from the muzzle.

The Ballistics Range. Figure 1 is a sketch of the Electrophysical Laboratory illustrating the ballistics tunnel used for this investigation. Figure 2 provides a view of the control console and the windows at the front of the tunnel. The pyrometer meter is visible through the right side window.

A right side view of the tunnel exterior is shown in Figure 3. The door to the firing chamber is seen in the foreground. The input air ducts feeding into the tunnel are mounted near the ceiling. The electrostatic signals are recorded on the oscilloscope shown midway down the range.

Figure 4 is a photograph of the tunnel interior. The photoelectric equipment for triggering the oscilloscope sweep is in the foreground. Two targets for detecting the projectile's electrostatic charge are visible down range. They are located at 10 and 30 feet from the gun muzzle. The muzzle is located 5'1" above the floor. The bullet trap at the rear of the tunnel is visible through the rear shooting aperture. The tunnel is continually ventilated with forced filtered air.

Targets. Figure 5 illustrates the construction of a target. The unit consists of an inner conductor of copper tubing, and an outer metal shield. The target shields, photoelectric trigger, equipment alignment tracks, and rifle are grounded to the AC- power grounded-conduit.

The copper tubing in these targets is formed into a closed loop. A coaxial cable is coupled to the target so that the inner cable conductor is directly coupled to the copper loop while the cable shield is directly coupled to the target shield. The cable is then coupled to a Tektronix 564 Storage Oscilloscope.

Figure 2. Control Console

Figure 4. Tunnel Interior

Figure 3. Tunnel Exterior

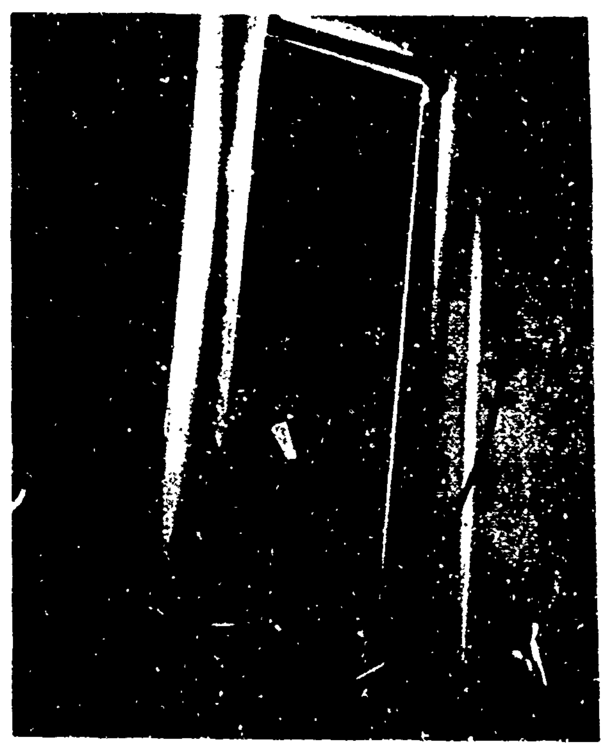


Figure 5. Electrostatic Target

__'lloscope Recordings__. The electrostatic signal waveforms shown in the ››sequent photographs are somewhat distorted due to cable capacitance. arget tests with a short cable feeding the oscilloscope through a Micronia Admittance Neutralizer demonstrated that the actual waveform shape approximates a square wave. The available Admittance Neutralizers were not used for these experiments since they were not capable of neutralizing the large capacitance of the long cables required for practicable spacing of the various equipment.

Since the timing interval of the firings was critical, it was necessary to develop a technique for placing as many oscilloscope traces as possible on each photograph. In a relatively short time, the oscilloscope technician was required to monitor the traces, relocate the sweep to a new position for each forthcoming trace depending upon the amplitude of the previous trace, photograph and develop the print, and reload the camera. To do this within the time requirement, it was first proven that two targets (one 20 feet beyond the other) would pick up the electrostatic bullet-signal with no change in polarity or appreciable change in amplitude. The majority of photographs shows a sequence of traces taken first downward on one side of the oscilloscope screen using one target, and then up the second side of the screen using the second target. (See Figure 8 for an example). The oscilloscope trace moves from left to right, starting with a smooth horizontal sweep which leads into the bullet signal, and ends with a noisy horizontal trace.

On the next photograph (See Figure 9) the order of recording the traces was reversed so that minimum readjustment was required for oscilloscope controls. The above procedure provides the reason for adopting the U-shaped sequence of traces on the various photographs.

Where the U-shaped sequence exists, a relatively wide vertical trace near the center of the photograph will be seen. The vertical trace is characteristic of the beam locator method used in the oscilloscope to reveal the location of the subsequent trace. The trace may be relocated through the use of a beam locator control on the oscilloscope panel.

The occasional horizontal line through a signal trace is due to oscilloscope trace triggering by an unfiltered radio interference pulse.

Except for Series G, oscilloscope time and amplitude controls are set to 2 milliseconds per centimeter and 20 millivolts per centimeter, respectively. (Time is represented on the X axis.) For Series G measurement data, refer to the settings given on the pages of the subject photos.

__Firing Chamber__. The rifle cradle is shown in Figure 6. The cradle is mounted on bearings to absorb rifle recoil. Use of the cradle enables repeatable accurate firing.

A close view of the rifle (M-2 Carbine) is given in Figure 7. The grounding braid is secured to the front portion of the barrel. The pyrometer thermocouple is mechanically secured under the barrel band. The thermocouple

Figure 6. Rifle Cradle

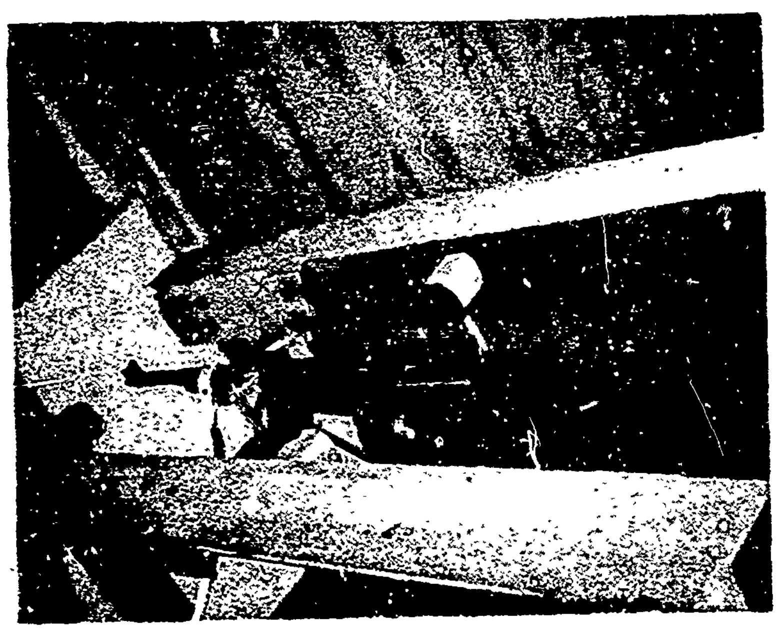


Figure 7. Rifle--close-up view .

cable leading to the pyrometer meter can be seen along the left side of the barrel. The bullet chamber, considered to be the area of highest temperature, is not the site of the thermocouple because the mechanical motion of the rifle action precludes such an arrangement. The thermocouple is 6" in front of the bullet chamber and 12" behind the rifle muzzle.

Terminology and Definitions. The following is provided to clarify the meaning of various terms as used in this investigation.

Target: An electrostatic transducer upon which the in-flight projectile induces a voltage. It consists of a conductive loop and a grounded shield.

Firing: The process of propelling the projectile from the launcher. The launchers used in this investigation are rifle, slingshot, air pistol, and wood ruler. The respective projectiles are 30 caliber M-1 Ball ammunition bullet (for rifle and slingshot), Crosman (air pistol) 22 caliber pellet, and #64 rubber band.

Signal: A voltage pulse induced on the target by the electrostatic charge on the in-flight projectile.

Signal-Polarity: The electrical positive, negative, or zero characteristic of the signal.

Signal-Polarity Stability: The condition in which consecutive firings produce repeated signals of single electrical polarity (i.e., positive, negative, or zero polarity).

Thermal Inertia: In this investigation, the behavior of thermal phenomena at the rifle barrel demonstrates a marked similarity to the behavior of inertia-of-motion phenomena. Data obtained from these experiments indicates that variations of signal polarity are manifestly related to both variation in temperature rate of change and variation in temperature direction (decreasing, zero, or increasing). From the data observed, it is herein hypothesized as a conclusion that the phenomena of thermal inertia exists and that it may be applied to explain and control the signal-polarity stability.

Signal Trace: An illustration of the signal waveform as traced out on the oscilloscope screen by the cathode ray beam.

Operational Circuitry. A bullet leaving the rifle intercepts the light beam of a photoelectric circuit. The circuit provides a signal which triggers the oscilloscope sweep. The bullet continues along its trajectory through a target, inducing a signal upon the target loop by virtue of its electrical characteristics. The signal is fed into the storage oscilloscope and recorded on its screen by the synchronized sweep. After a sequence of signals is recorded on the screen, a Polaroid camera is used to photograph the screen (for the purpose of evaluation).

Procedural Notes. The temperature of the rifle is noted prior to each firing of the rifle.

The relative humidity of the tunnel was recorded periodically and proved to be essentially constant throughout an experiment.

All experiments were performed several times. The photographs shown are representative of the particular series described.

All temperatures are given in degrees Centigrade.

EXPERIMENTS

Seven series of exploratory experiments are described. Each relates to the phenomenon of signal-polarity-stability as a function of projectile launcher temperature.

SERIES A. Recording at 5° Temperature Increments

This series was performed to determine whether a correlation exists between the gun barrel temperature and the bullet's electrostatic signal.

The rifle barrel temperature was increased from ambient (22.5°) by firing the gun. The resulting signal was not recorded. As the pyrometer meter pointer passed through the 30° scale division, a bullet was fired through a target and the signal recorded on the oscilloscope screen. Signals were recorded in 5° intervals (e.g., 30°, 35°, 40°, 45°). Where the pyrometer indicated that the gun barrel temperature would not normally reach the next higher 5° temperature increment, the oscilloscope intensity control was turned down and the temperature increased by firing the gun. The oscilloscope intensity was then turned up to enable recording of a 5° increment signal. As the pyrometer indicated that the temperature was passing through a 5° calibration division, the temperature value was recorded, a bullet fired, and the signal automatically recorded. The gun barrel temperature increase was thus maintained and 5° increment signals recorded (Figures 8 and 9).

After a temperature of 180° was attained, bullets were fired in 10° gun-cooling decrements. A 10° decrement was selected to permit a sufficiently stable cooling interval between firings (Figure 10).

Observations: In Figures 8 and 9, where the temperature increase increments are illustrated, there is an initial area of polarity instability. Both positive and negative signals appear, apparently without sequential order. There then occurs a range of negative signals, generally of stable amplitude. Finally, there appears a change in amplitude of the negative signals with apparent trends toward a greater amplitude. Reruns of this series to 200° showed greater amplitude stability for these larger negative signals. The appearance of low amplitudes at 170° and 175° (Figure 9) did not appear in the reruns.

For the decreasing temperature portion of the series (Figure 10) polarity instability is characteristic, with a positive polarity trend at the lower end of the temperature run. Note: In this run, the temperature dropped too quickly from 180° to 155° to obtain signal traces between these two temperatures.

SERIES A
20mv./cm
2ms./cm

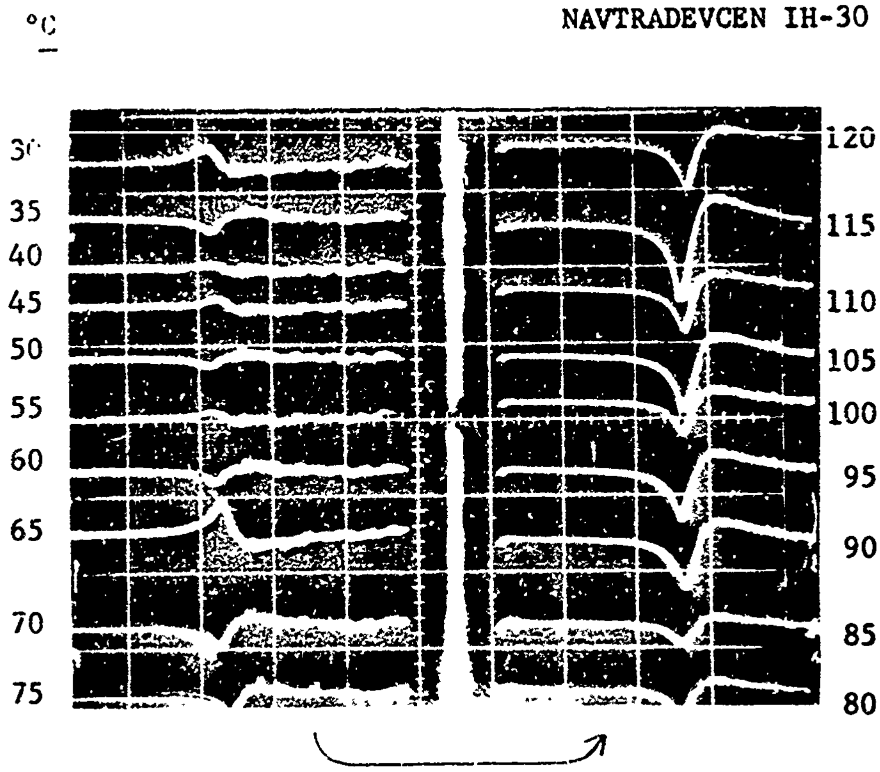


Figure 8.
Temperature Increasing

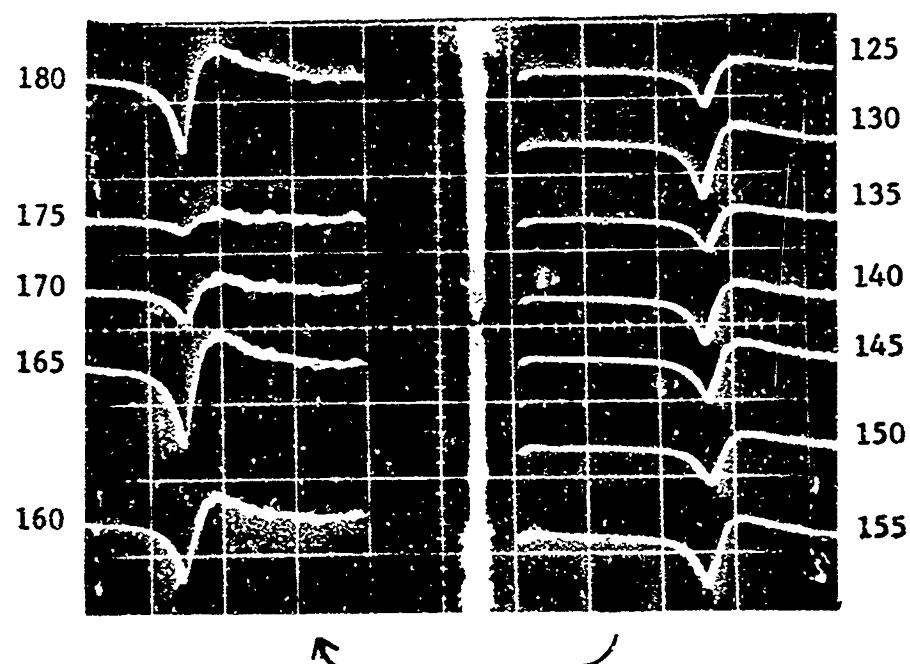


Figure 9.
Temperature Increasing

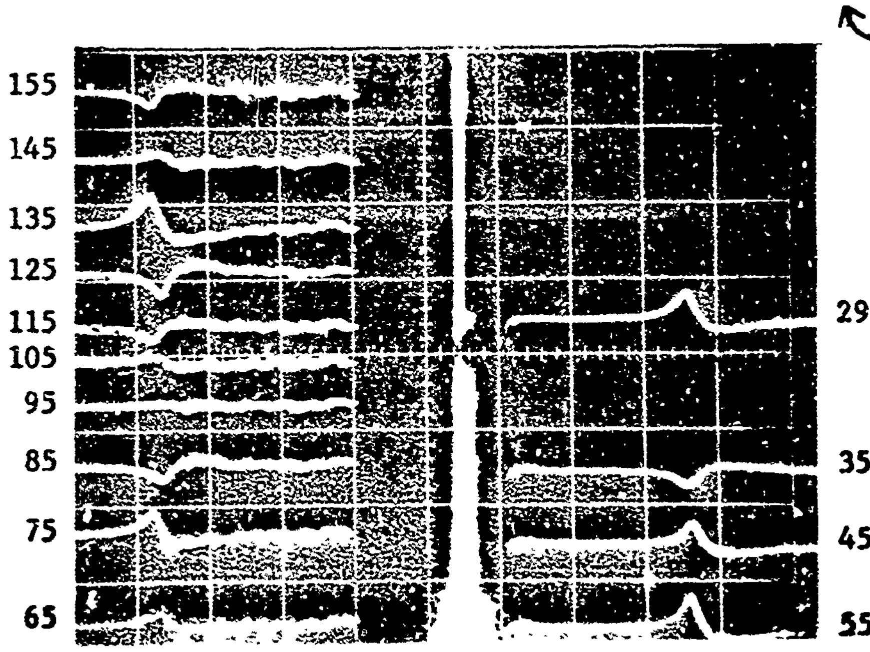


Figure 10.
Temperature Decreasing

SERIES B

Series A data provided a sequence of signals in 5° temperature increments. Series B provides a sequence of signals generated in 10 second increments as an exploratory probe into a time function increment.

The ten second interval was chosen as the shortest and most practical interval for maintaining steady firing, in consideration of normal delays such as gun jamming, oscilloscope adjustment, and film changing requirements for the camera.

SERIES B-1. Firing at 10 Second Intervals

This is a test to determine whether there is a difference between the Series A low range signals (at 5° increments) and the same temperature range when tested in 10 second intervals (Figure 11).

Observations: The two series provide essentially similar results. Up to about 70° the signal polarities are unstable. From about 70°, signals are negative. (Series B-1 reruns provide consistent negative signals above 70°).

SERIES B-2. Forced Launcher-Cooling

Since the cooling of the rifle in Series A (Figure 10) appeared to affect the signals, and since the existence of a temperature-polarity plateau is suggested from the consistent appearance of the stability switchover point (about 70°), a fan was introduced to decelerate the launcher heating process by circulating the surrounding air. A 10 second firing interval was then applied, with forced circulating air about the rifle. Figures 12 to 15 illustrate the resulting projectile signals.

Observations: The signals indicate a polarity instability throughout the temperature area tested (24° to 90°). An examination of the signals at the former "plateau" point (about 70°) suggests the possibility of the switchover as a function of a broad temperature-area phenomena, i.e., the switchover point is not necessarily confined to a single temperature value, but may be controlled.

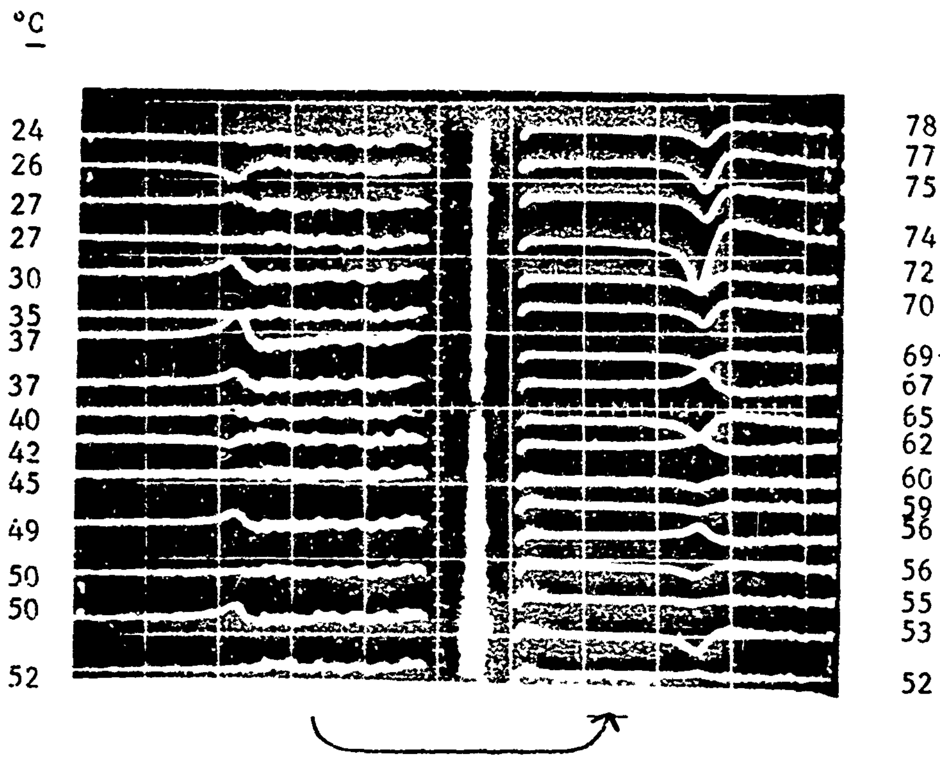


Figure 11. Series B-1
Firing at 10-second Intervals
(20mv./cm, 2ms./cm)

Series B-2, Forced Launcher-Cooling
(20mv./cm, 2ms./cm)

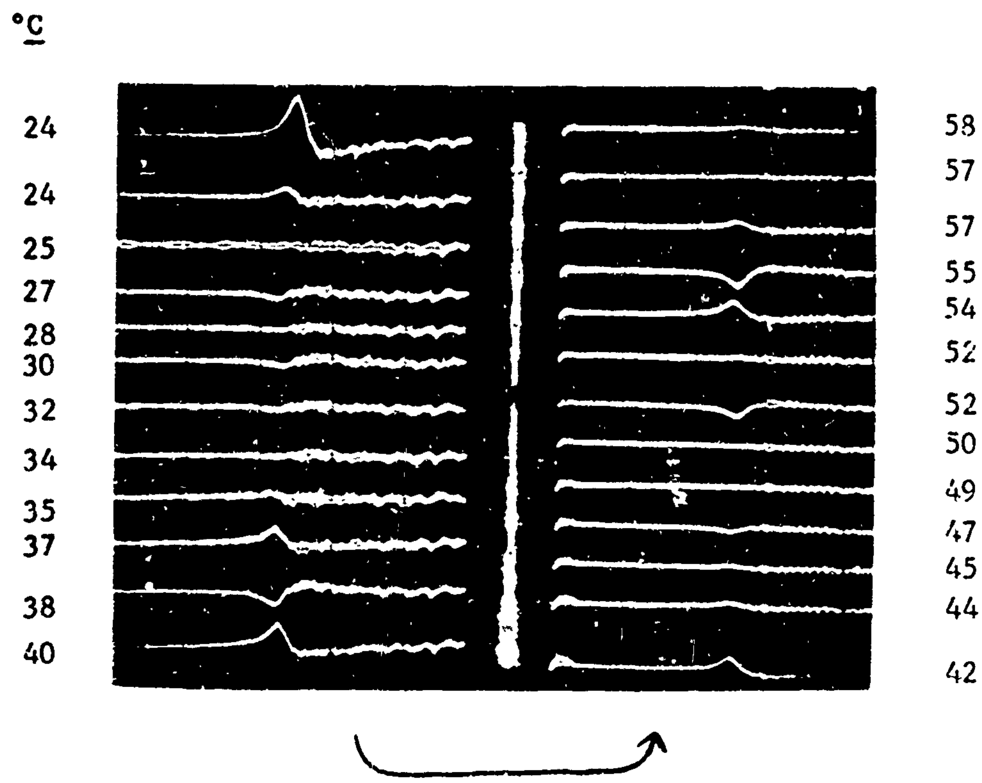


Figure 12.

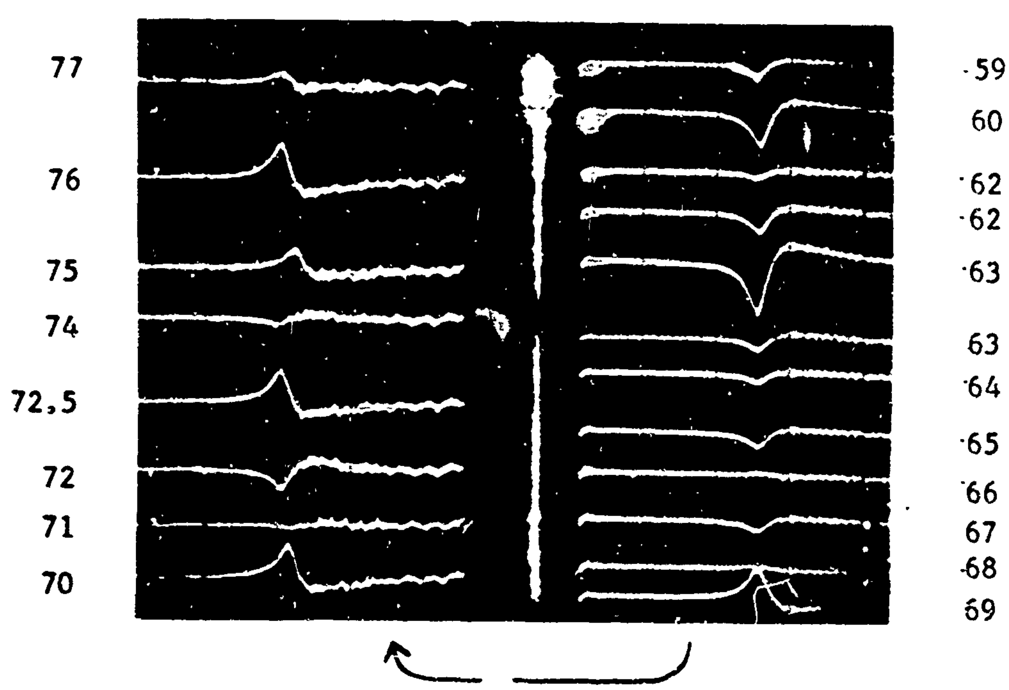


Figure 13.

Series B-2, Forced Launcher-Cooling
(20mv./cm, 2ms./cm)

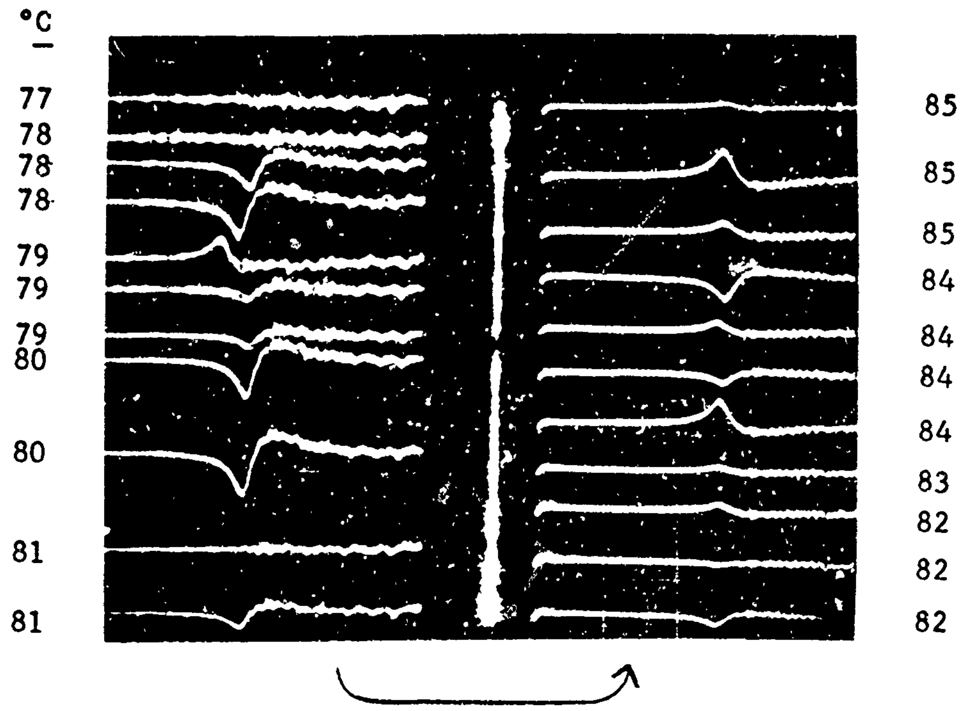


Figure 14.

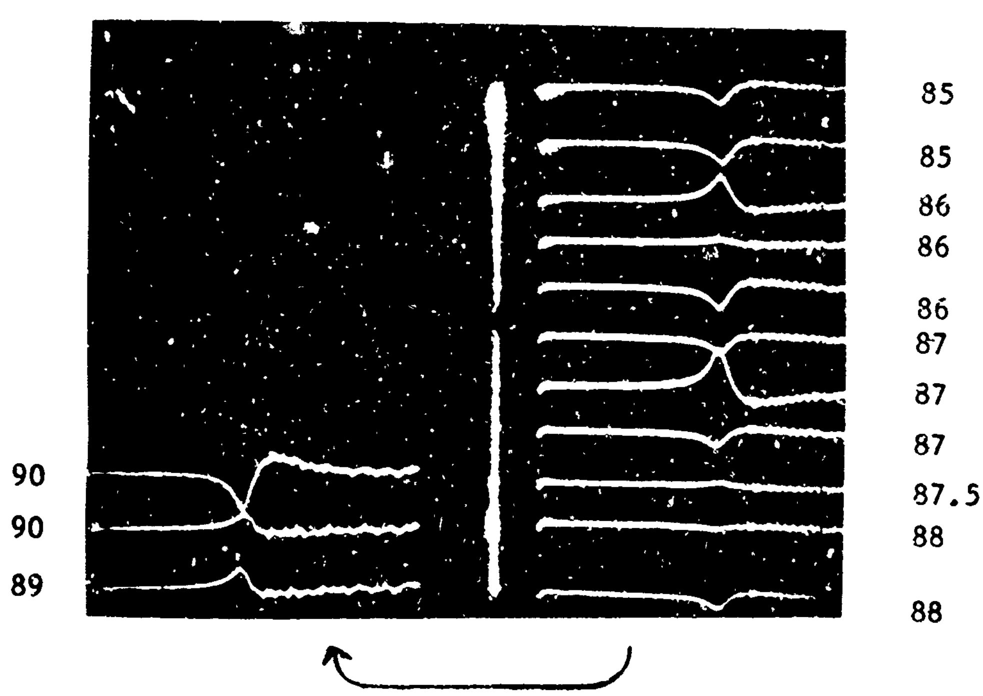


Figure 15.

SERIES C. Temperature Boosting by Rapid Gunfire

Series C tests were designed to determine whether a relatively rapid temperature boost followed by a change in temperature rate-of-change would affect polarity-stability.

In these tests the rifle was rapidly heated to a selected temperature by firing bullets. The rate of firing was then decreased to one bullet every ten seconds.

SERIES C-50. The launcher was rapidly heated to the selected temperature of 50 degrees, followed by a bullet firing every ten seconds (figures 16-18).

Observations: The change in temperature-rate point (about 50°) provides an area of instability.

Series C-50
Temperature Boosting to
50° by Firing Bullets
(20mv./cm, 2ms./cm)

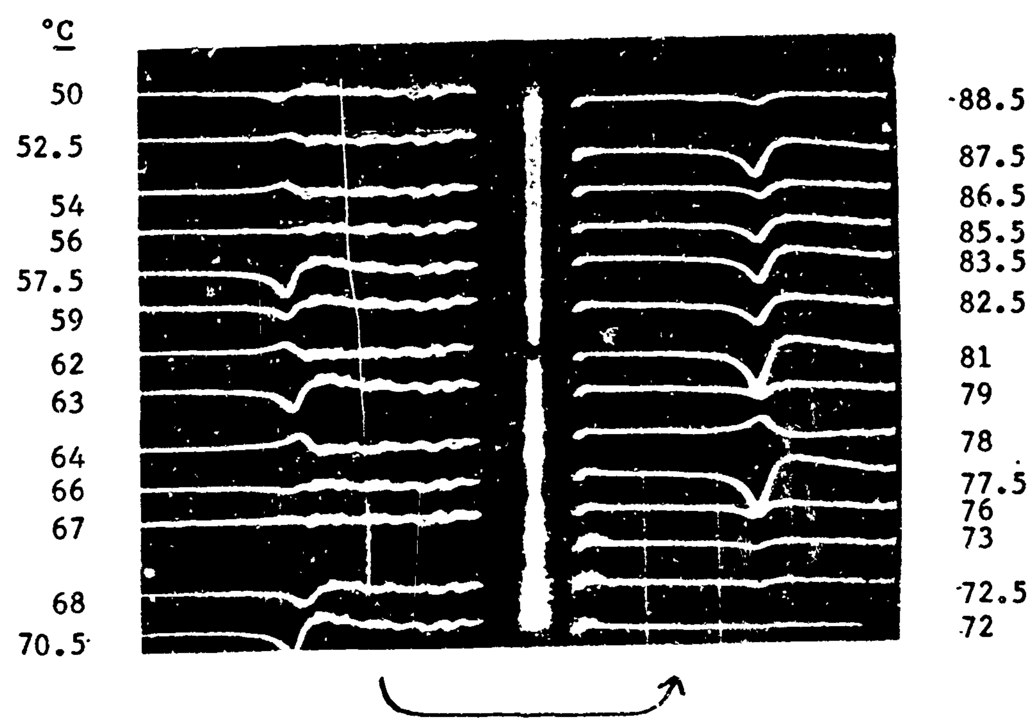


Figure 16.

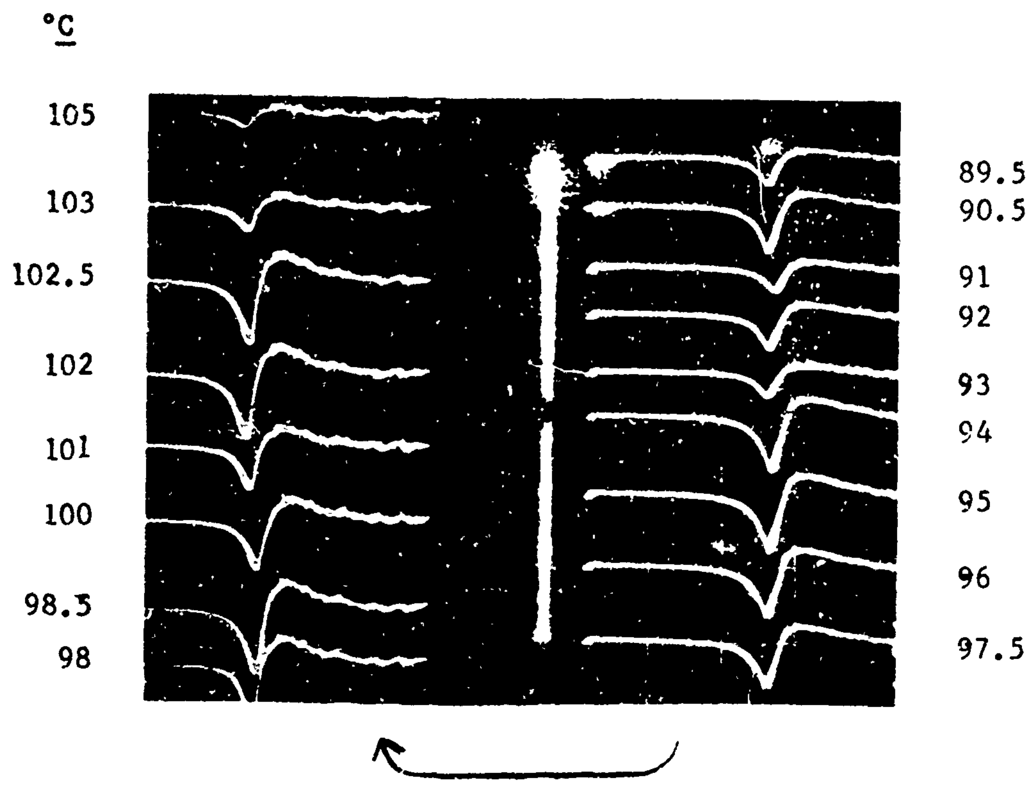


Figure 17.

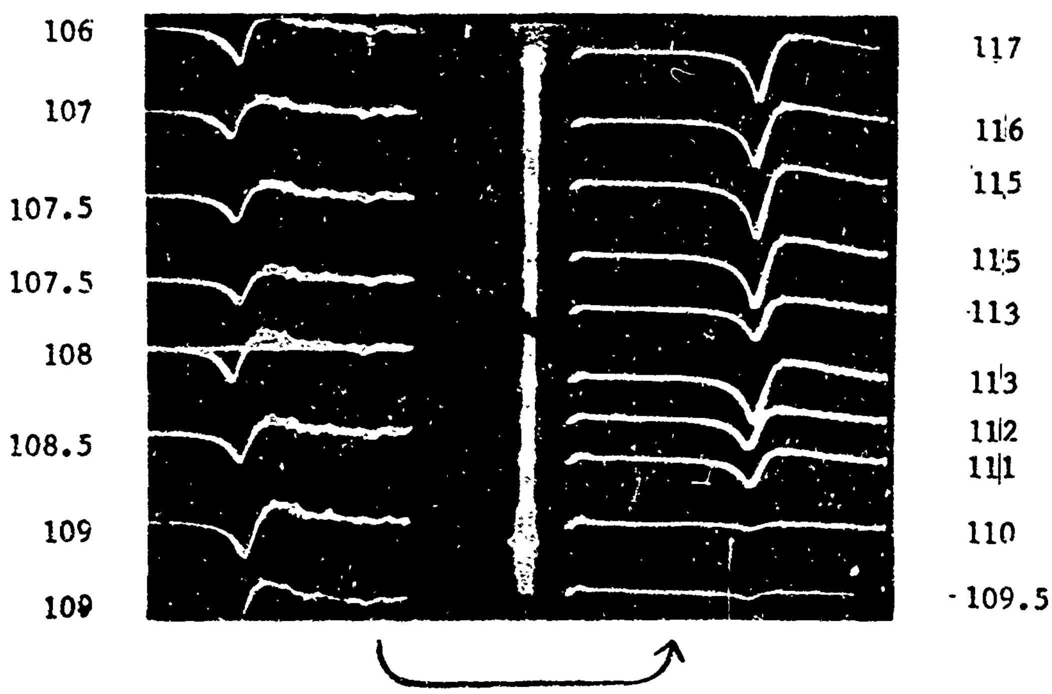


Figure 18.

SERIES C-75. The launcher was rapidly heated to the selected temperature of 75°, followed by a bullet firing every ten seconds (figures 19-21).

Observations: Figure 19 indicates an upward shift in the area of instability, as compared with Series A, B-1, and C-50. The stable negative polarity signals at the higher temperatures (figures 20 and 21) are compatible with the higher temperature signals of Series A. These events suggest the possible existence of thermal inertia effects.

Series C-75
Temperature Boosting to
75° by Firing Bullets
(20mv./cm, 2ms./cm)

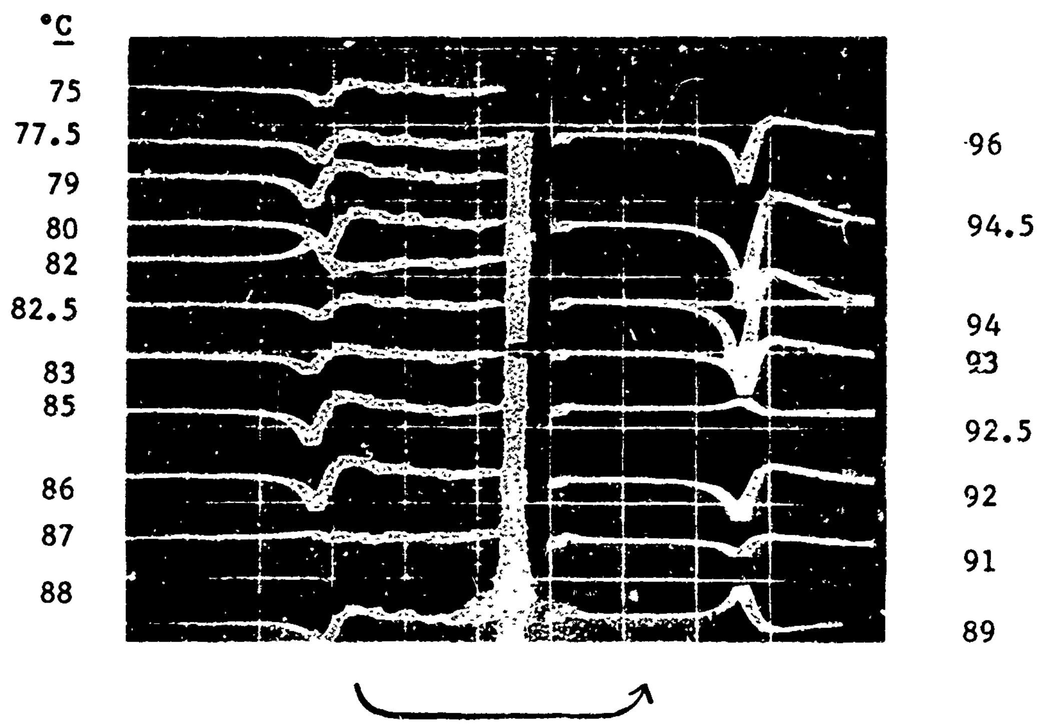


Figure 19.

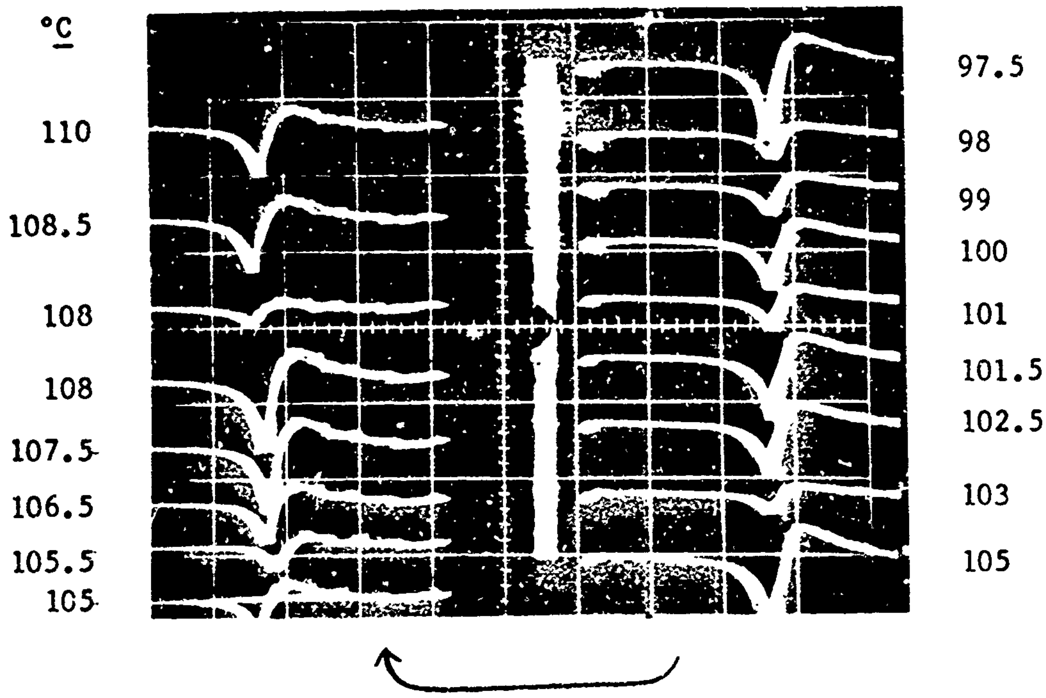


Figure 20.

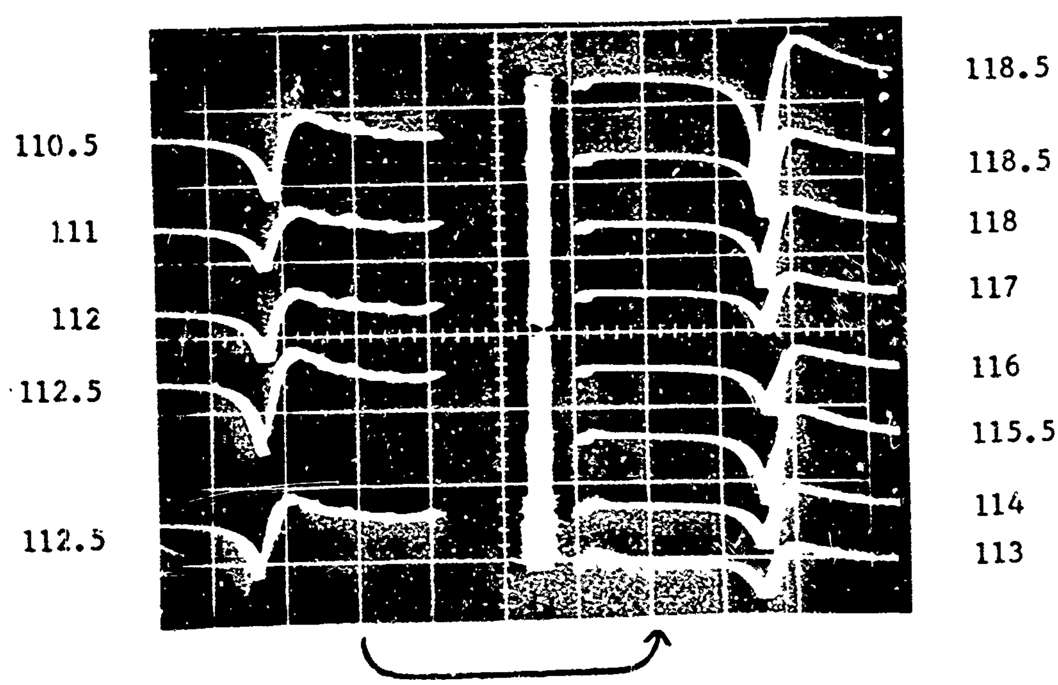


Figure 21.

SERIES D. Temperature Boosting by Propane Torch

In Series C, the launcher was rapidly boosted to specified temperatures by firing bullets. There is a possibility that bullet firing causes some storage effect in the rifle (e.g., concentration of gun fire plasma, and thermal inertia). In an attempt to obviate such effects, another method of preheating was introduced. In Figure 22, a Bernzomatic Propane Torch is shown as the booster agent. The torch is moved about the launcher until the pyrometer indicates that the selected gun barrel temperature has been attained. The 10 second firing procedure used in the previous series then followed.

SERIES D-50. The launcher temperature was boosted to 50°, followed by the 10 second firing procedure (Figures 23 and 24).

Observations: The signals attained negative stability much more rapidly than in C-50.

SERIES D-75. The launcher temperature was boosted to 75°, followed by the 10 second firing procedure (Figures 25 - 27).

Observations: The photograph reveals greater negative stability than in C-75.

Series D data suggests the possibility of some storage effect due to bullet firings.

The first signal trace of D-50 (Figure 23) and D-75 (Figure 25) reveals the existence of a positive signal, followed by traces containing negative signals. This suggested the occurrence of an instability engendered by the long delay during which the torch was removed, the rifle was loaded, and the rifle was fired.

Series D-50
Temperature Boosting to
50° by Propane Torch
(20mv./cm, 2ms./cm)

Figure 22.

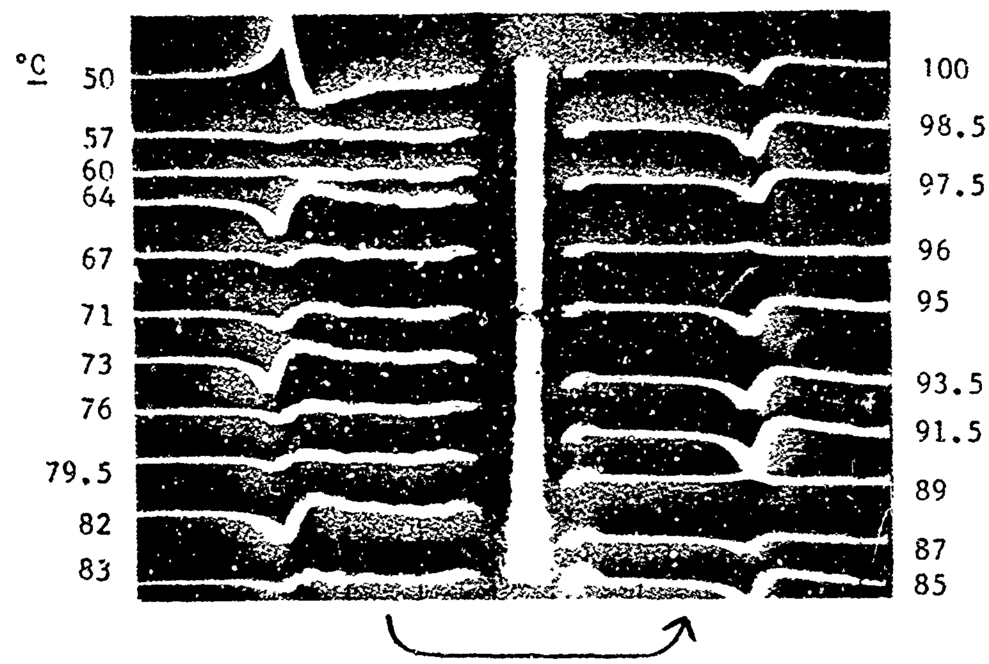


Figure 23.

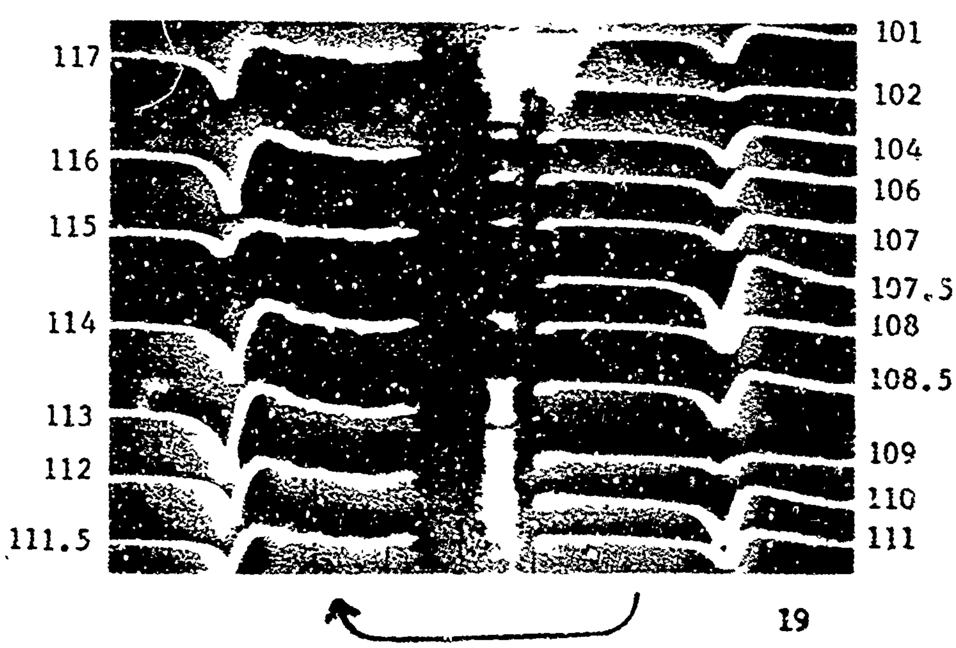


Figure 24.

Series D-75
Temperature Boosting to 75° by Propane Torch
(20mv./cm, 2ms./cm)

°C

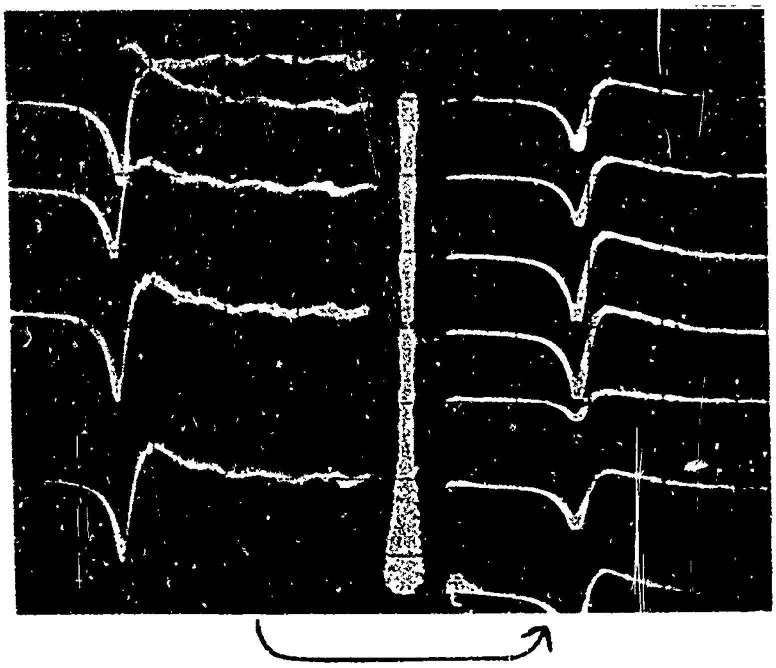


Figure 25.

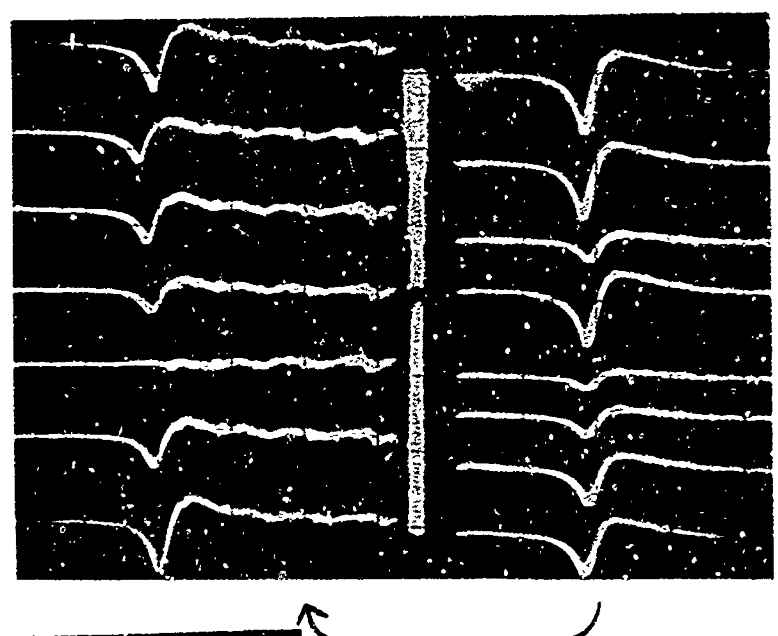


Figure 26.

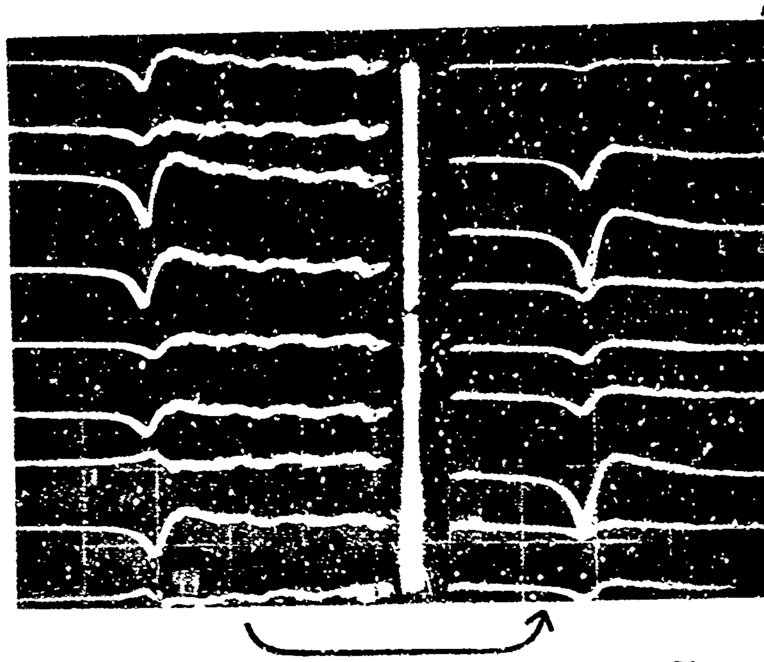


Figure 27.

SERIES E. Single Temperature Firing

This series was designed to investigate signals associated with a single temperature, actively controlled. A bullet was fired at a selected temperature, and the signal recorded. After the launcher had cooled down to the selected temperature, the procedure was repeated.

Two temperatures were selected; ambient (22.5°), and a randomly chosen one (77°). A number of launchings was tested for each value (Figures 28 and 29).

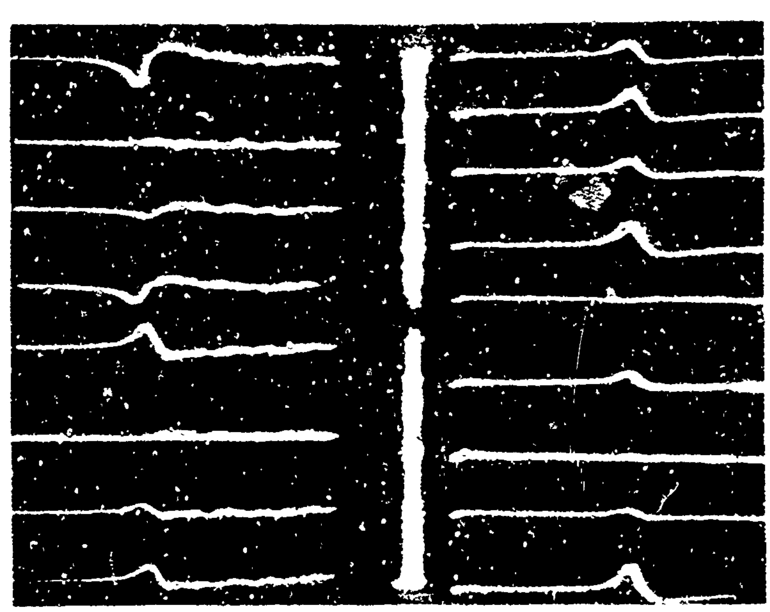
Observations: Polarity instability predominated in both cases, with a preponderance of positive signals. For the last three firings of E-77, the temperature was permitted to rise in order to detect any tendency toward stability. No conclusive evidence of this was demonstrated in E-77 reruns.

Series E supports the hypothesis that polarity stability is a function of thermal inertia; as the launcher is cooled, the thermal inertia changes direction resulting in a polarity instability. Whether discrete response levels exist as suggested by the data, is a matter of further research, since this consideration is not within the subject area of this particular investigation.

SERIES E. Single Temperature Firing
(20mv./cm, 2ms./cm)

°C

22.5
22.5
22.5
22.5
2225
22.5
22.5
22.5



22.5
22.5
22.5
22.5
22.5
22.5
22.5
22.5
22.5

Figure 28. 22.5° (Ambient)

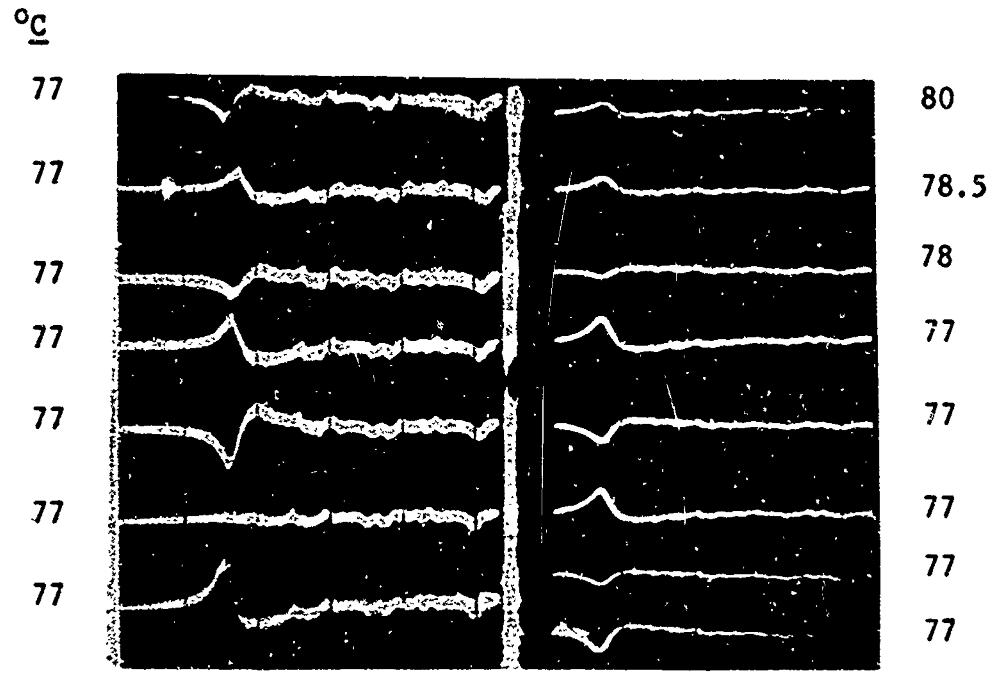


Figure 29. 77°

SERIES F. Reduced Temperature Range.

Series A and B-1 photographs illustrate a polarity changeover to a stable negative at 70°. In view of observations from data in the previous series regarding inertia effects, a new series beginning at a lower temperature was run similarly to Series A.

The launcher was sprayed with CO_2 until the temperature dropped to a value below 0°.

Two bullets were fired, bringing the temperature up to 0°. As in Series A, the rifle was fired to raise the temperature in 5° increments at which time a bullet was launched and its signal recorded (Figures 30 and 31).

Observations: The lower-temperature signals were stable positive after the initial firings. The changeover to negative signals was abrupt (i.e., without vacillating areas) at 45°. Two reruns of Series F produced switchover temperatures at 40° and 55°, respectively. Series F data supports the previous evidence of thermal inertia phenomena in this investigation and suggests that the subject temperature ranges are floating, rather than that they maintain absolute limits.

SERIES F. Reduced Temperature Range
(20mv./cm, 2ms./cm)

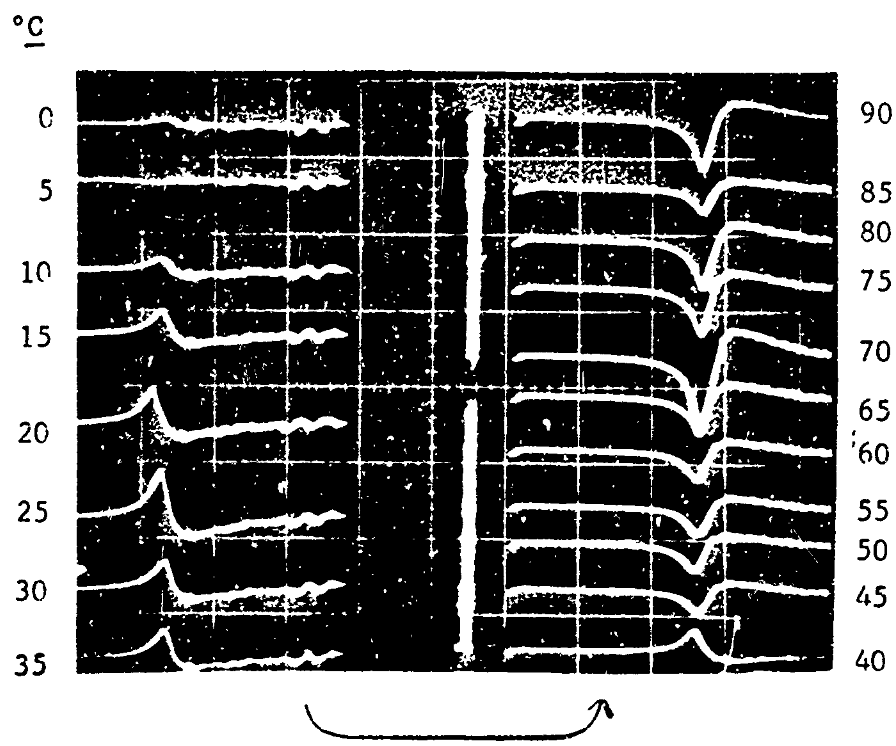


Figure 30

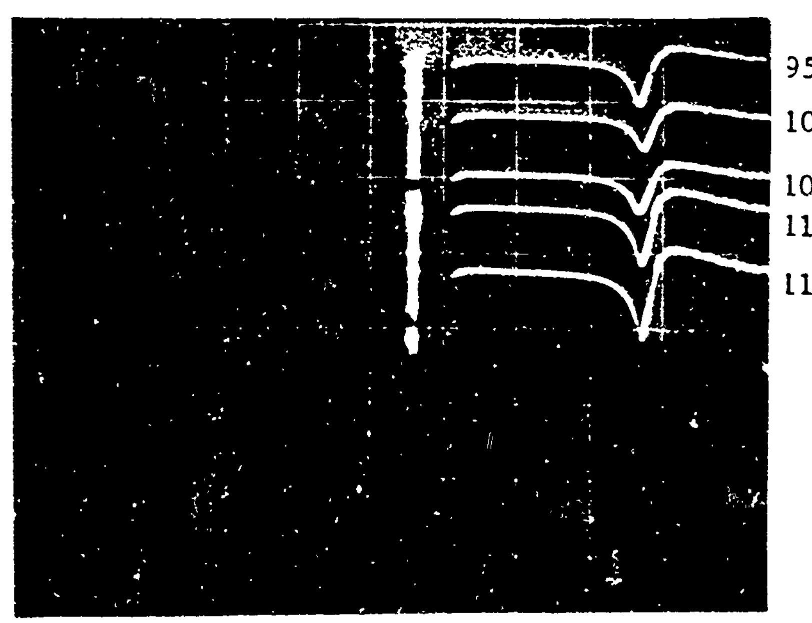


Figure 31.

SERIES G. Fixed Temperature Launchers.

In an attempt to eliminate the effects of appreciable temperature variation, three forms of launchers which operate at relatively fixed temperatures were used. (22.5° ambient temperature).

SERIES G-S (Slingshot). The bullet portion of 30 Caliber M-1 Ball Round ammunition (which was the type used in previous firings) was separated from the shell and propelled through the target by means of a slingshot (Figures 32 and 33). It should be noted that the projectile was not grounded at the launcher as in previous series, and that the projectile was a conductor while the launcher propelling mate·.al, an insulator.

Observations: All signals were negative. The bullets producing higher amplitude signals passed closer to the target inner conductor. The bullets producing lower amplitude signals passed closer to the center of the target. Although the larger amplitude signals were induced by slower projectiles, as evinced by signal locations on the calibrated screen, substantiating slingshot experiments indicated that the amplitude was not an inverse function of velocity, but of projectile-target spacing.

SERIES G-A (Air pistol). A Crosman pumped-air pistol Model 130 (Figure 34) fired 22 caliber metal pellets through the target. The pellets' velocity was a function of the number of pump strokes used to charge the pistol air reservoir. Figure 35 illustrates the signals induced from the pellets. The number at the left of Figure 35 indicates the number of pumps used for that launching. The projectile was grounded through the launcher and marksman. Both projectile and launcher were electrical conductors.

Observations: All signals were positive.

SERIES G-R (Rubberband). Size 64 rubberbands, 3.5" in length (long diameter) by 3/16" in width, were propelled from a wood ruler (Figure 36). The projectile and launcher were grounded through the marksman. Both projectile and launcher were insulators. The Series G-R projectile was the only projectile used (during the investigation) which was an insulator. Signals are illustrated in Figure 37.

Observation: All signals were negative.

Without exception, the constant temperature launchers produced stable-polarity pulses.

SERIES G-S. Fixed Temperature Launcher
(10mv./cm, 50ms./cm)

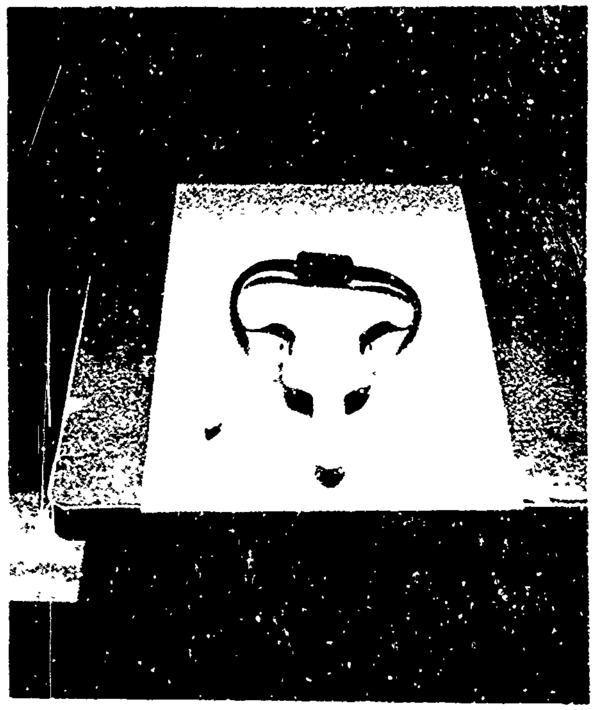


Figure 32. Slingshot Launcher

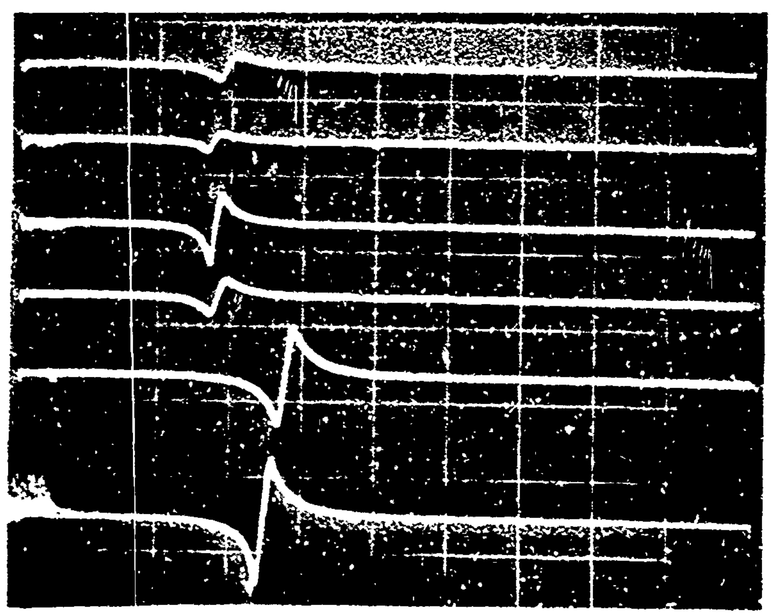


Figure 33. Slingshot Signals

SERIES G-A. Fixed Temperature Launcher
(10mv./cm, 10ms./cm)

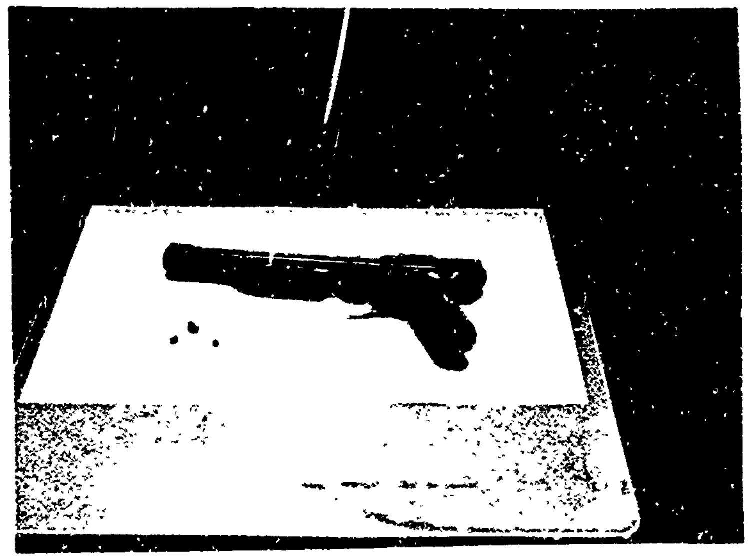


Figure 34. Air Pistol Launcher

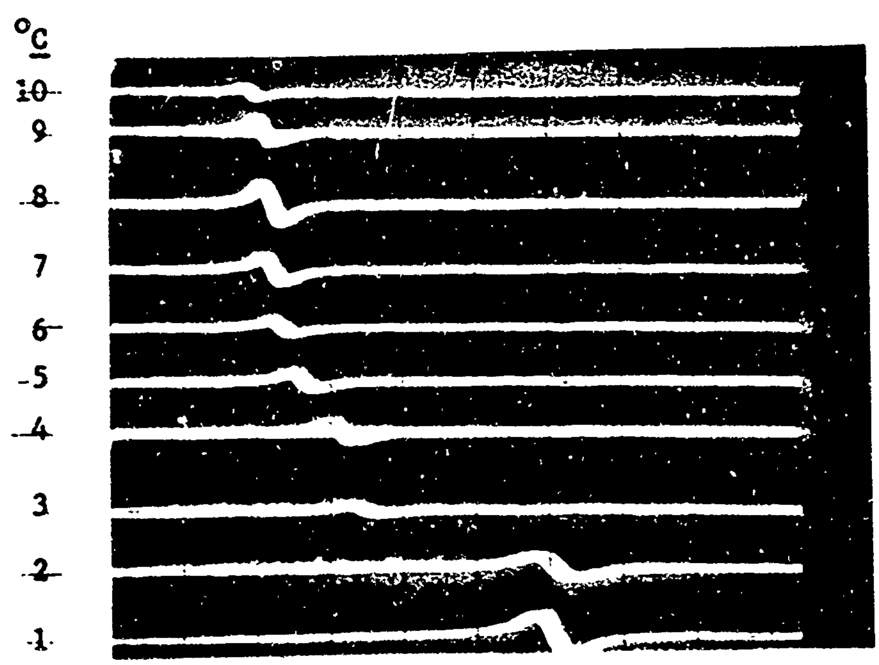


Figure 35. Air Pistol Signals

SERIES G-R. Fixed Temperature Launcher
(500mv./cm, 5ms./cm)

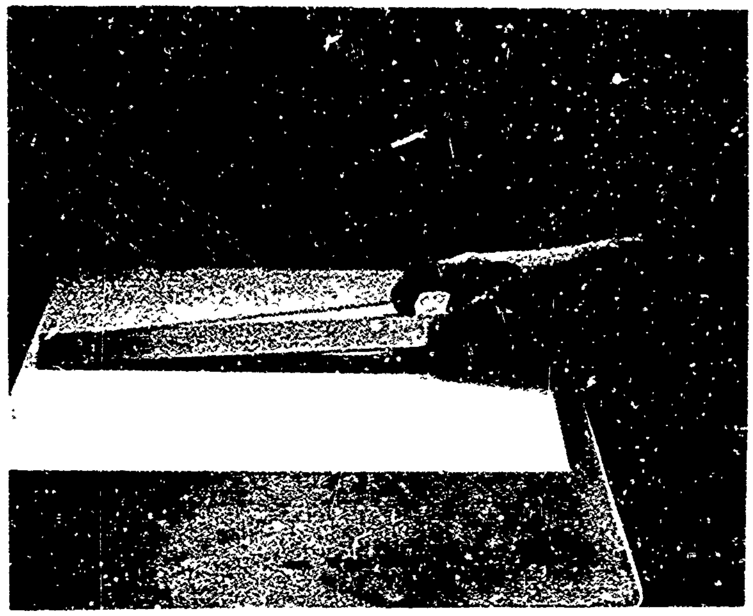


Figure 36. Rubberband Launcher

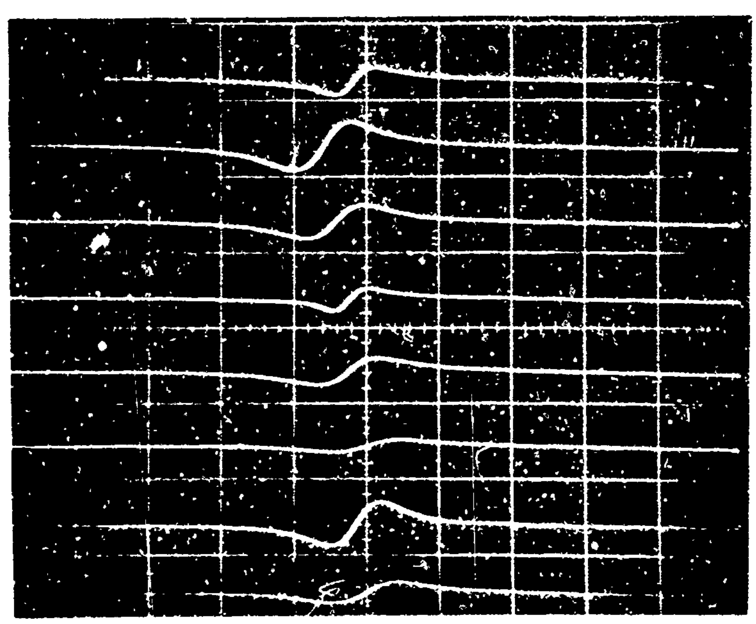


Figure 37. Rubberband Signals

CONCLUSIONS

To provide conclusive data regarding the thermal-electrostatic phenomena herein described, it is recommended that further investigation include quantitative as well as qualitative oriented experimentation; a corroborating theory be devised to explain the basis and mechanics of the phenomena, substantiated by its application to the control of the phenomena; and that techniques for obtaining improved experimental-data accuracy be utilized.

(1) Changes in the launcher's thermal inertia condition tend to affect signal polarity-stability, polarity-instability, and degree of signal instability. The degree of signal instability is a measure of the signal-amplitude variation within a group of consecutive signals.

(2) As the thermal inertia stabilizes, signal polarity tends to stabilize, and the degree of signal instability tends to decrease. The foregoing statement applies to the condition of constantly increasing launcher temperature. In Series A through F, a rifle was used as a launcher. Firing increased the rifle temperature. The temperature increase prevented the use of the rifle for evaluating signals associated with constantly decreasing temperature launchings.

The unstable-polarity signals associated with the initial firings of the rifle launchers (See Series A, B-1, and F photos); the characteristic signal-polarity instabilities associated with the fan-cooled rifle (Series B-2); the stability of initial firings after a rapid temperature boost (Series C and D); the increased stability associated with initial firing of Series D as compared to Series C with the hypothesized storage effects; the instability evident when the temperature consistently cools to a fixed value (Series E) and the polarity-stable signals associated with operationally constant-temperature launchers (Series G), - are all compatible with a thermal inertia hypothesis.

In Series G, the operational temperatures of the launchers remained essentially ambient. While the signal-polarity associated with each Series G launcher was stable within the individual series, (G-S (Slingshot), G-A (Air Pistol), or G-R (Rubberband)), all launchers (G-S, G-A and G-R) did not provide projectile signals of the same polarity (negative for G-S, positive for G-A, and negative for G-R). An analysis of launchers, per se, is not within the scope of this investigation. The following observation is provided as a matter of pertinent associated information.

Series	Stable Signal Polarity	Launcher Material	Projectile Material	Projectile Grounded?
G-S	Negative	Insulator	Conductor	No
G-A	Positive	Conductor	Conductor	Yes, through launcher and marksman
G-R	Negative	Insulator	Insulator	Yes, through launcher and marksman
E	Positive	Conductor	Conductor	Yes, through launcher and grounding strap

It is emphasized that this data applies to the ambient temperature areas.

A significant observation regarding signal amplitude bears further investigation. In Series G firings, larger amplitude signals were obtained when the trajectory was located closer to the target conductor. The low amplitude signals were obtained when the trajectory was closer to the target center. Observations of rifle firing indicate that signal amplitude may be a function of trajectory-target conductor separation. It was generally observed that the first firing from a gun at rest for several hours provides a conspicuously larger amplitude than the immediately subsequent firings. Using a bullseye paper target at the bullet trap, it was also observed that the first firing from a rested rifle was inches from the center of the paper target. After rifle warmup (after approximately six firings), centerings were consistently scored at the center of the paper target, suggesting a relationship of signal amplitude with trajectory-target conductor spacing. The larger amplitude produced by the first firing of the rifle is not perceived in previous photographs since the first firing was not used for recording, but for raising the temperature to the first required increment (5° or 10 seconds).

APPLICATIONS

The data obtained during this investigation provides a facet in an electrostatic reference framework applicable to the following devices:

1. Nondestructive Target. There exists requirements for indestructible targets on tank gunnery ranges. When presently used targets are destructed; the firing ceases, trainees hold-fire, and trained support-personnel replace the destructed targets with new ones. An intangible electrostatic target, consisting of an area of space sensitive to a projectile moving through it, would be virtually indestructible. Feasible test models of such targets have been constructed. (The design of nonmaterial aiming targets to enable the trainee to locate the projectile-sensitive-true-target, is under consideration at this laboratory.)

2. Electrostatic Interaction Control. This application is based upon the detection of electrostatic charges on adjacent bodies. The detection device automatically operates the flight controls of its vehicle. This basic device may be used to:

a. Maintain spacing between projectiles, vehicles and other craft.

b. Prevent collisions with satellites, spacecraft, aircraft, meteorites and similar space debris.

c. Provide evasive maneuvers (e.g., aircraft vs. sidewinder).

d. Provide an electrostatic fuze methodology.

3. Surveillance: a) Moving object detection, b) identification of moving objects by electrostatic signature recognition.

4. Space vehicle communication by modulating the vehicle's electrostatic charge.

5. Research Tool: The application of the electrostatic charge as a tool for studying Thermal Inertia as a physical phenomena.

6. Function Generator: A simple signal generator for ballistic range gating and similar applications; the waveform can be shaped by the physical pickup-conductor form, so that a desired waveform can be generated as the projectile goes by. (Use of a conductive metal spline will permit a latitude of variation.)

7. Transducer: A passive transducer applicable for velocity measurements when used to control a chronograph.

RECOMMENDATIONS

This investigation has been exploratory, into an area concerning which little data is available. This investigation has indicated that (1) there is a relationship between the thermal postures (static and dynamic) of the launcher and the electronic signal appearing at the target transducer when the projectile intercepts the transducer field of response, and (2) characteristics of the transducer signal are related to the recent launcher thermal history (the prior to firing: temperature, rate of temperature change, and direction of temperature change). Sources of possible inaccuracy in this investigation may be described as follows:

1. Instrumentation Lag. The pyrometer utilized a thermocouple with a rated lag of several seconds. It is suggested that a calibrated temperature sensing system with a response in the order of 0.1 millisecond be employed in further investigations of the subject.

2. Human Error Sources (e.g., distortion of response, distraction of attention, poor judgment, poor timing, and lag). To minimize this source of inaccuracy, it is recommended that an adequate timing and recording system be utilized to continuously record and visually indicate launcher temperature as a function of time, thermal rate of change, time interval between firings, ambient and boost temperatures, and mark the time of event, warmup firing, signal firing, and such other reference points desired.

The system may further be refined through use of a thermal feedback loop control system. This would enable a controlled thermal rate of change through regulated warmup firings. Additional precision and evaluation accuracy may be made available through automatic oscilloscope beam setting and camera triggering. A timer with visual and audible output would provide the gun operator with clear, accurate, and dependable firing signals.

This study can be expanded to include: signal variations as a function of recent past history, other temperature controlling effects and parameters (e.g., time duration of the controlling stimuli), higher order effects and interactions affecting the charge, signal characteristics as a function of the launcher's location in the temperature spectra, charge measurement, charge origin, stability factors, existence of thermal inertia or other controlling parameters, analysis of instability and thermal inertia phenomenon, relation of the polarity to the Faraday series, extended temperature ranges; a technique applicable to constantly decreasing temperature runs, environments for determining the effects of various ambient temperatures; temperature gradient variations in the launcher; thermal rate of change phenomena; variations in conductivity between launcher and ground; launcher and projectile material and conductivity variations; correlations between polarity-stability and thermodynamic theory; lag (response as a function of time); and related electrostatic effects (e.g., ionization, grounding, projectile and launcher friction, humidity, potential differences, polarity switchover, and signal variation as a function of distance from the muzzle).

Applicable investigation may include the use of this phenomena to detect changes in thermal inertia, physical spacing, and projectile hit-miss targets.

An acknowledgement is herein expressed for the contributions of Robert B. Terry, William J. Porthouse, and Franklin N. Frederick, who actively participated in these experiments and were responsible for a number of improvements in the investigatory equipments and operational techniques.

Appreciation is expressed to the Defense Documentation Center for their assistance in providing a number of reports chronicled in the Appendix.

APPENDIX

Cornell Aeronautical Laboratory, Inc: Study and Investigation of Methods of Dissipation of Static Electricity on Helicopters. DDC Report No. 252149. TREC Technical Report 60-55.

R. A. Davidson: A System for the Study of Projectile Charging. DDC Report No. AD-336 30. OOR Project No. 845.

R. A. Davidson and W. S. Partridge: Velocity Report (Investigation of Ionization Associated with Ultra-Speed Pellets). DDC Report No. AD-108 466. OOR Project No. DA-04-495-ORD-451.

R. A. Davidson and W. S. Partridge: Electric Charge Associated with Projectiles Fired From Rifles. DDC Report No. AD-138 151. OOR Project No. 845.

Eglin Air Force Base: Final Report on Scoring Methods Study. DDC Report No. 406166. ASD Tech. Doc. Report No. ASD-TDR-63-17.

P. Krupen and E. B. Rogers: Measurements of the Electric Charge on Some Aircraft. Diamond Ordnance Fuse Laboratories Report R-310-60-5. (For Official Use).

Librascope, Inc: Status Report: BUWEPS Contract NOw 61-0698c.

M. Loyd memo to O. Schreiber Subject: Small Arms Scoring System. 7 Aug. 1962.

S. Frankel: Electrostatic Field Due to Charge Distribution Induced on a Missile by Neighboring Target.

S. Frankel: Distant Electrostatic Field of a Charged Missile.

S. Frankel: Electric Field Measurement Requirements for Missile Target Scoring.

S. Frankel: Theory of Charge - Independent Electrostatic Scoring .

S. F. Singer and E. H. Walker: Electrostatic Screening of Bodies in Space. DDC Report No. AD-263-806. AFOSR Doc. No. 1399.

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DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Electronics Laboratory U. S. Naval Training Device Center Port Washington, New York	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b GROUP

3. REPORT TITLE

AN EXPLORATORY INVESTIGATION INTO THE POLARITY STABILITY OF THE ELECTROSTATIC CHARGE ON AN IN-FLIGHT PROJECTILE.

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Research

5. AUTHOR(S) (Last name, first name, initial)

Groder, Morris L.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
July 1965	33	

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO.	Technical Report: NAVTRADEVCEN IH-30
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
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13. ABSTRACT

This paper describes exploratory experiments performed to determine the effects of gun barrel temperature on the stability of an in-flight bullet's natural electrostatic charge.

The data derived from these exploratory experiments indicate that (1) there is a correlation between the polarity (negative-positive-zero) stability of the projectile's electrostatic charge and the thermal inertia effects in the rifle; (2) discrete mobile signal phenomena exist as a function of the thermal conditions in the launcher; and (3) it is possible to predict and/or control specified characteristics of the electrostatic charge on an in-flight projectile.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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