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MEASUREMENT OF BORE EROSION

S. J. KRUPSKI
F. J. AUDINO

DECEMBER 1977

US ARMY ARRCOM

PRODUCT ASSURANCE DIRECTORATE
WATERVLIET ARSENAL
WATERVLIET, N.Y. 12189

TECHNICAL REPORT

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In recent years changes in cannon ammunition have led to the occurrence of a wear (erosion) maxima downbore from the origin of rifling. Conventional inspection equipment is not adequate to obtain the necessary data for the study and evaluation of this wear progression.

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20. ABSTRACT (cont'd)

New inspection equipment has been developed for the 105mm., M68 gun tube which will provide the necessary data for use in the study and evaluation of erosion and its effect on cannon tube serviceability.

MATERIALS TESTING TECHNOLOGY PROGRAM (AMS 4931)

Report No.: WVT-QA-7701

Title: Measurement of Bore Erosion

THIS PROJECT HAS BEEN ACCOMPLISHED AS PART OF THE US ARMY MATERIALS TESTING TECHNOLOGY PROGRAM, WHICH HAS FOR ITS OBJECTIVE THE TIMELY ESTABLISHMENT OF TESTING TECHNIQUES, PROCEDURES OR PROTOTYPE EQUIPMENT (IN MECHANICAL, CHEMICAL, OR NONDESTRUCTIVE TESTING) TO INSURE EFFICIENT INSPECTION METHODS FOR MATERIEL/MATERIAL PROCURED OR MAINTAINED BY AMC.

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ABSTRACT

In recent years changes in cannon ammunition have led to the occurrence of a wear (erosion) maxima downbore from the origin of rifling. Conventional inspection equipment is not adequate to obtain the necessary data for the study and evaluation of this wear progression.

New inspection equipment has been developed for the 105mm., M68 gun tube which will provide the necessary data for use in the study and evaluation of erosion and its effect on cannon tube serviceability.

CROSS-REFERENCE DATA

Bore Erosion
LVDT
X-Y Plotter
Propellent Additives

ACKNOWLEDGEMENT

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I. INTRODUCTION

During the early 1960's the greatest wear in gun tube bores occurred at the origin of rifling. For the 105mm., M68, a condemnation criteria was based on .075 inch wear at the origin of rifling as the accuracy limiting factor.

With conventional ammunition, wear maxima at the origin of rifling decreased with distance downbore. Wear reducing propellent additives caused a change in pattern to a second local wear maxima. These maxima were much smaller than the amplitude at the origin of rifling.

In late 1973 and early 1974, severe flight degradation in additive ammunition in the M68 prompted an extensive investigation. It was found that second wear maxima exceeded the maxima at the origin of rifling (see Fig. 1). This erosion condition has been generally referred to as secondary wear. Secondary wear appears in a region 1 to 2 inches from the origin of rifling to 25 inches downbore (see Fig. 2).

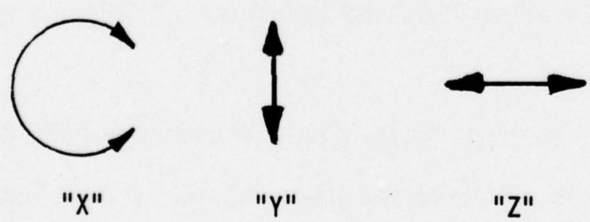
Since erosion does not occur evenly around the bore circumference conventional methods of measuring were not adequate. The use of star and pullover gages only indicate a change in diameter. Therefore, a new system was required with capability of measuring radii about an established center line as well as the circumferential location of the various radii measurements.

II. SYSTEM REQUIREMENTS

The secondary bore erosion measuring system required had to measure and plot very minute changes resulting from erosion on the lands and grooves of cannon tube bores, circumferentially and downbore 25 inches from the origin of rifling.

In this way, data gathered from use of such a system at firing tests could determine the progression of erosion relative to the type and number of rounds fired. The tests would also include a study of erosion in cannon tubes made of various types of steels as well as electro-plated cannon tubes.

The requirements of a bore erosion measuring system as described above dictated a design that would provide the capability of measuring in three axes or planes; "X" data, sensor head rotation, "Y" data, probe tip deflection and "Z" data, downbore distance.



The following section describes the bore erosion measuring system designed, procured and tested to provide the necessary equipment for the bore erosion study on the 105mm., M68.

III. SYSTEM DESCRIPTION (See Fig. 3)

A precision instrument is described that has been designed and set up to determine and record radial and axial point or line scan measurements inside long bores up to 25 inches long within diametral boundaries of 4.228 ± 0.075 inches.

The system consists of a BORE INSERT UNIT that is a precise electromechanical assembly containing a rotating sensor head and an X-Y PLOTTER that produces a trace of sensor head probe radial displacement vs angle of head rotation in a plane perpendicular to the axis of bore being scanned.

An ELECTRONICS UNIT is attached to the X-Y PLOTTER containing signal processing electronics, and electronic digital readout of probe tip radial position, and a control for electronic range suppression of the head rotation signal.

The system is shown in Figure 4 and its specifications follow.

SPECIFICATIONS

General		
X-Y Plotting	Area	11 x 15 inches
(See Fig 5)	Accuracy	± 0.2 % of full scale
X Data	Range	0 Deg to 360 Deg
Sensor Head Rotation	Overtravel	5 to 6 Deg
(See Fig 6)	Dial	1 Deg markings
	Setability	Within ± 30 Arc Minutes
	Engraving Acc.	Within ± 10 Arc Minutes
	Sensor	± 0.1 % Linearity
	Suppression	0 to 360 degrees
	Max Sensit.	Usable to 1 Deg/inch of trace
	Sensor Type	Resistance element
	Motion	Handwheel control

Y Data Probe Tip Deflection (See Fig 7)	Calib. Range	±0.0750 inches
	Sensor Range	±0.100 inches
	Accuracy	±0.0003 inches of digital reading
	Resolution	0.0001 inches digital 0.00005 inches analog
	Trace Expans.	To 20 millionths per chart grad. (0.0002 inch deflect./ chart inch)
	Sensor Type	LVDT
	Sensor Motion	Spring Restrained
Z Data Axial Bore Traverse (See Fig 6)	Range	0 to 25 inches
	Total Travel	27.9 inches
	Readout	Direct Linear Scale
	Setability	± 0.05 inches
	Scale Accur.	± 0.010 inches
	Motion Control	Knurled Palm Wheel no backlash scewed roller drive
	Accuracy	Tracking straightness to be tested; better than ± 0.005 inches, better than ±0.002 repeatability at constant temperature.

BORE INSERT UNIT

The primary element of this electromechanical assembly is the 48 inch ARM. The ARM consists of six precisely ground roller bearing tracks representing the state of the art in grinding parallel and straight surfaces in range of 48 inch lengths. Precision is of the same order of magnitude as flatness of equivalent length laboratory grade granite plattens.

A series of holes were incorporated in the ARM for application of a compensating bar that can be used to alter the axial straightness of the ARM for changes in its dimensional stability.

The unit embodies four major items representing its points of precision and reference as follows (refer to figure 3):

1. The forward Reference Ring
2. The rear Gaging Ring
3. The ARM tracking surfaces (six)
4. The Head rotational plane (ball bearing)

The unit has adjustment areas that are used operationally or in major assembly operations as follows:

5. ARM side support rollers with eccentric studs for preloading and alignment (eight places). Range is ± 0.005 inches for 180° rotation.

6. ARM vertical support rollers with eccentric mounting for preloading and alignment (four places). Range is ± 0.005 inches for 180° rotation.

7. ADJUSTABLE PAD (rear) bearing points (four) spaced 90° apart. The pads are split and the expanding tapered set screws must not be screwed in beyond the "flush to the end" point. This provides a fine adjust range of 0.020 inches expansion in positioning the rear of the assembly for axis coincidence with the center line of the bore. Spacers are provided to accommodate this "fine range" to various chamber diameters of small variation.

8. GAGING RING (rear). This is a hardened disk with a precise tolerance (± 0.0001) roundness specification. This disk has been aligned to be within 0.0005 inches coaxial with the average axis of the six roller tracks. The disk is not pinned allowing further adjustment and is held in place by six screws, four of which also pass through the control housing flanges. Adjustment would require removal of the housing.

9. REFERENCE RING (forward). This is a precise hardened ring held to ± 0.0001 roundness tolerance of the spherical surface about its center line. The ring is a slip fit, can be replaced, but is non-adjustable. Curvature is such that bottoming of the assembly will align it coaxially with the chamber taper at this point.

10. Sensor head rotational plane. The sensor head assembly is attached to the ARM by four internal screws. The plane of rotation is determined by a single ball bearing where-in preload can be changed by an outer race spacer change. Radial free play (in the direction of probe tip measurement) is in the order of 0.0001 inches. This assures operator feel of tip loading and thus minimization of tip breakage and head damage.

DATA PROCESSING AND DISPLAY - ELECTRONICS

This function is represented by the X-Y Plotter, the ELECTRONICS UNIT, and direct reading dials - scales. Refer to Figure 3.

One power cord attached to the plotter serves the complete system. One switch, located on the plotter control section, controls the power ON-OFF function. One cable connects the BORE INSERT UNIT with Plotter/ELECTRONICS UNIT assembly. Fuse protection is through the provisions made for the recorder.

The X-Y Plotter front panel controls are fully active as marked. The signal input points are at the rear connector location. The "top-side" signal input locations are active but not used.

The ELECTRONICS UNIT contains the electronic digital readout and circuitry for analog signal processing. A Head rotation signal suppression control is located adjacent to the digital display. The suppression allows recording of angular rotation at high gain with ability to always maintain the trace on the chart.

As shown in Figure 3, four adjust points are located at the ELECTRONICS UNIT as follows:

1. Digital fine span adjust. Located behind front right corner of display window.
2. Digital zero adjust. Same location as "1."
3. LVDT span adjust. Screw driver adjustment thru hole in side of case.
4. Suppression range adjust. Adjacent location to item "3.", unmarked.

The digital display shows probe tip deflection either side of a zero reference position to a resolution of 0.0001 inches. A sign indication is present to show which side is active. The zero reference has been set up to read zero for the expected cannon rifling diameter. This may be adjusted by relocation and locking of the LVDT housing.

The two major assemblies are inter-connected by a shielded cable that carries only low level DC power and the return DC signals. AC excitation and signal demodulation are done locally by circuitry in the SENSOR HEAD.

A small electronics board is located in the rotating sensor head assembly that serves to generate a sensor carrier frequency and demodulate a sensor output signal and amplification. A gain control pot is located on the board for LVDT signal setup.

MECHANICAL ALIGNMENT

Means are provided for altering the ARM tracking path with respect to its carrier cylinder by use of roller studs and shafts that have been eccentrically machined. This also is the preloading means for the ARM.

The complete assembly is aligned by means of four split pads spaced 90° apart at the instrument rear. The adjustment may be relocated to accommodate various ZONE A diameters by application of pad spacers. The assembly forward section is self locating by means of an integral hardened ring with an outer spherical surface.

Adjusting means-ranges are as follows:

1.	ARM relocation	0 to ± 0.005 inches in the lateral direction at each roller station (180° shaft rotation). 0 to ± 0.005 inches in the vertical direction at each roller station (180° shaft rotation).
2.	Assembly rear	Fine range of split pads in direction normal to the plane of the split, 0 to ± 0.010 inches. Incremental relocation of the fine range to accommodate diameter change in Zone A. 0.030 inch diameter change spacer set 0.064 inch diameter change spacer set 0.094 inch diameter change by combination of above. Note: The tapered screws for fine adjust must not be turned in beyond the flush condition in expanding the pads. Use spacers to bring the adjustment within range.

IV. TESTING RESULTS

Testing of the system to assure proper performance was accomplished in a 105mm., M68 gun tube with plots shown in figures 8 and 9. Figure 8 illustrates a complete circumferential plot, full scale on the plotter set to accept 360° probe rotation.

Adjustment of the amplification of both the X and Y scales gave us a representation of 2 grooves and lands spread over full scale. This is shown in figure 9. The digital readout on the plotter is used to measure actual depth of rifling so actual plotter amplification can be recorded.

V. CONCLUSIONS

Based on the testing and evaluation results, it is concluded that the system developed and designed under this project provides a practical and effective means of collecting measurement data required for the study and evaluation of secondary bore erosion.

VI. IMPLEMENTATION

Present plans are for utilization of the bore erosion measuring system to obtain measurement data as part of an erosion study to be conducted by Watervliet Arsenal.

FIGURE 1: ERODED GUN TUBE

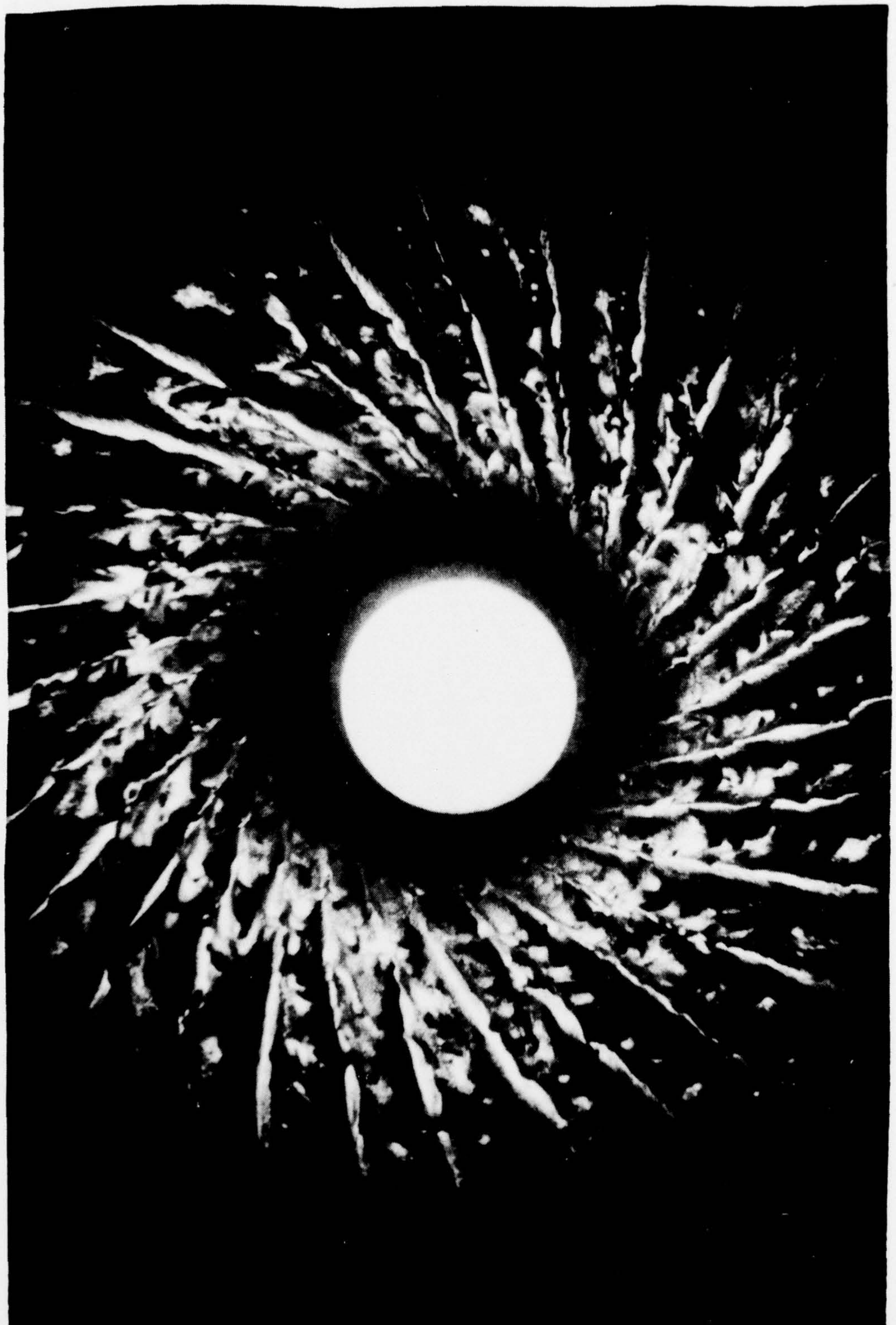


FIGURE 2: 360° VIEW OF ERODED TUBE BORE

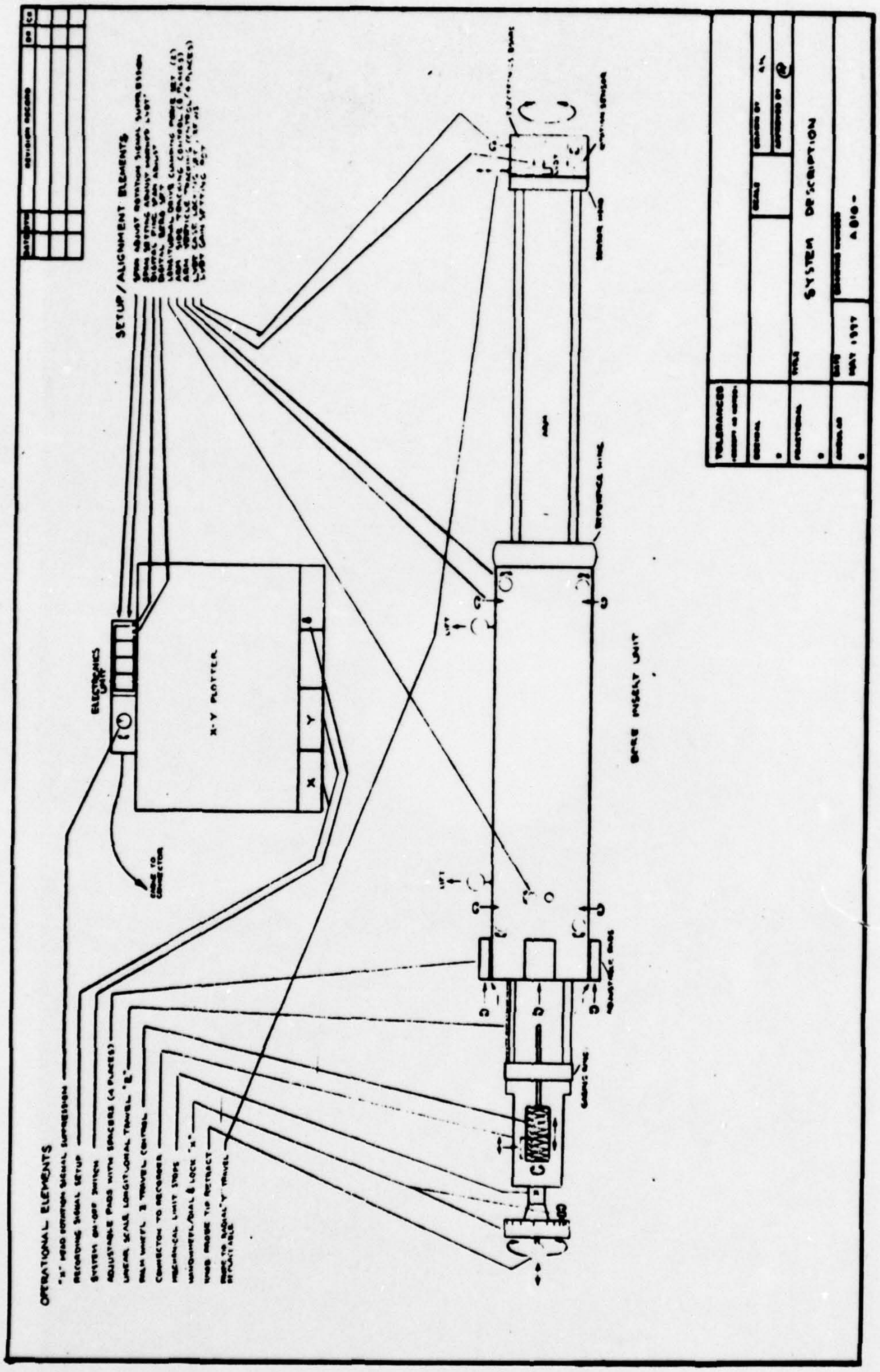


FIGURE 3: SYSTEM DESCRIPTION

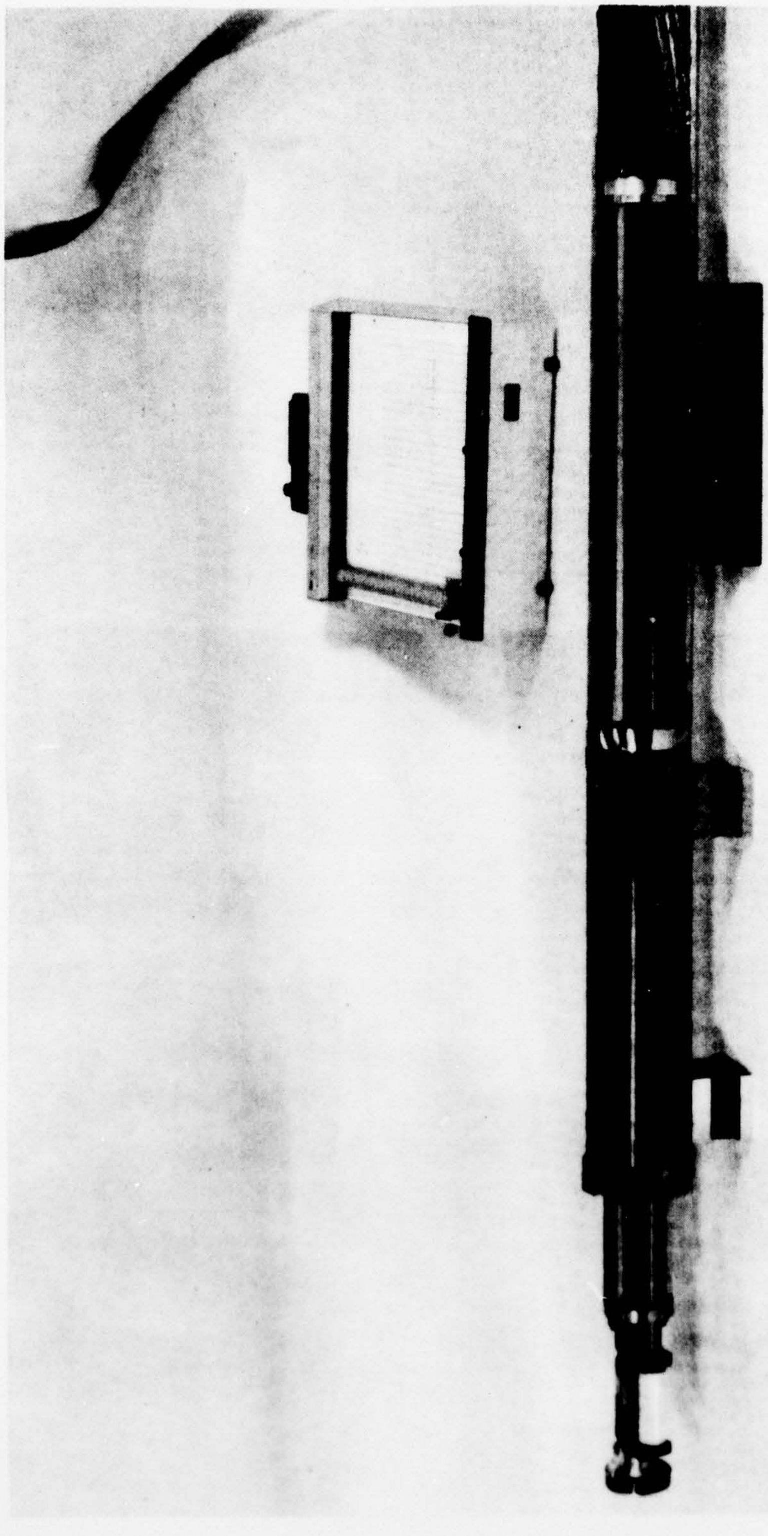


FIGURE 4: COMPLETE MEASURING SYSTEM

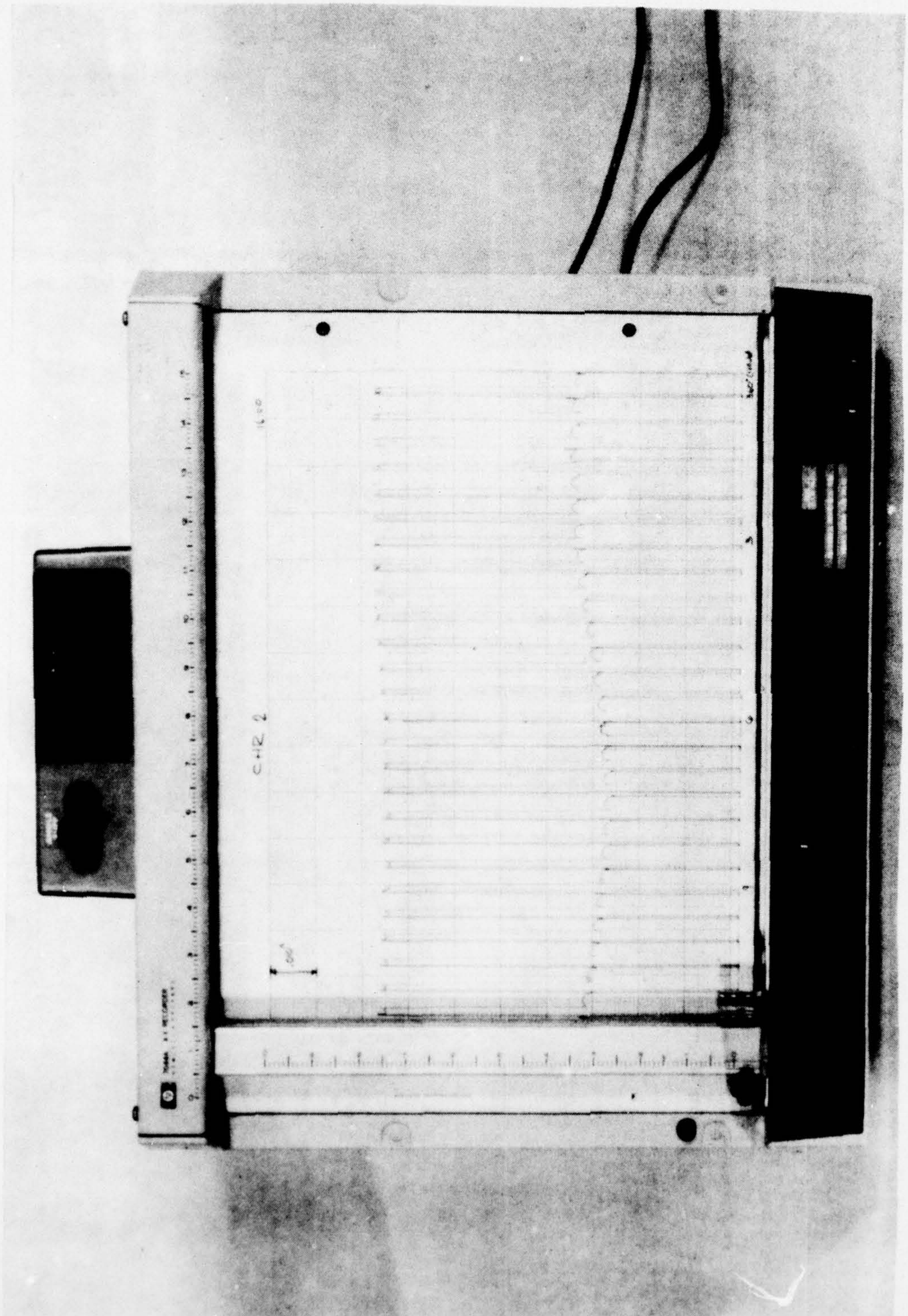


FIGURE 5: PLOTTER WITH TEST PLOT

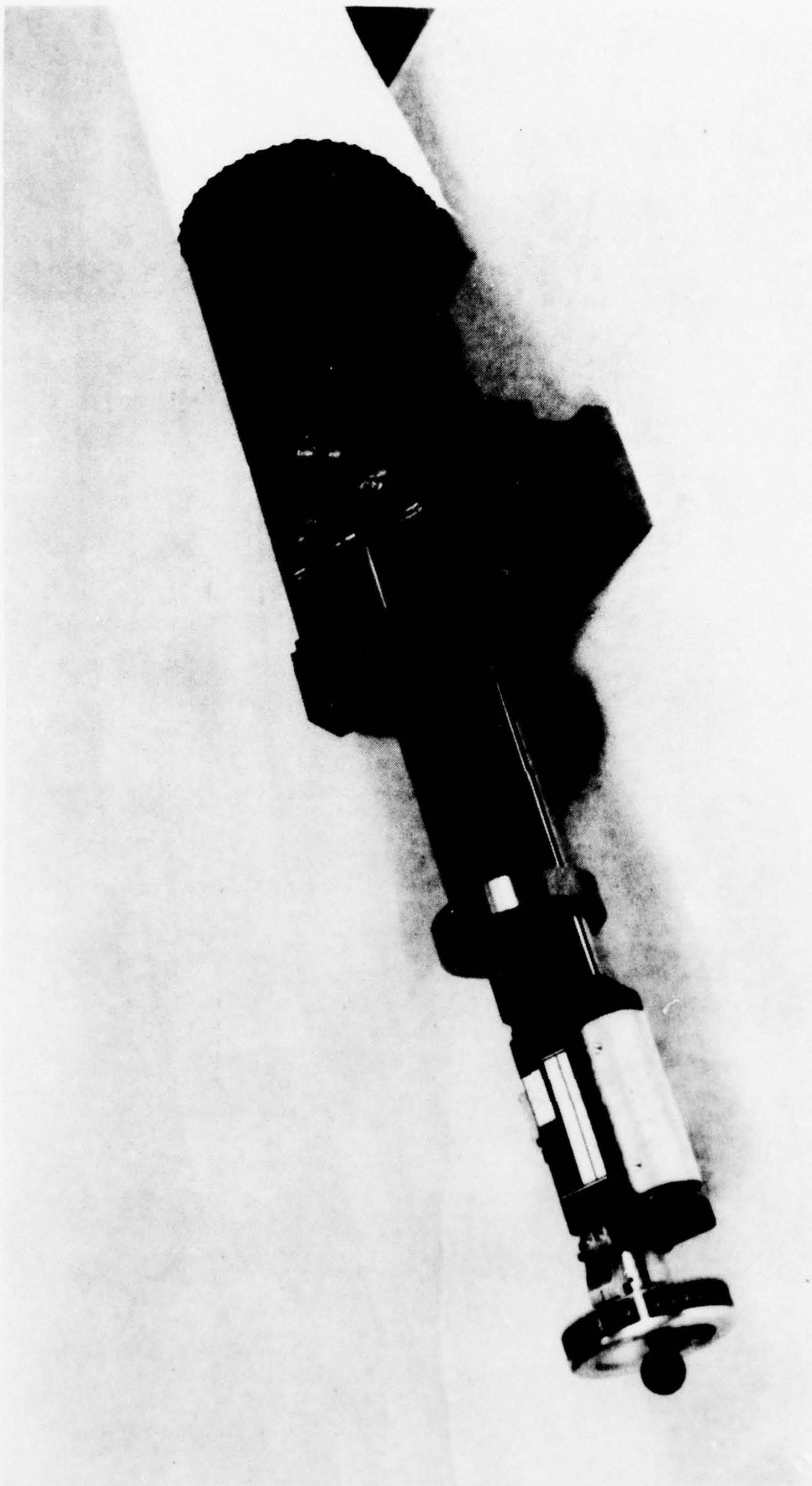


FIGURE 6: ROTATING HANDLE AND DOWNBORE ADJUSTMENT

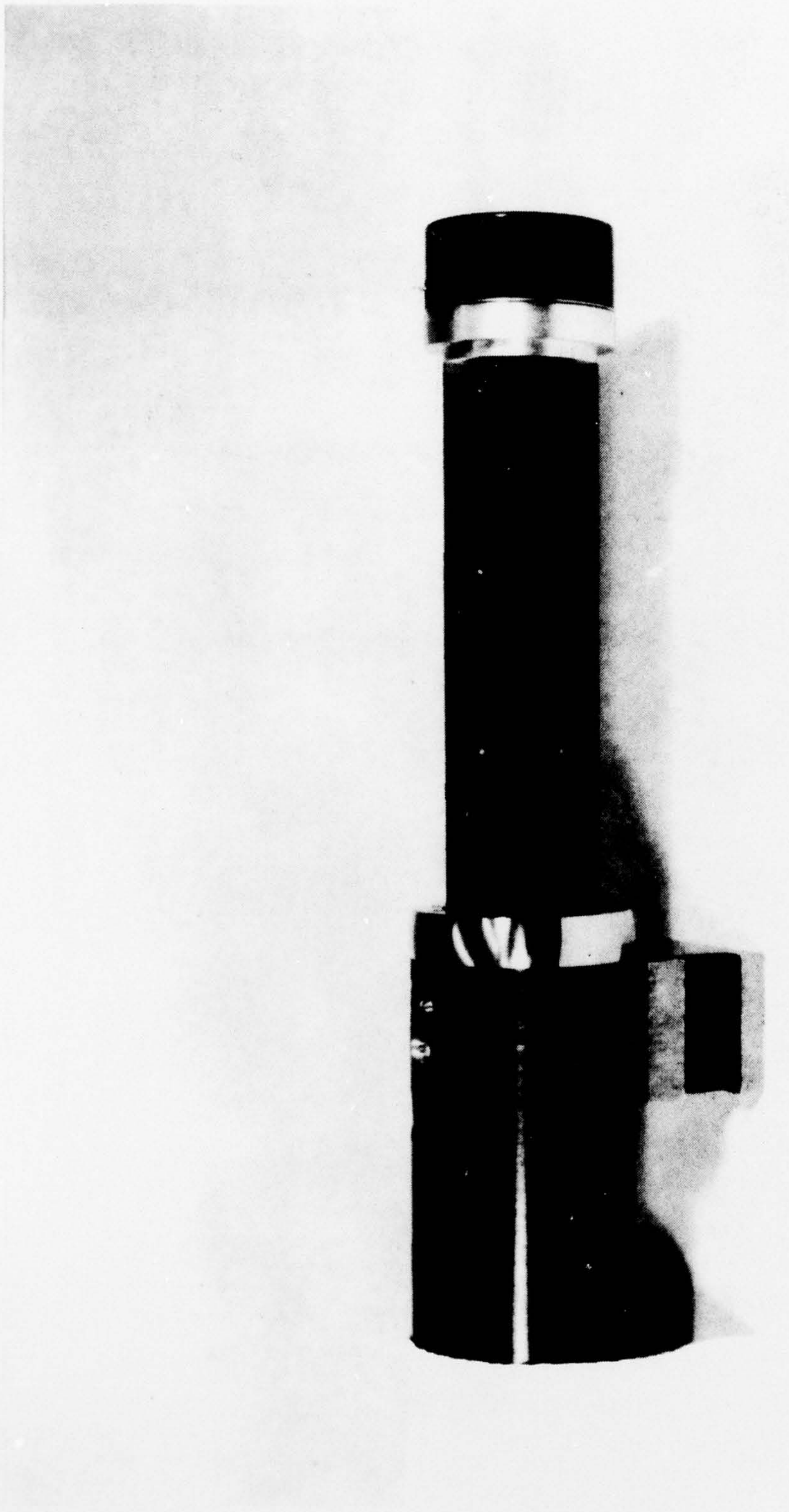


FIGURE 7: LVTD TIP EXTENDED

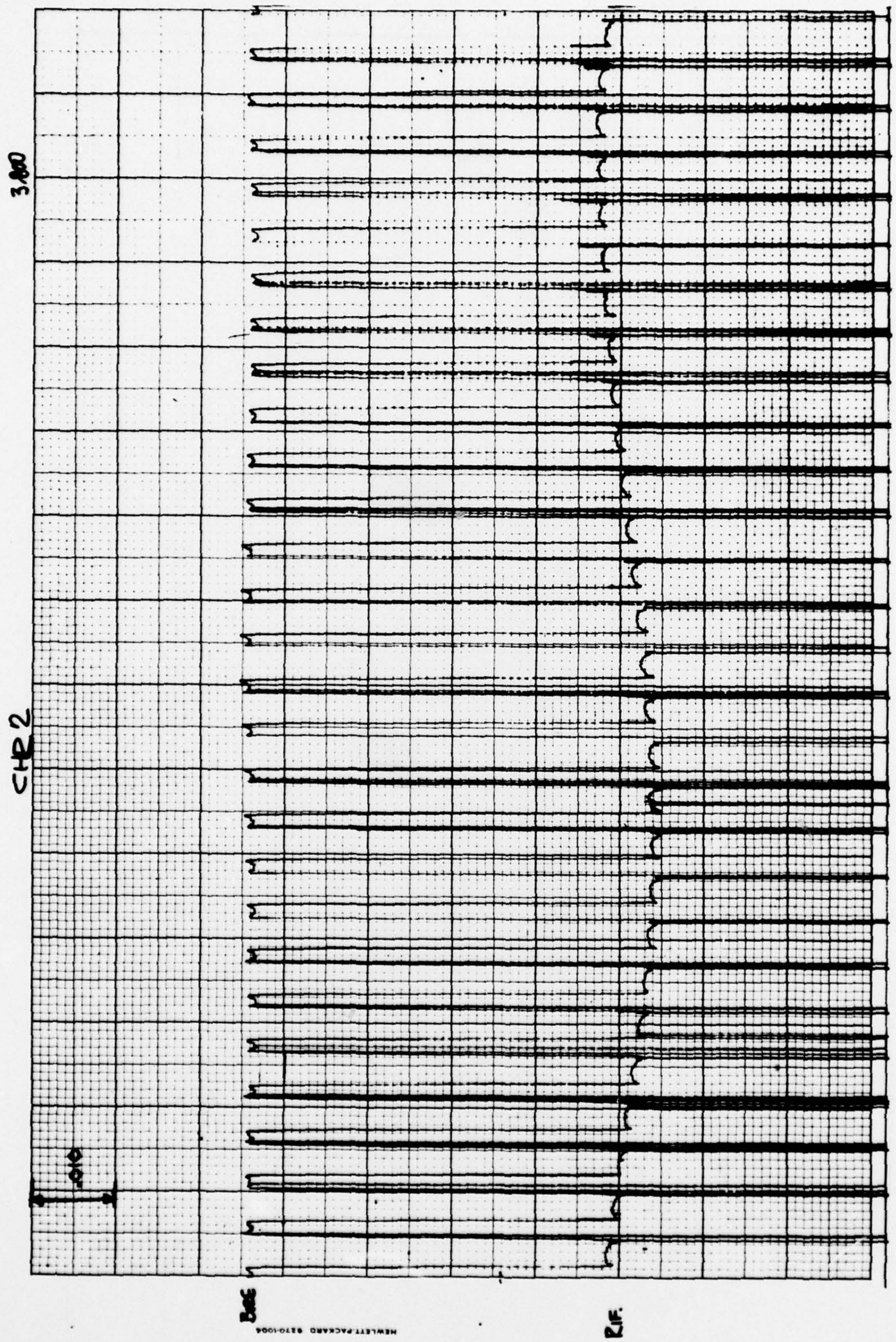


FIGURE 8: COMPLETE 360° TEST PLOT

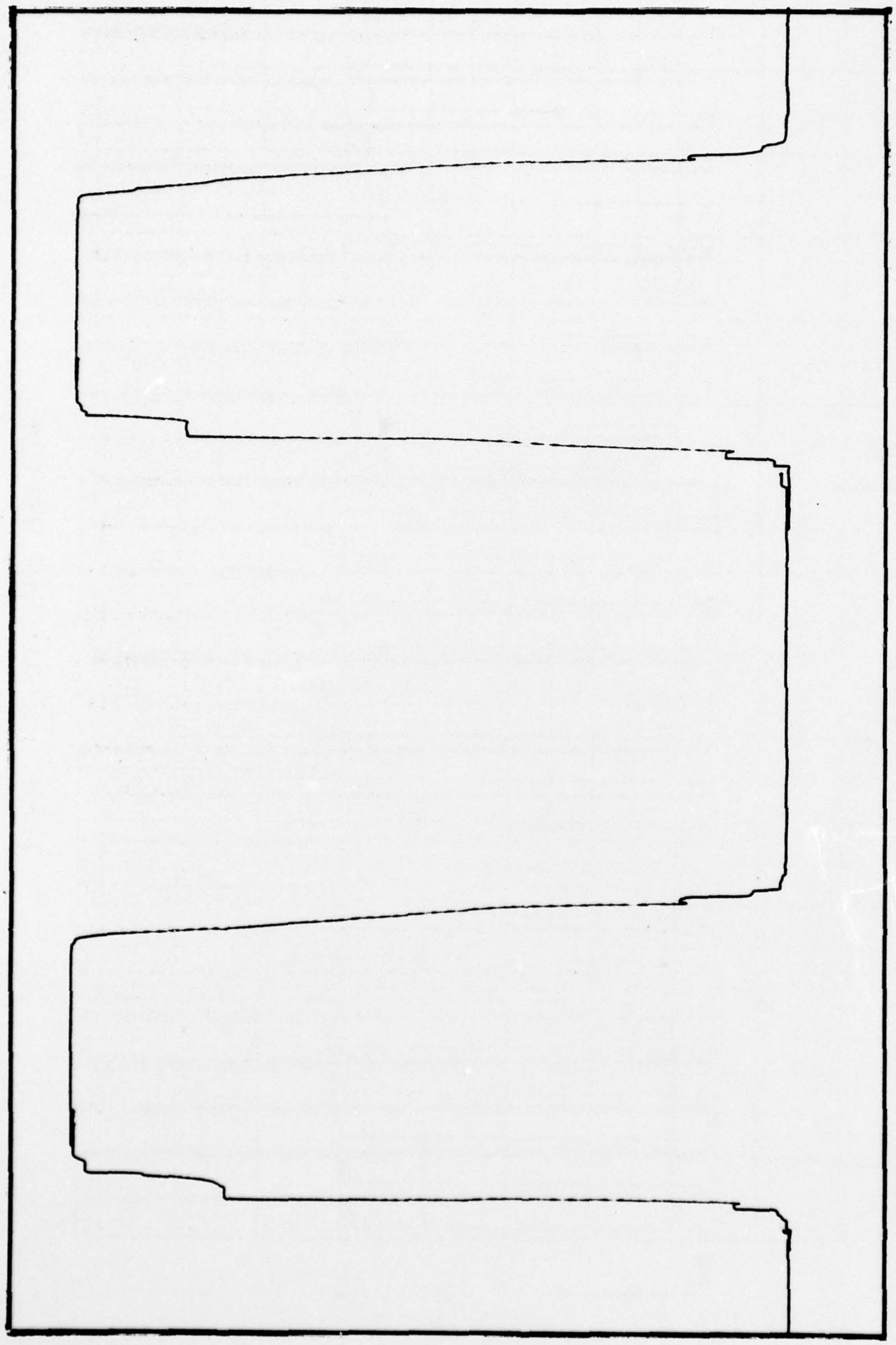


FIGURE 9: EXPANDED TEST PLOT (2 GROOVES)

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