WVT-QA-8301

Dynamic Measurement of Rifling Twist

S. Krupski
R. Campolmi

February 1983

Product Assurance Directorate

Watervliet Arsenal
Watervliet, New York
12189

Technical Report

AMCMS No. 5397.OM.6350
Pron No. AW-8-P5191

MATERIALS TESTING TECHNOLOGY PROGRAM (AMS 49831)

Report No.: WVT-QA-8301

Title: Dynamic Measurement of Rifling Twist

THIS REPORT 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.

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: WVT-QA-8301	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (*and Subtitle*): Dynamic Measurement of Rifling Twist	5. TYPE OF REPORT & PERIOD COVERED: Final, June 79 - June 81
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): S. Krupski, R. Campolmi	8. CONTRACT OR GRANT NUMBER(s): AMCS NO 5397.OM.6350
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Product Assurance Directorate, Watervliet Arsenal, Watervliet, NY 12189	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AW-8-P5191 (04) M7-M7
11. CONTROLLING OFFICE NAME AND ADDRESS: U.S. Army Armament Materiel Readiness Command, Rock Island, IL 61201	12. REPORT DATE: February 83
	13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (*if different from Controlling Office*)	15. SECURITY CLASS. (*of this report*): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (*of this Report*)

Approved for Public Release: Distribution Unlimited

17. DISTRIBUTION STATEMENT (*of the abstract entered in Block 20, if different from Report*)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)

Rifling Twist
Rotary Encoder
Laser Interferometer
Computer Interfacing

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

Rifling Twist is machined in cannon tubes to increase stability of rounds in flight. At Watervliet Arsenal, measurement of rotational and longitudinal motion of the rifling machines utilized to create rifling is considered an acceptable method of twist rate verification. This report describes the latest equipment utilized in this measurement, its advantages over previous methods, and its limitations.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

ABSTRACT

Rifling Twist is machined in cannon tubes to increase stability of rounds in flight. At Watervliet Arsenal, measurement of rotational and longitudinal motion of the rifling machines utilized to create rifling is considered an acceptable method of twist rate verification. This report describes the latest equipment utilized in this measurement, its advantages over previous methods and its limitations.

ACKNOWLEDGEMENT

The author greatly acknowledges Mr. A.G. Gallo for his advice and direction in this project and the technical assistance contributed by Mr. J. Dwyer and Mr. T. McCloskey.

1. INTRODUCTION

By the close of the American Civil War, rifled gun tubes had come into general use. Although the principle was known long before that time, and had already been applied to small arms, the machinery with the necessary capability for accurately rifling cannons did not exist until the mid-nineteenth century.

Rifling consists of a number of helical grooves cut in the bore of a cannon, beginning in front of the chamber area and extending to the muzzle. These grooves impart a rotational motion to the projectile which stabilizes it in flight. Projectiles are designed with rotating bands of soft metal, slightly larger in diameter than the bore of the gun. As the projectile is forced through the bore under the action of propellent gases, the lands cut through the rotating band engraving it to conform to the cross section of the bore, enabling obturation and causing rotation of the projectile. The rate of twist of rifling can be uniform, increasing, or a combination of the two in different areas of the bore.

2. THE RIFLING PROCESS

At Watervliet Arsenal rifling is put in gun bores by broaching i.e., a series of progressively larger cutters mounted on an extended "rifling bar" are pushed through a gun tube. As the rifling bar is moved through the gun bore, rotation of the rifling bar occurs and a specific angle of rotation is generated for a given distance traveled longitudinally. The rotation is controlled by a system of gear drives or by a helical guide groove cut in the O.D. of the bar. The rate of rotation of the bar and rifling broach at a particular downbore distance must be inspected to insure the rifling twist in the gun tube conforms to drawing requirements. Traditionally, because of the nature of the process, inspection of the rifling bar has been considered an adequate indication of the twist which is established in the gun tube.

3. INSPECTION TECHNIQUES - A HISTORY

Inspection of a rifling bar requires measurement of an angle of rotation and of linear distance traveled. Over the years state-of-the-art inspection of these features has changed considerably. Initially inspection of the rifling bars was done by stacking gage blocks to measure linear distance and strapping a sine bar to the rifling bar to make a measurement of angle of rotation. This method required a complex mechanical set-up at each inspection point. The inspection was very time consuming, and due to the large number of required mechanical interfaces, was subject to errors. To perform a complete rifling bar inspection using these techniques and to manually record the readings required between 32 and 64 man-hours. Obviously, during this time, production had to be interrupted.

In recent years, rotary encoders which measure rotational position came into widespread use. A rotary encoder is an electro-optical device that utilizes a light source, photodetector, and a serrated glass wheel to provide a digital readout of shaft rotation in degrees. The sine bar set-up was replaced with an encoder strapped to the rifling bar with a heavy brass pendulum attached to provide a verticle reference. This pendulum maintains a zero point from which the rotation of the rifling bar can be measured. The value of this rotation is then displayed on a digital readout.

Measurement of linear distance traveled was converted to more advanced techniques with the utilization of the laser interferometer. This length measurement system utilizes the standard wavelength of helium-neon generated laser light as a primary length standard (See Fig 1). It is recognized as an accepted length standard by the National Bureau of Standards. The laser system also utilizes a digital readout system. Both these readout systems give information which is gathered at each inspection point.

This data is recorded and calculations indicating deviation from nominal twist rates are made. An advancement of this system utilized a Hewlett-Packard calculator to take readings from each readout device at the push of a button, and to perform the necessary calculations. Inspection of a rifling machine utilizing this improved system required approximately eight man-hours. A major delay still remained in that the rifling bar had to be stopped at each inspection point in order to take simultaneous readings of angle and distance. Errors are introduced into the inspection process when the machine is stopped. Any backlash, wind-up, etc. in the machine is introduced into the measurements by each stop and start. It was desirable to take readings as the rifling bar was in motion but neither the equipment nor the push button operation was adequate to sample both readout devices simultaneously. Any difference in the exact time the readings of angular position and linear position are taken introduced an uncertainty error in actual composite position and, therefore, a false representation of actual twist rate.

4. SYSTEM DESCRIPTION

The intent of the project was to develop a new system to measure rifling twist more quickly and accurately. The chosen method was to employ a rotary encoder of slightly greater resolution than those presently used mounted in a fixture that would be pushed through the tube, simulating the actual rifling operation. A new, faster computer has been employed to take linear readings from the laser interferometer system and angular readings from the rotary encoder within computer execution time. The actual time between these two samplings must be small enough such that the change in position of the head during this time is negligible, that is, the angular and linear readings correspond to essentially one head position. A model 9825 Hewlett-Packard desktop computer is utilized. A program was written in such a way as to minimize the actual finite "computer time" required between linear and angular read statements. This new procedure and equipment have made it possible to take accurate readings "on the fly" that is, without stopping the motion of the rifling machine.

A measuring head was designed and built to hold the rotary encoder and to guide the rifling bar through the gun tube. This head is mounted in place of the rifling cutter and is pushed through a smooth bore gun tube which has not yet progressed to the rifling operation. The head must support the rifling bar as it traverses through the gun tube. This head houses a rotary encoder with .005 degree resolution. The encoder was specified with special low friction bearings which help the shaft mounted pendulum seek a more consistent vertical reference to gravity. Several materials and pendulum configurations were evaluated to find the combination which gives the most repeatable results within the space restrictions. Any pendulum effects related to the ability to establish this zero reference show up in excessive scattering of data points about the smooth curve. These errors are caused when the pendulum is pushed to an off vertical position by bearing friction and then falls back to and past its zero position. As the measuring head passes through the tube the head and encoder body rotate while the encoder shaft remains referenced to gravity. The encoder readout shows actual rotation of the would be rifling cutter. Obviously, minimizing the deviations of the pendulum from true zero leads to a more accurate inspection system.

5. PRESENT USE

The system developed under this project is now being utilized by the Calibration Branch of the Metrology Laboratory Division of the Product Assurance Directorate. Inspection of a typical rifling bar now takes two men approximately two hours. Most of this time is consumed during system set-up. Multiple runs are often taken to show system repeatability. Data is presented both as numerical values (See Fig. 2) and as a plot of "downbore" position vs. circumferential and linear error (See Fig. 3). Circumferential error is the deviation in thousandths from a nominal rotation. Rifling twist is generally specified as "one turn in XX calibers" (caliber = bore diameter). This translates to 360° rotation, or one circumference of the bore, in a specified linear or "downbore" distance. Errors are specified as an error in rotational angle, circumferential travel around the bore surface or as a linear or "downbore" error assuming the rotation to be nominal. These are all proportional and the graphical presentation allows the responsible people to evaluate the inspection results using whichever criteria they prefer.

As the system is used today, the head to guide the encoder through the tube is not required in most inspections. It has been found that the encoder can simply be strapped to the rifling bar utilizing a double vee-block. Readings are taken "on the fly" with much improved accuracy and great time savings over previous incremental methods.

6. CONCLUSIONS

Measurement of rifling twist on the machines used to rifle cannon is now performed routinely at Watervliet Arsenal. Calibration people have become skilled in the capabilities of the equipment and, because of the interfaced computer, are able to adjust the inspection process or the readout information as desired. Readings can be taken at selected intervals or continuously, as fast as the computer can sample the two devices. Numerical presentations can be changed by minor program changes as can graphical presentations. Programming can provide different measurement scales, colored plots for repeat runs, presentation of allowable tolerance zones or presentation of data in any method desired.

The rotary encoders, laser equipment, and interfaced computer equipment utilized for this inspection are being utilized throughout the Arsenal. Work has been done recently to adapt this equipment to measure the actual twist of the rifled tube. This is a verification of the rifling operation and will give information as to broach condition, possible twisting of the rifling bar, poor condition of the gears in the machine drive or guide key wear. All these are process varibles which must be controlled. The advancement in the state-of-the-art of rifling twist inspection realized by implementation of this project has allowed a better understanding of rifling in tubes and has enabled design engineers to study more closely rifling twist requirements as related to projectile performance.

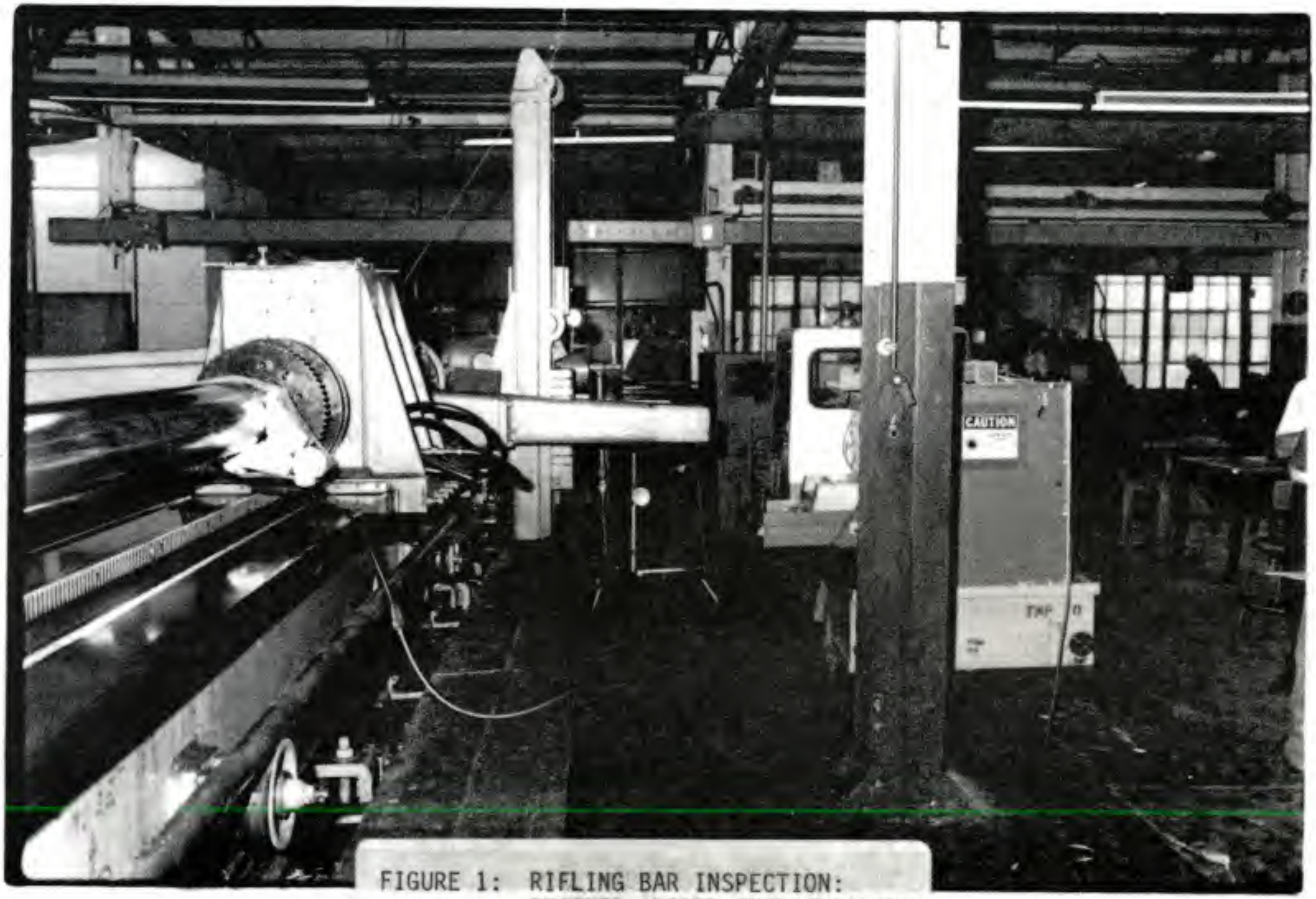

FIGURE 1: RIFLING BAR INSPECTION: ENCODER, LASER INTERFEROMETER

RIFLING BAR INSPECTION REPORT

Tube: 105m/m M68

Date: 14 Aug. 81

Bar Dwg. No. GEAR RIF.

Bar Insp. No.: GI-76-1

Basic Bore Dia. 4.1340

Twist: 1 Turn in 18.0000 Calibers

Down Bore Distance	Total Twist	Nom. Circum. Movement	Circum. Error	Down Bore Error
>>>> ORIGIN OF RIFLING <<<<				
0.0000	0.0000	0.0000	0.0000	0.0000
4.0017	19.3450	0.6984	-0.0005	0.0031
8.0048	38.7700	1.3971	0.0016	-0.0090
11.9951	58.0700	2.0935	0.0014	-0.0080
16.0010	77.3900	2.7927	-0.0008	0.0044
20.0058	96.7350	3.4917	-0.0019	0.0107
23.9988	116.0800	4.1886	-0.0009	0.0050
28.0045	135.4550	4.8877	-0.0010	0.0059
31.9949	154.7250	5.5842	-0.0023	0.0133
35.9984	174.1450	6.2829	-0.0005	0.0027
40.0011	193.5200	6.9815	-0.0001	0.0005
44.0028	212.8700	7.6799	-0.0004	0.0026
48.0042	232.2650	8.3783	0.0009	-0.0050
52.0044	251.5650	9.0765	-0.0010	0.0059
56.0031	270.9050	9.7744	-0.0012	0.0070
59.9945	290.1700	10.4710	-0.0029	0.0164
63.9979	309.5100	11.1697	-0.0039	0.0222
68.0019	328.9650	11.8686	-0.0008	0.0048
71.9942	348.2500	12.5654	-0.0019	0.0109
76.0011	367.6600	13.2647	-0.0010	0.0058
79.9993	386.9750	13.9625	-0.0020	0.0115
83.9978	406.2500	14.6604	-0.0045	0.0259
87.9976	425.6900	15.3585	-0.0013	0.0074
91.9990	444.9750	16.0568	-0.0040	0.0226
96.0005	464.2850	16.7552	-0.0057	0.0328
100.0021	483.7100	17.4537	-0.0034	0.0192
104.0033	502.9150	18.1520	-0.0089	0.0508
108.0035	522.2950	18.8502	-0.0079	0.0451
112.0042	541.5550	19.5484	-0.0113	0.0647
116.0029	561.0400	20.2463	-0.0063	0.0360
120.0043	580.3850	20.9447	-0.0067	0.0387
124.0054	599.7100	21.6430	-0.0079	0.0453
127.9940	619.0400	22.3392	-0.0067	0.0384
131.9979	638.3650	23.0380	-0.0084	0.0479
136.0027	657.7750	23.7370	-0.0071	0.0406
140.0053	677.1350	24.4355	-0.0072	0.0415
143.9976	696.5150	25.1323	-0.0049	0.0280
148.0053	715.9000	25.8318	-0.0050	0.0288
151.9971	735.2300	26.5285	-0.0044	0.0250
155.9979	754.5350	27.2268	-0.0062	0.0355
159.9998	773.8750	27.9252	-0.0070	0.0399
164.0027	793.2300	28.6239	-0.0073	0.0420
167.9935	812.5250	29.3204	-0.0078	0.0446
171.9994	831.9750	30.0196	-0.0053	0.0302
175.9938	851.1700	30.7167	-0.0099	0.0570
179.9984	870.4700	31.4156	-0.0126	0.0722
184.0045	889.9300	32.1148	-0.0098	0.0560
188.0051	909.4550	32.8131	-0.0036	0.0207

FIGURE 2: COMPUTER PRINTOUT INSPECTION REPORT

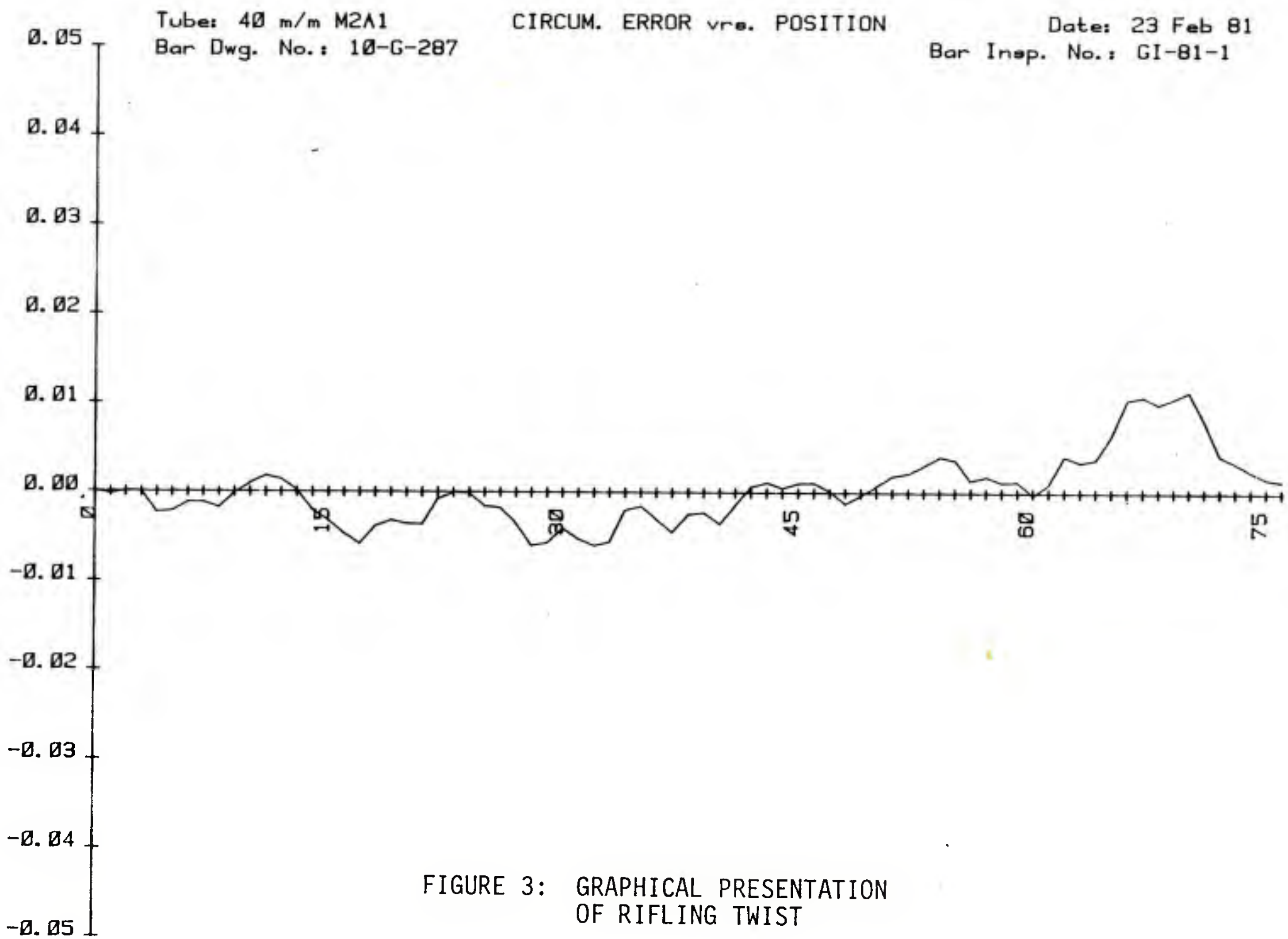

FIGURE 3: GRAPHICAL PRESENTATION OF RIFLING TWIST

TECHNICAL REPORT INTERNAL DISTRIBUTION LIST

	NO. OF COPIES
COMMANDER	1
TECHNICAL LIBRARY ATTN: DRDAR-LCB-TL	5
DIRECTOR, OPERATIONS DIRECTORATE	2
DIRECTOR, PRODUCT ASSURANCE DIRECTORATE	1
ASSOCIATE DIRECTOR, BENET WEAPONS LABORATORY	2

NOTE: PLEASE NOTIFY COMMANDER, WATERVLIET ARSENAL, ATTN: SARWV-QAE, WATERVLIET, NY 12189, OF ANY REQUIRED CHANGES.

TECHNICAL REPORT EXTERNAL DISTRIBUTION LIST

	NO. OF COPIES
ASST SEC OF THE ARMY RESEARCH & DEVELOPMENT ATTN: DEP FOR SCI & TECH THE PENTAGON WASHINGTON, D.C. 20315	1
COMMANDER US ARMY MAT DEV & READ COMD ATTN: DRCDE 5001 EISENHOWER AVE ALEXANDRIZ, VA 22333	1
COMMANDER US ARMY ARRADCOM ATTN: DRDAR-LC -TSS (STINFO) DOVER, NJ 07801	1 2
COMMANDER US ARMY ARRCOM ATTN: DRSAR-QA -IR -LEP-L ROCK ISLAND ARSENAL ROCK ISLAND, IL 61299	1 1 1
DIRECTOR US ARMY BALLISTIC RESEARCH LAB ATTN: DRDAR-TSB-S (STINFO) ABERDEEN PROVING GROUND, MD 21005	1
COMMANDER US ARMY ELECTRONICS COMD ATTN: TECH LIB FT MONMOUTH, NJ 07703	1
COMMANDER US ARMY MOBILITY EQUIP R&D COMD ATTN: TECH LIB FT BELVOIR, VA 22060	1

	NO. OF COPIES
COMMANDER US ARMY TANK-AUTMV R&D COMD ATTN: TECH LIB-DRDTA-UL WARREN, MICHIGAN 48090	1
COMMANDER US MILITARY ACADEMY ATTN: CHMN, MECH ENGRG DEPT WEST POINT, NY 10996	1
US ARMY MISSILE COMD REDSTONE SCIENTIFIC INFO CEN ATTN: DOCUMENTS SECT, BLG 4484 REDSTONE ARSENAL, AL 35898	2
COMMANDER US ARMY FGN SCIENCE & TECH CEN ATTN: DRXST-SD 220 7TH STREET, N.E. CHARLOTTESVILLE, VA 22901	1
COMMANDER US ARMY MATERIALS & MECHANICS RESEARCH CENTER ATTN: DRXMR-PL -D -FI -S -M -AT WATERTOWN, MA 02172	2 1 1 2 1

NOTE: PLEASE NOTIFY COMMANDER, WATERVLIET ARSENAL, ATTN: SARWV-OAE, WATERVLIET, NY 12189, OF ANY REQUIRED CHANGES.

TECHNICAL REPORT EXTERNAL DISTRIBUTION LIST (CONT.)

	NO. OF COPIES
COMMANDER US ARMY RESEARCH OFFICE P.O. BOX 12211 RESEARCH TRIANGLE PARK, NC 27709	1
COMMANDER US ARMY HARRY DIAMOND LAB ATTN: TECH LIB 2800 POWDER MILL ROAD ADELPHIA, MD 20783	1
DIRECTOR US ARMY INDUSTRIAL BASE ENG ACT ATTN: DRXPE-MT ROCK ISLAND, IL	1
COMMANDER NAVAL SURFACE WEAPONS CEN DAHLGREN, VA 22448	1
DIRECTOR US NAVAL RESEARCH LAB ATTN: DIR, MECH DIV CODE 26-27 (DOC LIB) WASHINGTON, D.C. 20375	1 1
NASA SCIENTIFIC & TECH INFO FAC P.O. BOX 8757, ATTN: ACQ BR BALTIMORE/WASHINGTON INTL AIRPORT MARYLAND 21240	1
COMMANDER DEFENSE TECHNICAL INFO CENTER ATTN: DTIC-TIR -LTD CAMERON STATION ALEXANDRIA, VA 22314	10 2
DIRECTOR BATTELLE COLUMBUS LAB 505 KING AVE COLUMBUS, OHIO 43201	1

NOTE: PLEASE NOTIFY COMMANDER, WATERVLIET ARSENAL, ATTN: SARWV-QAE, WATERVLIET, NY 12189, OF ANY REQUIRED CHANGES