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LASER INTERFEROMETER CALIBRATION STATION.(U)
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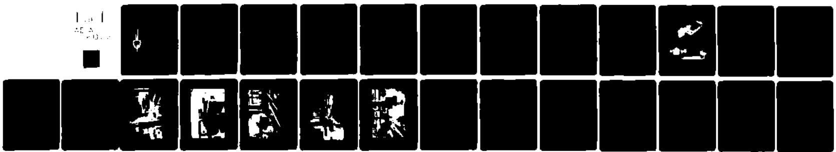

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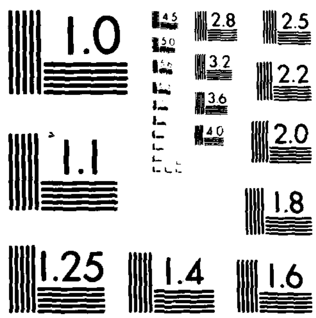

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WVT-QA-8101

LASER INTERFEROMETER
CALIBRATION STATION

R.W. CAMPOLMI
S.J. KRUPSKI

OCTOBER 1981

U.S. ARMY ARMAMENT COMMAND

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

TECHNICAL REPORT

AMCMS No. 5397.OM.6350

Pron No. AW-8-P5191

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

The laser interferometer is a versatile tool, used for calibration over both long and short distances. It is considered traceable to the National Bureau of Standards. The system developed under this project was to be capable of providing for the calibration of many types of small linear measurement devices. The logistics of the original concept of one location for calibration of all mics, calipers, etc. at a large manufacturing facility proved unworkable. The equipment was instead used for the calibration of the large machines used to manufacture cannon tubes.

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MATERIALS TESTING TECHNOLOGY PROGRAM (AMS 4931)

Report No. WVT-QA-8101 Title: Laser Interferometer Calibration Station

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) FOR MATERIEL/MATERIAL PROCURED OR MAINTAINED BY AMC.

LIST OF ILLUSTRATIONS

TABLE

ACKNOWLEDGEMENT

The authors wish to acknowledge Mr. Benjamin R. Taylor for the project concept and initial project development and Mr. Albert G. Gallo for subsequent project development.

1. INTRODUCTION

Previous investigations into the use of Laser Interferometry for linear distance measurements at Watervliet Arsenal[1&2] resulted in the development of a Constant Force Device[3] (CFD) and an improved method for calibrating both short and long length standards. A decision was made to build a general purpose system which could be used for calibration of micrometers, gage blocks, length standards, mechanical and electronic probes, cartridges, indicators, etc. This is a report on that project.

2. PRINCIPLES OF INTERFEROMETRY

A basic Laser Interferometer consists of a Laser Head which emits a double frequency, coherent beam of light; a combination beam splitter/retroreflector or remote interferometer; a moveable retroreflector also known as a "cube corner" and a Laser Display which contains a high speed electronic counter and a digital read-out. The electronics in the Display count the phase shifts generated by the laser beam being divided and recombined in the remote interferometer. One leg of the beam travels to the cube corner and the other leg provides a reference. The advantage of this system is that only the movement of the cube corner is measured.

---

[1] F.J. Audino and B.R. Taylor, "Applications of Laser Interferometry in Precision Measurements", Watervliet Arsenal Technical Report: WVT-QA-7405.

[2] "Functional Descriptions and Applications of Laser Inspection Systems", Product Assurance Pamphlet, AMSAR-WV-P-702-16, Sep 1975.

[3] US Patent #3975100

The cube corner is attached to the object whose travel is being measured. The wavelength of this laser in a vacuum is a constant 6328 Angstroms or approximately .000024 inches. With compensation for air temperature, pressure and humidity, this constant is used to calculate the distance moved with a resolution of one millionth of an inch. This system also benefits from the fact that it is considered "a priori" traceable to the National Bureau of Standards and does not require routine calibration.[4]

3. SYSTEM CONCEPT

The Laser Interferometer Calibration Station Material Testing Technology Project was conceived as a method for quickly and accurately calibrating micrometers, length standards, electronic measurement cartridges (LVDTs), etc. Features of this system are: improved repeatability using the Constant Force Device; versatility; print on command, eliminating the need for the operator to interpret and record readings and the ability to handle an infinite number of calibration points with no degradation in accuracy.

The original system concept, shown in Fig. 1, had the laser mounted under the granite base with two right angle beam benders to bring the beam to the top surface of the table. The first station encountered by the beam was a micrometer measurement station. Two Constant Force Devices and a retroreflector were utilized to obtain readings at any location along the micrometers travel. The last station is the LVDT calibration station which is shown in Fig. 2. Fig. 3 depicts a later version of the station with a surface mounted laser. Air slides are incorporated to reduce friction and increase accuracy. This system has enough flexibility to allow additional stations to be added as the need arises.

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[4] U.S. Dept of Commerce, N.B.S., Letter, dtd Oct 18, 1975

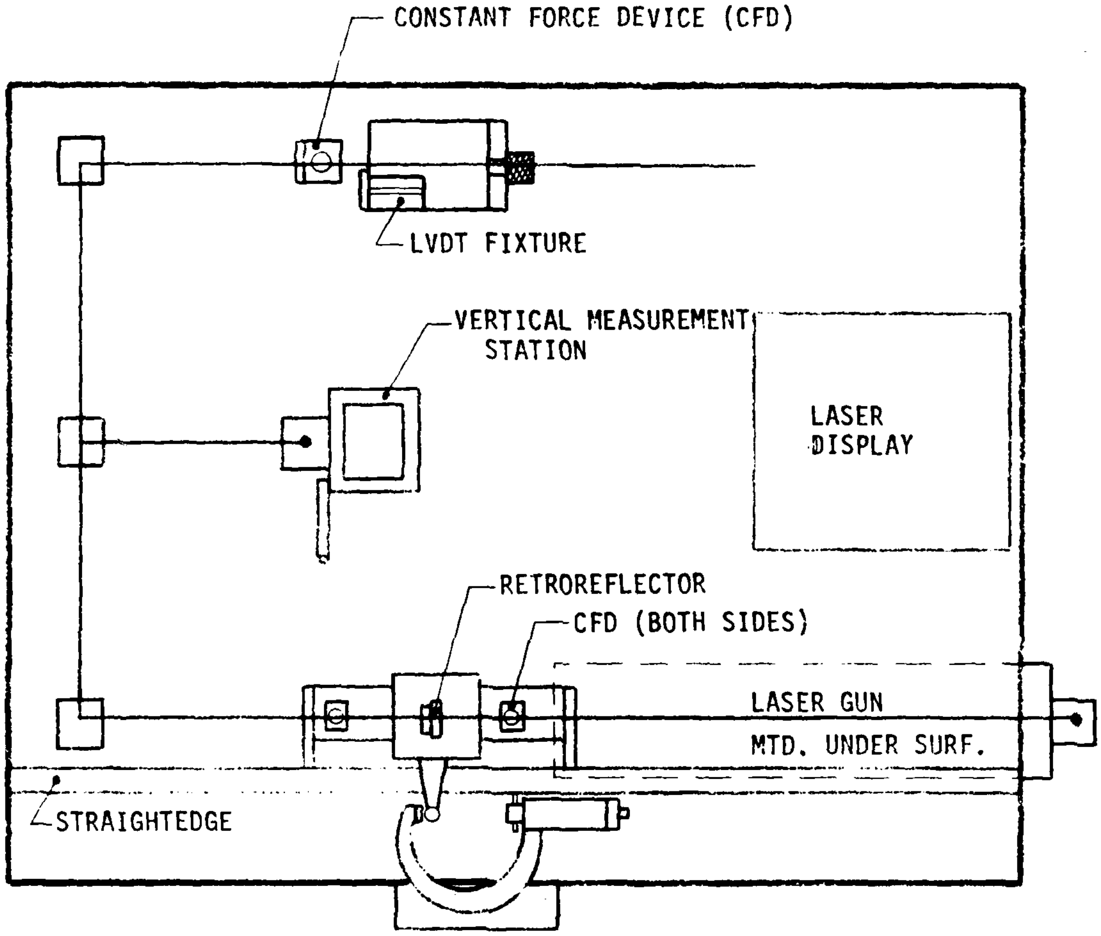

FIGURE 1. LASER INTERFEROMETER CALIBRATION STATION-SYSTEM CONCEPT

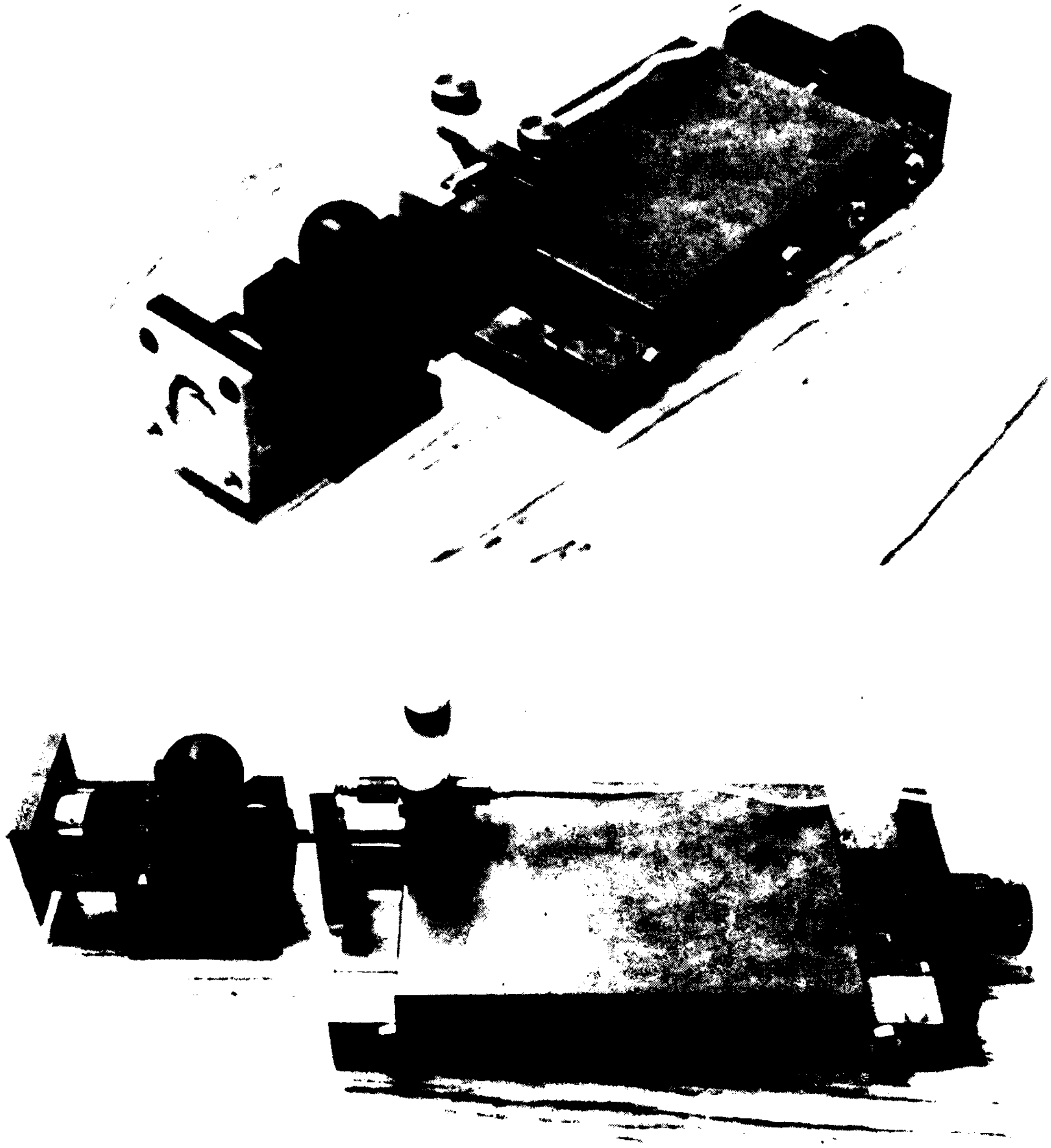

FIGURE 2. ELECTRONIC CARTRIDGE CALIBRATION STATION

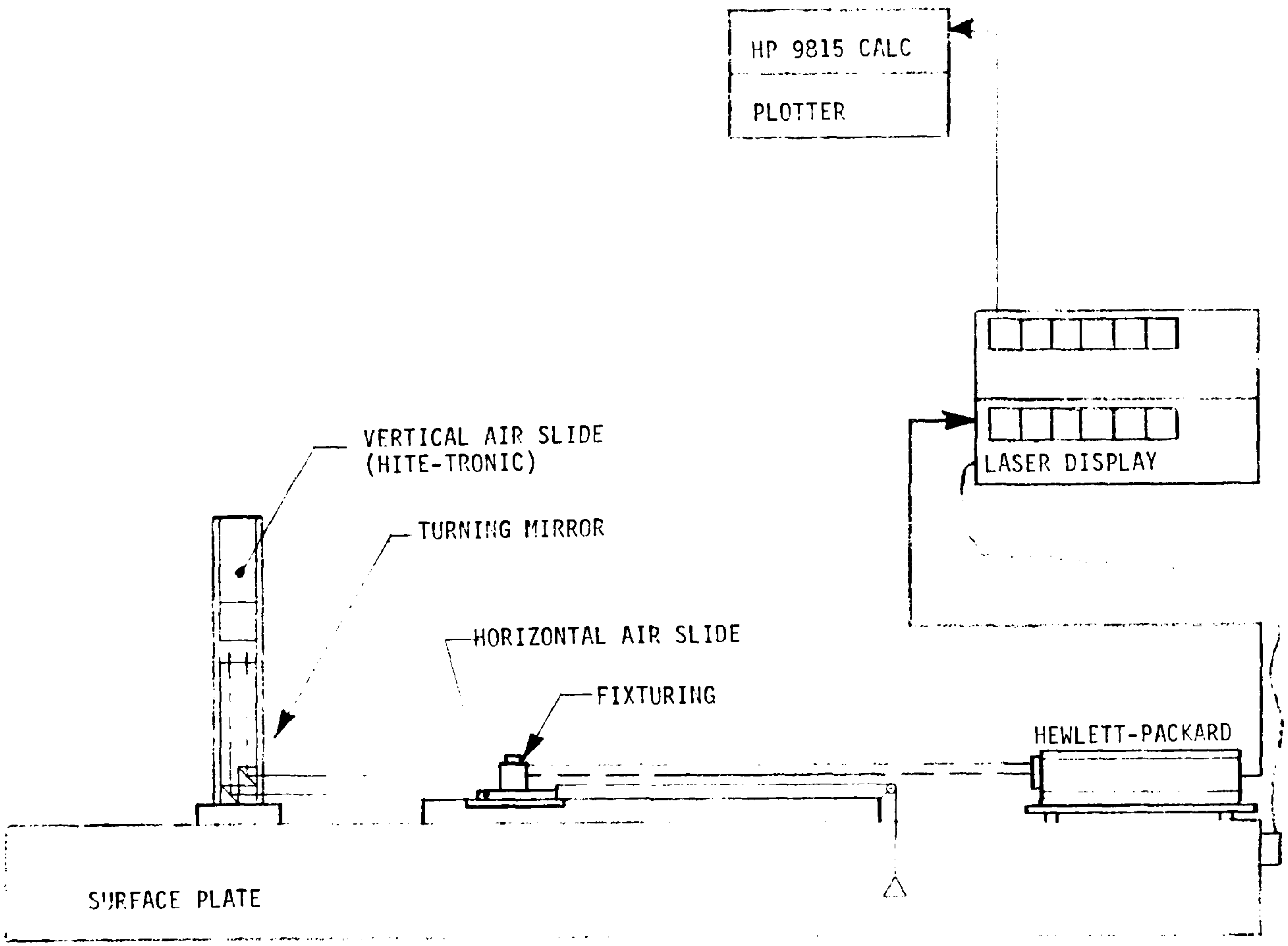

FIGURE 3. VERTICAL AND HORIZONTAL MEASUREMENT STATIONS

4. ACCOMPLISHMENTS

A Hewlett Packard Laser System (see Table 1) was purchased. This system was used in preliminary studies and during the design phase. The LVDT calibration station was built and tested. The fixture for the micrometer station went through several design iterations to produce a micrometer holding fixture which could accept mics from 1" to 12" for calibration, providing readings over the full range of travel, while retaining the required rigidity and convenience of operation. This last requirement was never totally fulfilled.

At this time, a logistical problem arose. Currently calibration of micrometers is done at the Surveillance Cribs located in each shop. If calibration was done at only one calibration station, it would be in the Product Assurance Gage Lab. Since the Lab is located away from the shop areas, mics brought to the Gage Lab for calibration would be out of service for a period of time and an additional cost incurred for transportation. Because there are insufficient mics to create a pool of "floaters", and because none of the organizations would bear the cost of transportation, the system soon acquired a "nice to have but not practical" status. As a result, it was decided that further expenditure of effort was not warranted.

5. ALTERNATE USES

Since the laser was purchased, it has been used to perform a variety of calibration functions. The passive Remote Interferometer and the retroflector[5] make the system ideal for calibration of N.C. machine tools, coordinate measuring machines (CMMs), rifling bars, etc. where calibration over long distances is involved.[6]

[5] R.R. Baldwin, G.B. Gordon, and A.F. Rude, "Remote Laser Interferometry", Hewlett Package Laser Measurement System Application Note 156-1.

[6] T.H. Hoffer, "Calibration of a Machine Tool", Hewlett Package Measurement System Application Note 156-4.

TABLE 1

System, Laser, HP 5526A
  Laser Head
  Laser Display

Interferometer, Remote HP 10565B & 10556A (Retro Reflector)

Bender, Beam HP 10558A

Retroflector/Mount HP 10550B

Mirror, Turning HP 10557A

Case, Storage HP 10634A

Case, Storage HP 10635A

Mount, Reflector HP 10659A

Adapter, Straightness HP 10579A (2 pc)

Interferometer, Short-Range Straightness HP 10690A (Includes reflector)

Kit, Footspacing HP 10583A

Adapter, Straightness, Vertical HP 10693A

Splitter, Beam HP 10567A

Connecting Cables

System Laser HP 55262 Calculator Mod 9815A

System Parts List

Fig 4. shows the system being used to calibrate an optical comparator. Fig. 5 depicts the system installed on the Gage Surveillance Section's Calibration Cart. This Cart travels throughout the Arsenal shops where it is used for specialized calibration tasks. The laser has been especially valuable for the calibration of rifling bars.

With the exception of the 120mm tank gun which has a smooth bore, all large caliber gun tubes produced for the Army are rifled. Rifling consists of a number of equally spaced helical grooves cut in the bore of the gun. These grooves impart rotation to the projectile as it is launched, and the resulting spin provides in-flight stability. Manufacture of these grooves is done by a series of broaches, each slightly larger than the previous one, which are mounted on the end of a long bar called a rifling bar and pushed down the bore of the gun tube. A helical groove cut in the bar engages a pin in the machine which generates the required degree of rotation in the broaches and the resulting twist in the rifling.

Deviations in the rifling twist can cause variations in projectile performance, therefore, the twist of the rifling bars is periodically checked to insure conformance with the specification. The twist is expressed as ________ turns in ________ caliber, e.g. the 105mm M68 is one turn in eighteen calibers. A caliber is the bore size of the gun or 105mm. Therefore this may be stated as one turn in 1890mm or 74.412 inches.

Calibration of a rifling bar is shown in Figs. 6, 7 and 8. The bar itself is visible in all three photos. The helical groove can be seen in the extreme right hand side of Fig. 6 near the steady rest.

FIGURE [illegible]. PHOTOGRAPH OF AN
OPTICAL COMPARATOR

FIGURE 5. CALIBRATION CART

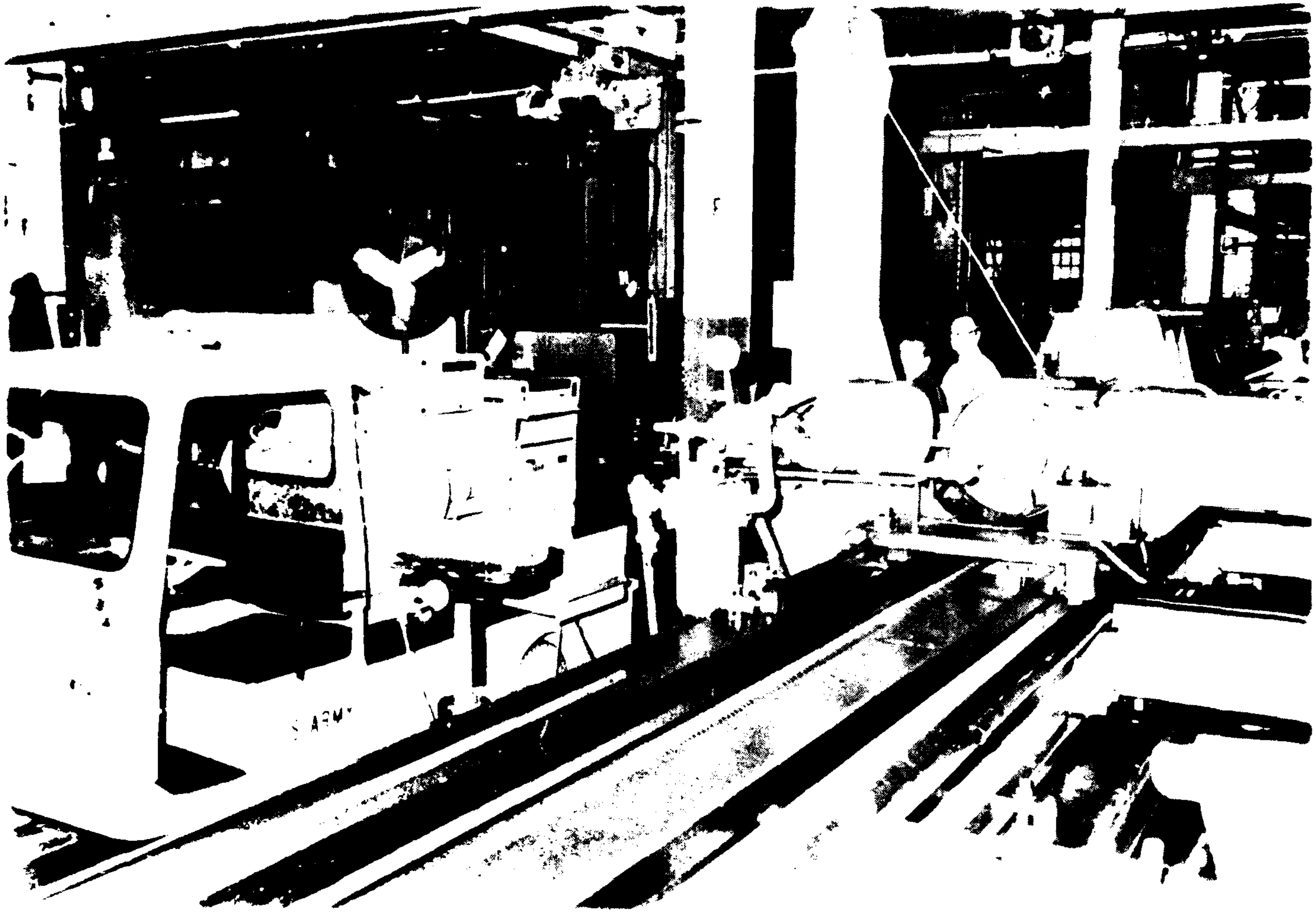

FIGURE 6. CALIBRATION CART SETUP FOR RIFLING BAR CALIBRATION

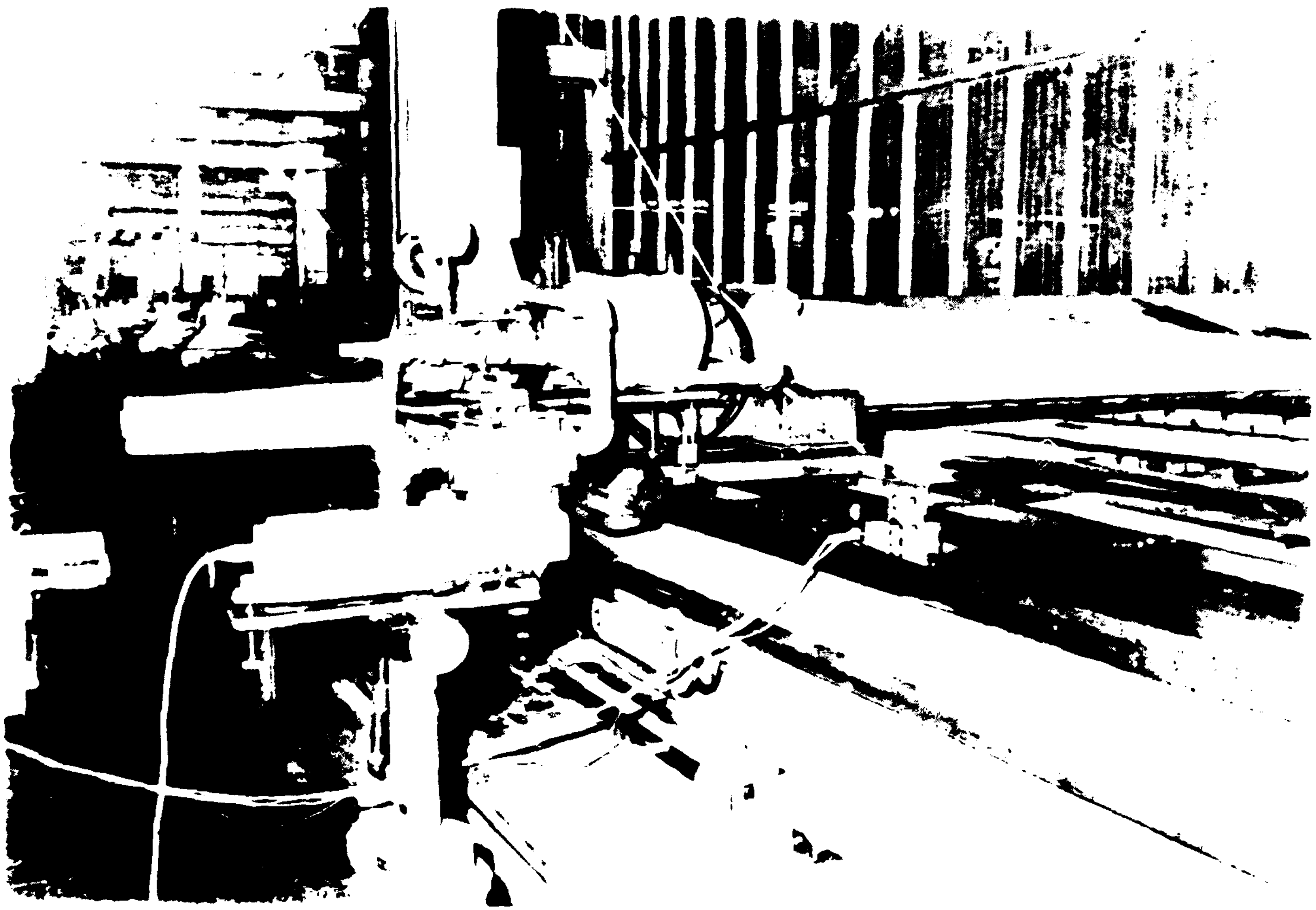

FIGURE 7. LASER HEAD, REMOTE INTERFEROMETER AND RETROREFLECTOR

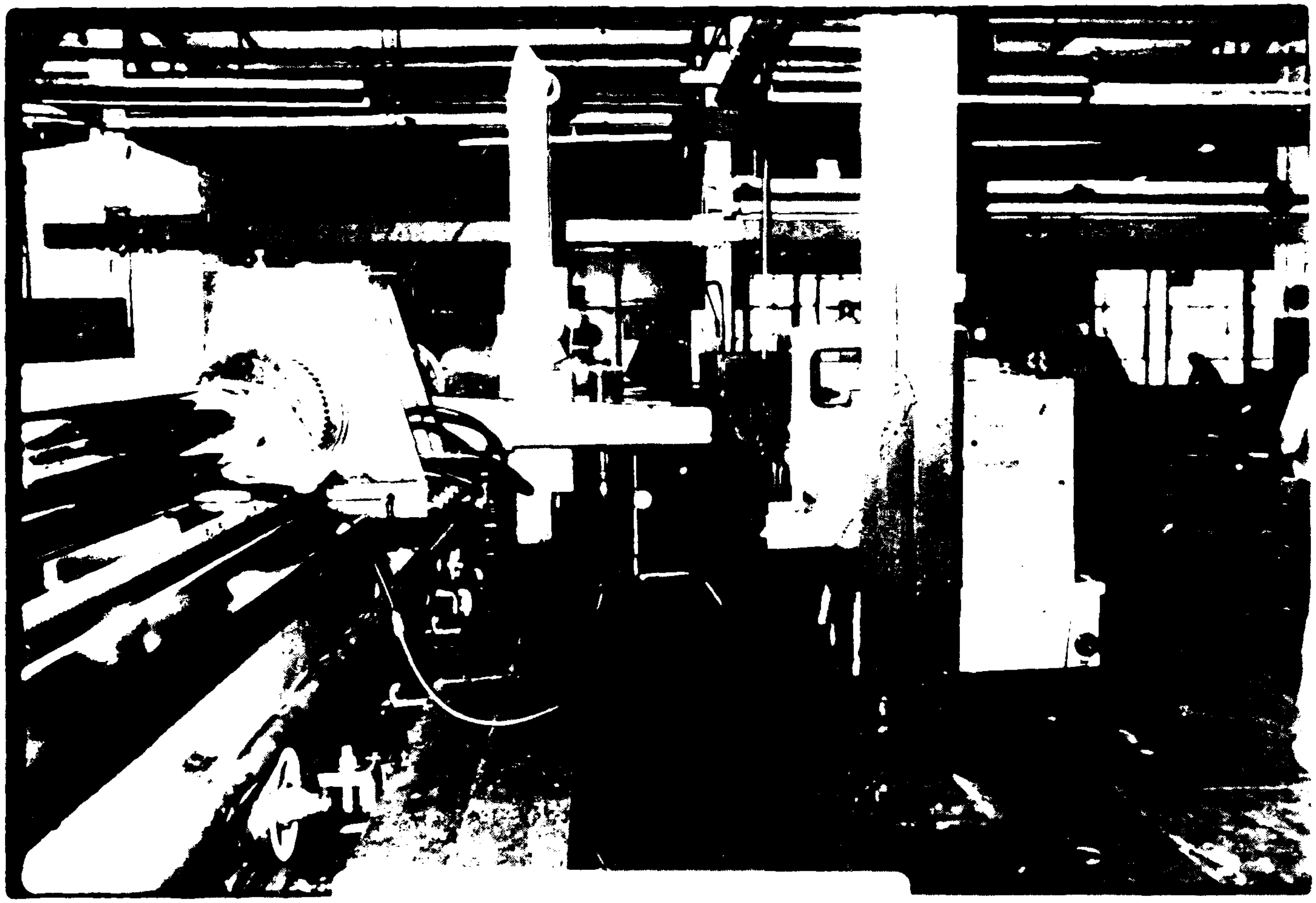

FIGURE 8. RIFLING BAR WITH ATTACHED ROTARY ENCODER

To read the rotational movement of the bar, a rotary encoder is strapped to the bar (Fig. 8). A pendulum references the encoder to gravity, and the data from the encoder is fed to the Hewlett Package calculator through the interface, installed on the cart (Fig. 5).

The laser is mounted on a tripod along side the machine bed and aimed at a retroreflector which is sitting on the way of the machine (Figs. 6 & 7). This retroreflector is combined with a beam bender which turns the laser beam 90 degrees and bounces it off the cube corner which sits on the moveable carriage. In this manner, the carriage travel is accurately measured.

The rifling sequence is initiated (the broaches are removed for calibration) and the linear and rotational readings are taken on the fly, automatically, via calculator command. The output is shown in Fig. 9. A program written for the calculator calculates the deviations and prints the inspection report on the spot. Two interpretations are provided; the first converts the deviations to a rotational error in inches at the circumference of the bore for a given downbore distance, the second converts the deviations to a downbore error at a given angular orientation. A second program plots these results, Fig. 10, so that the inspector has a graphic presentation of the inspection results.

This procedure represents a tremendous increase in accuracy and productivity over the previous manual method of calibration using gage blocks and sine bars. In general, the above statement applies wherever an accurate measurement of linear displacements is required. This is especially true if there is no convenient frame of reference available.

RIFLING BAR INSPECTION REPORT

Tube: 105mm 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	-0.0030
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	5.584[illegible]	-0.0023	0.0133
35.9984	174.1450	[illegible]	-0.0005	0.0027
40.0011	193.5200	6.9815	-0.0001	0.0005
44.0028	212.8700	[illegible]	-0.0004	0.0026
48.0042	232.2650	[illegible]	0.0009	-0.0050
52.0044	251.5650	[illegible]	-0.0010	0.0059
56.0031	270.9050	[illegible]	-0.0012	0.0070
59.9945	290.1700	[illegible]	-0.0029	0.0164
63.9979	309.5100	[illegible]	-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	[illegible]	-0.0020	0.0115
83.9978	406.2500	[illegible]	-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 9. RIFLING BAR INSPECTION REPORT

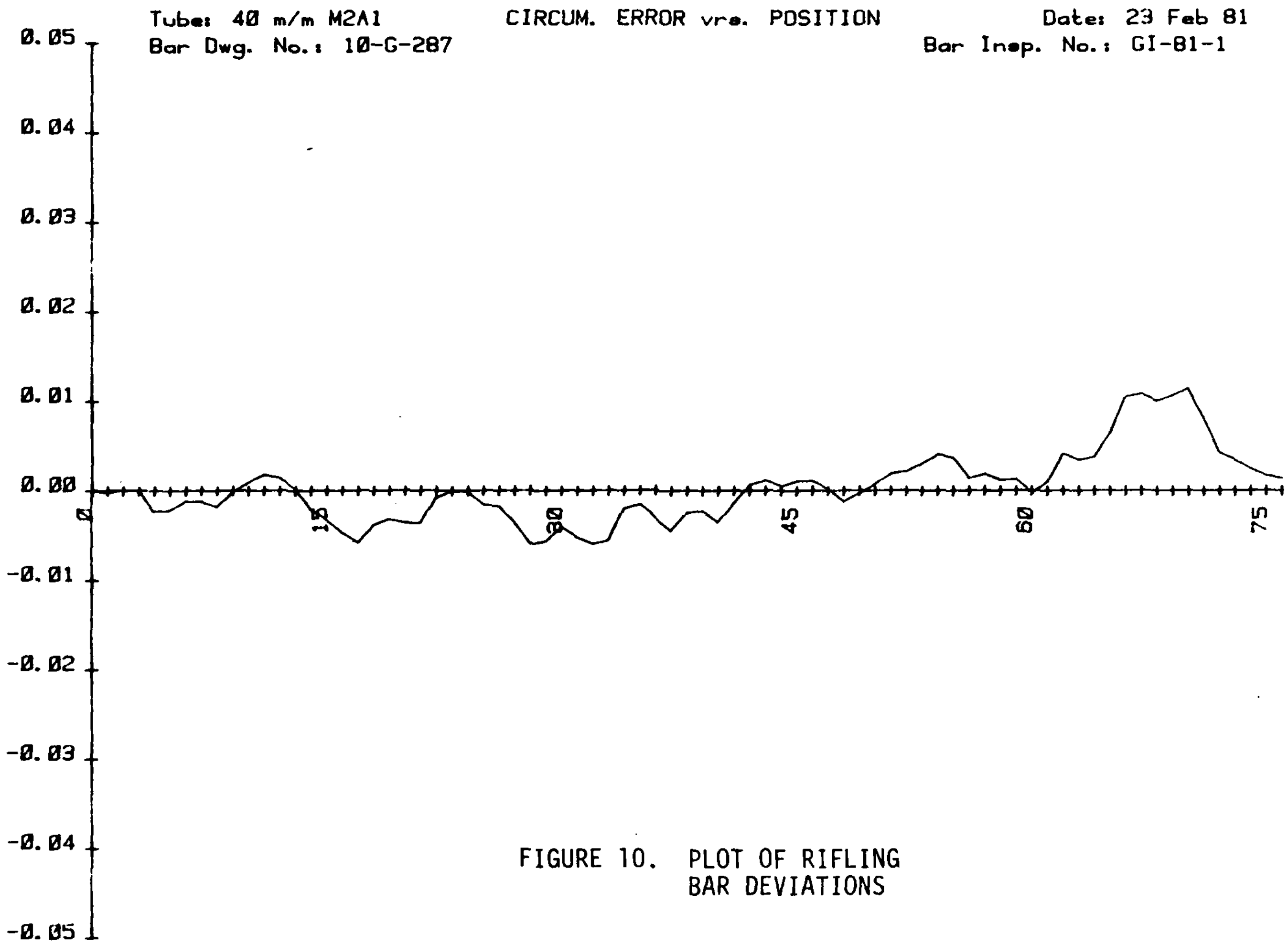

FIGURE 10. PLOT OF RIFLING BAR DEVIATIONS

5. CONCLUSION

The Remote Laser Interferometer is an extremely versatile tool, which has become an integral part of the calibration system used at the Arsenal. The concept behind the Laser Interferometer Calibration Station would probably have the greatest application in a small precision machine shop where dedicated fixtures could be built for those items requiring frequent calibration, and the precision gained by such a system would justify the cost of a dedicated laser system. Here at Watervliet Arsenal with over 2,000,000 square feet of manufacturing facilities spread over a 140 acre site, such a system has proved unfeasible.

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