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KNURL INSPECTION SYSTEM FOR 155-MM ROCKET-ASSISTED PROJECTILE M549

GENE GEORGE
CHRYSLER CORPORATION
HUNTSVILLE ELECTRONICS DIVISION
HUNTSVILLE, AL 35805

GEORGE ZAMLOOT
PROJECT ENGINEER
ARRADCOM

OCTOBER 1982

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
PRODUCT ASSURANCE DIRECTORATE
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Gene George, Chrysler Corp.
George Zamloot, Project Engineer, ARRADCOM

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This project has been accomplished as part of the U.S.Army's Materials Testing Technology Program, which has for its objective the timely establishment of testing techniques, procedures, and prototype equipment (in mechanical, chemical, or non-destructive testing) to insure efficient inspection methods for material/materiel procured or maintained by DARCOM.

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

The objective of this project was to design and fabricate a semi-automated, knurl inspection system to inspect the interface locking knurl surface on the 155-mm rocket-assisted motor body and warhead of the M549 projectile to the design parameters called out in the specifications. The system was designed to have adjustable limits for versatility and the ability to inspect at production rates.

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20. ABSTRACT (cont)

A General Automation 16/45 computer for operation of the system was not included in the contract; however, it was used for test and demonstration. The system has effectively demonstrated the application of the state-of-the-art electric optical technology to the inspection of artillery projectiles.

14. MONITORING AGENCY NAME & ADDRESS (cont)

Director
U.S. Army Materials and Mechanics
Research Center
ATTN: DRXMR-ST
Watertown, MA 02172

CONTENTS

FIGURES

INTRODUCTION

In accordance with the scope of Contract DAAK-10-79-C-0375, Chrysler Huntsville Electronics Division has developed an optical, semi-automated prototype knurl inspection system. This instrument (shown in Figure 1) is designed to inspect the interface locking knurl surface on 155 mm rocket assisted motor bodies and projectiles. The knurl surface inspected by this instrument is described by U. S. Army Drawings SK-MGH-8731 and SK-MGH-8732 and described as part number 9235995, warhead, 155 mm, M549A1.

The purpose of this knurl surface is as a locking aid to the course threads that screw the motor body onto the projectile (warhead). It is imperative that these items remain locked together during launch and flight. It was observed that the production 155 mm rounds are not presently being knurled. The larger 8-inch rounds are being knurled and require inspection. The knurl inspection system is a prototype and proof-of-principle instrument for the 8-inch round (automatic production gauging system).

The project objective was to develop an instrument to inspect locking knurls on both 155 mm motors and 155 mm warheads as per design specifications, with adjustable limits at moderate production rates.

A General Automation 16/45 computer required for operation of the system was not included in the contract and was not shipped with the unit. Chrysler's laboratory version of the computer was used for in-house test and demonstration.

Figure 1. Optical knurl inspection system

SYSTEM DESCRIPTION

Inspection System Overview

The optical knurl inspection system consists of a rotary scanner optical assembly that illuminates and scans the knurl surface; an electronic unit that interfaces with a computer that processes scanned data, compares derived parameters with preset limits to make Go/No Go decisions, and a mechanical housing with a pneumatic chuck to hold the round. An output port is available for logging statistical pass/fail data. The electronic scanner and optical system are rotated about the round which is secured by the pneumatic chuck. Each radial row of knurls are viewed by a pair of electro-optical scanners. The locking knurl surface is illuminated with intense white light at a 45 degree angle. Two optical relay systems provide images on self-scanning linear photo-diode arrays.

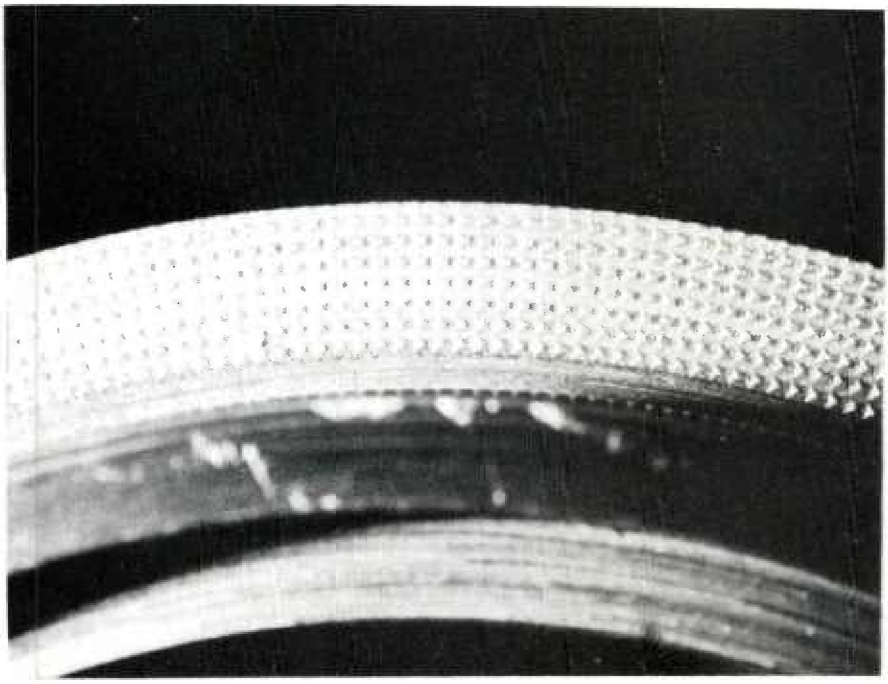
Optical/Mechanical Design

The optical housing assembly (Figure 1) is approximately 27 inches in diameter and 36 inches tall. The scanner assembly and optical package are mounted on a rotating platform. The lower end of the platform is attached to a pair of preloaded angular contact bearings. The round is lowered in the top of the machine. A plate which is pneumatically raised holds the round until a pneumatic chuck clamps it in position. The plate drops out of the way and the scanner platform starts to rotate. The knurl surface is illuminated by a 100 watt quartz iodine lamp, fiber optic relay and a projection optical system. A pair of very fast aspheric lenses focus the energy from the fiber optic onto the knurl surface. Four push/pull screws are used to adjust the aim of the projector in respect to the optical viewing system. Two optical systems are provided to image the knurl surface on linear photodiode arrays. A side view optical system looks down each row of radial knurls. This view, shown in Figure 2, is like observing six 90 degree pyramids in a row with one face toward the viewer. The depth-of-field is short enough that only the outside full height pyramid is in sharp focus. The optical magnification is adjusted so that each photodiode represents exactly 0.0005 inches of knurl height. This technique provides a direct electro-optical measurement approach to knurl height and circumferential pitch. The other optical system, called the end view, looks head on at the knurled surface. The optical magnification is adjusted so that each pyramid represents 64 photodiodes in the radial direction. The photodiode array is aligned to scan one radial row of knurls at a time, that is, a row of peaks, valleys or sides. The signal from this array is processed to determine knurl integrity along a radial row. These lenses, with a built-in focusing helix to aid magnification adjustment, have a 50 mm focal length. The photodiode arrays are mounted on ball slides and are adjustable in focus. On the bottom of the scanner platform an optical shaft encoder is mounted directly. A gear train couples power from the drive motor and safety switches. The scanner housing and holding chuck are rigidly held by a massive frame weldment. Metal covers provide light shielding for the linear arrays. The projector lamp housing and constant voltage transformer are also mounted on the framework.

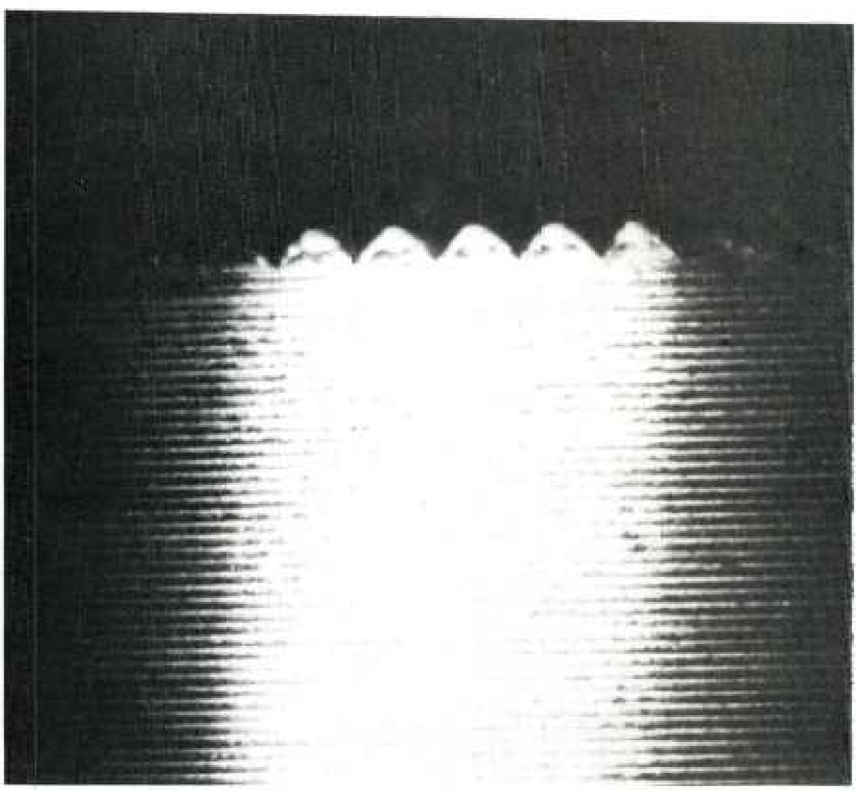
Electronics Design

The linear photodiode arrays selected for this system are 256 and 1024 element arrays by Reticon. The computer is a General Automation SPC 16/45 minicomputer.

End View Image



Side View Image



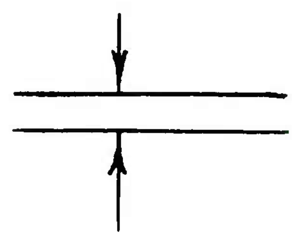


Figure 2. Optical systems

The 16 bit machine is augmented by a 32 channel discrete input, a 16 channel discrete input, a 32 channel discrete output, a 10 channel multiplexed A to D converter and a 3 channel D to A converter. A magnetic tape unit is used for program storage. In the end view electronic processing, the video is first processed with a level comparator and then converted to a 256 bit word. A first in first out (FIFO) memory then stores the word until it can be loaded into computer memory. The side view system is the synchronizing element for the data acquisition process. Again the video signal is processed by a level comparator and the width of the output pulse is measured. The data buffer then locates and stores the peak and valley outputs. The measurement of the angle of rotation is accomplished by an optical shaft encoder and a photodetector. The data buffers are strobed by the side view trigger pulse. All data is transferred to the computer for processing.

Data Processing System

The computer program with the aid of a real time operational input/output system will perform the following basic functions: process side view data, process end view data, process optical shaft encoder data, make decisions, and handle I/O operations. The inspection begins with the side view data being processed to locate the starting peak and valley. All positions are in respect to rotation angle which is used in the form of encoder counts. All limit switch data is converted to diode counts by a series of computation subroutines. End view data is gathered from the optical scanner three encoder counts beyond each side view determined peak. The two optical axes are offset slightly. Side view data is compared with knurl height maximum and minimum values and a decision is made based on the limit switch positions and measured heights. A pass/fail decision is made based on knurl height. The data used to calculate knurl surface width and datum -A- runout are summed, averaged and compared with preset limit data. A pass/fail decision is made based on this data. Each knurl in each row is checked by counting the pulse width data from the end view. This data is used to determine if all knurl pyramids are of proper height. The total number of acceptable knurls is compared with the preset limit data and a pass/fail decision is made. The total number of acceptable knurls is sent back to the electronic console for display. The total number of radial grooves (number of peaks) is compared with the number 450. If the number of radial grooves is different than 450 the part is failed. The number of radial grooves is sent back to the electronic console for display. Lamps on the control panel are turned on by relay set circuits. Up to four fault lamps can be turned on. A master pass or fail lamp and the inspection complete lamps are lighted at the end of the run. A signal is sent back to the electronic console upon completion so the motor can return to the load position. A subroutine is provided to convert all data to ASCII for hard copy, if required. A device control block is provided for use as a physical device description in interfacing and controlling peripheral equipment.

SYSTEM SPECIFICATIONS

The Optical Knurl Inspection System is a stand alone test unit. It consists of an electronic/pneumatic console and an optical measurement unit.

- o The unit is designed to inspect part number 9235995 knurl surfaces of 155 millimeter (M549A1) rocket assisted projectiles (warheads) and motors.
- o The unit operates on 110-120 VAC at 1000 watts.
- o The unit requires an air supply of 75 psi at 1 cfm.
- o The unit displays the "Number of Radial Grooves" and the "Number of Acceptable Knurls."
- o Preselectable tolerance switches are provided for "Knurl Surface Width." The range of adjustment is .001 to .099 inches for both the maximum and minimum switches. The setting for inspection per drawing is max. 0.015 and min. 0.015 ($0.278 \begin{smallmatrix} +.030 \\ -.000 \end{smallmatrix}$ inches).
- o Preselectable tolerance switches are provided for "Knurl Height." The range of adjustment is .001 to .099 inches. The setting for inspection per the drawing ranges from 0.020 to 0.010 inches with a nominal value of 0.016 inches.
- o A preselectable tolerance switch is provided for "Datum -A- Runout." The range of adjustment is from .001 to .020 inches. The setting for inspection per drawing is .010 inches (5.729 ± .005 inches).
- o A preselectable tolerance switch is provided for "Percentage of Acceptable Knurls." The range of adjustment is 1 to 99 percent.

- The unit accepts only rounds with 450 radial grooves.
- The weight of the optical unit is approximately 350 pounds. The weight of the electronic console is approximately 200 pounds.
- The unit is compatible with a General Automation SPC-16/45 mini-computer.
- The inspection time is 20 seconds per knurl surface. The loading, unloading and rewind time is not included in the inspection time.
- The optical resolution on which all measurements are based is approximately ± .0006 inches.

DEVELOPMENTAL STATUS AT COMPLETION OF CONTRACT

The system has effectively demonstrated the application of state-of-the-art electro-optical technology to inspection of artillery projectiles. Tests to date have proven that critical defects can reliably be detected, measured, categorized and displayed. The subsystems have been integrated and testing begun, but system debug and checkout was not completed. Checkout of the hardware/software combination was started and would typically result in some modifications to both hardware and software. Also, during this operation calibration of the measured data would have been finalized. The testing accomplished uncovered several areas where modification could refine the system in terms of accuracy and repeatibility. These areas are discussed in the following paragraphs where the status is reviewed by engineering discipline.

Data Processing Software - The software development was undertaken early in the R&D program. Time was not sufficient to properly debug and check out the software. The data from the end view optical system is not being processed by the computer at this time. The side view data is being transferred into the computer but not being processed by all subroutines.

Electronics - The side view portion of the electronics tested out very well. The measurement repeatibility is ± one photodiode and therefore the measurement accuracy is ±0.0006 inches.

The end view electronics, although operating, has not been tested on conjunction with the computer.

Testing has indicated that performance of the electronics could be improved by synchronizing the strobe clocks for the end view and side view photodiode arrays. This approach would reduce the cross coupling (cross talk) of clock pulses between array processors.

Sufficient flexibility and adjustability have been designed into the electronics to make calibration very easy. Also, the storage registers and photodiode arrays are large enough to scan a larger 8 inch round without major modifications to the electronics design.

Optical - This part of the system functions very well. The resolution of the side view optical system is ± 0.0006 inches. Allen wrench adjustments are available for calibration of Datum -A- runout, Knurl Height nominal center, and the correspondence between the side view and the end view. Magnification and focus adjustments are also available on the optical assembly. The light output through the 48 inch long fiber optic coupling is sufficient but not optimum. A two to three fold increase in available light would increase the signal-to-signal noise ratio. The light source is presently a 100 watt quartz-halogen lamp. An increased light intensity would also allow a sharper cutoff on the optical image of the inside row of knurls.

The optical system is designed specifically for the 155 millimeter knurl surface. Extensive modification or a scaled up design would be required to inspect 8 inch surfaces.

Mechanical - The structural and mechanical package has proven to be rugged and stable. The rotary mechanism functions well and limit switches provide ample adjustments. The pneumatic components and projectile holding apparatus have operated flawlessly. The chuck was leveled and centered to ±.001 inches in respect to the rotary spindle axis. A vernier adjustment mechanism for centering the chuck would be very helpful for initial setup.

The rotary mechanism would adapt easily to the larger 8 inch round, but the structural members and chuck assembly would require a complete redesign.

OPERATIONAL PROCEDURE

- Depress Power On switch.
- Red Power On lamp will come on. Chuck will be open and plate will be in the upper position. The amber Load light will be on.
- Load round into chuck with knurl surface down.
- Depress both Start switches at one time. Chuck will close automatically and amber Run lamp will come on. At the completion of inspection the amber Complete lamp will come on. The number of radial grooves will be displayed, the number of acceptable knurls will be displayed and either a pass or fail lamp will come on.

ADJUSTMENTS AND CALIBRATIONS

Fine tuning and debugging of the knurl test system may be accomplished via the adjustment and calibration of screws, switches, knobs, and controls, whose locations are shown in Figures 3 through 7.

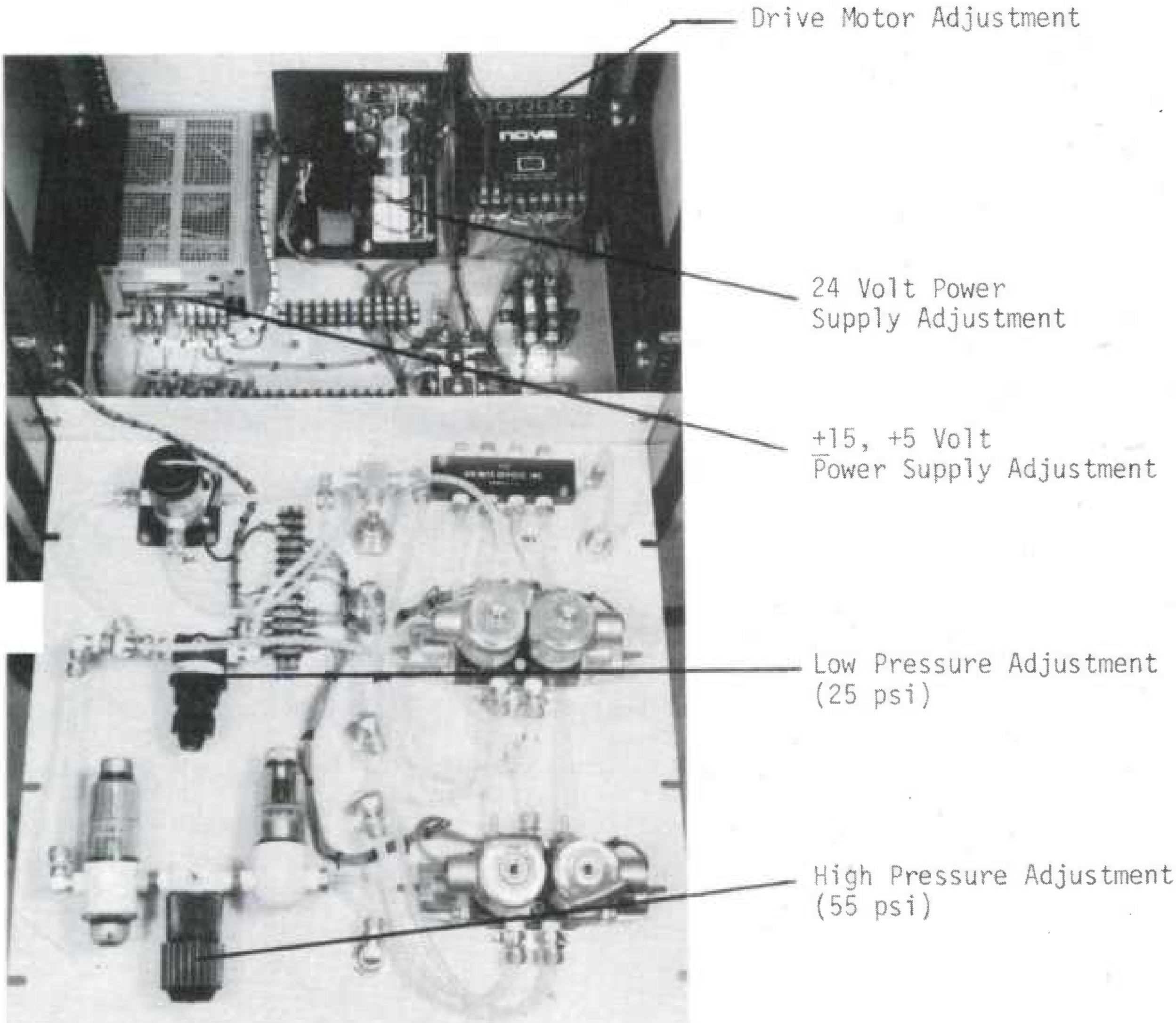
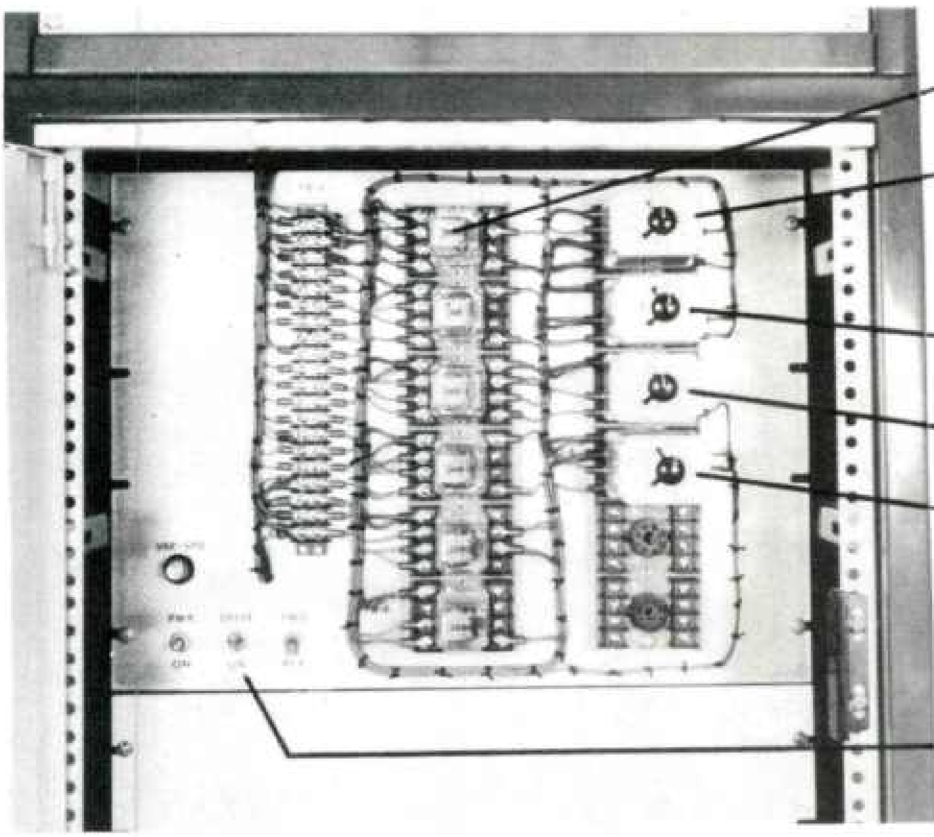


Figure 3. Adjustment of pneumatic controls, power supplies and drive motor electronics



To drive away from stops and
adjust speed of drive motor.

Figure 4. Relay panel adjustments

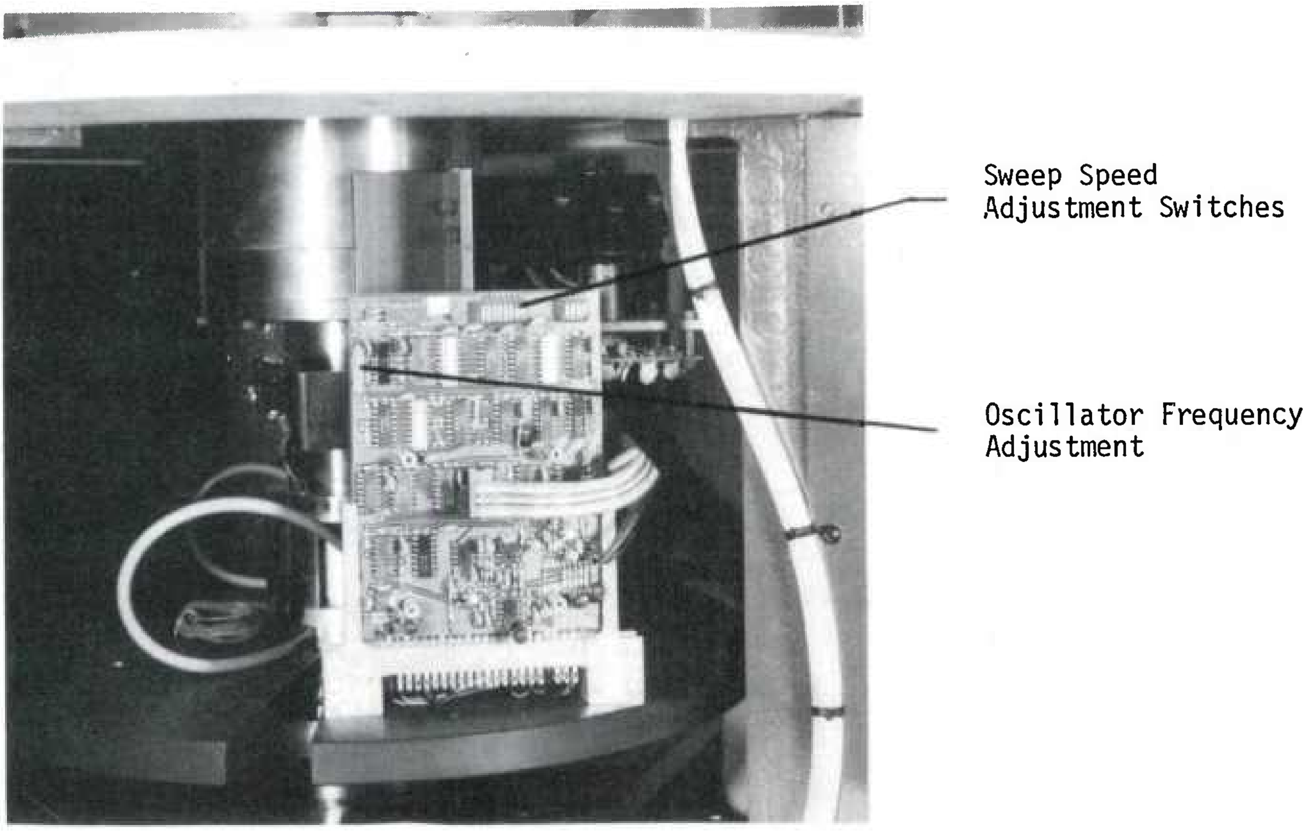


Figure 5. Reticon CKT board adjustments

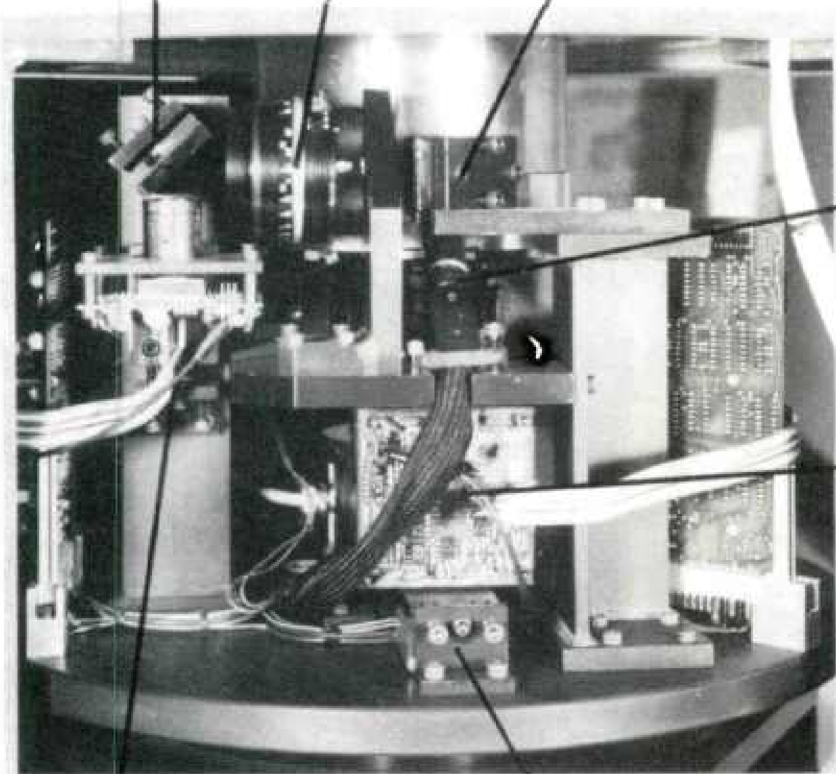
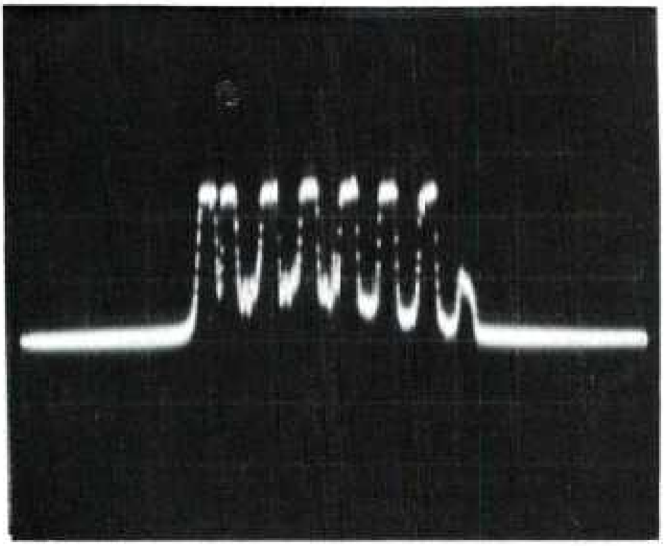
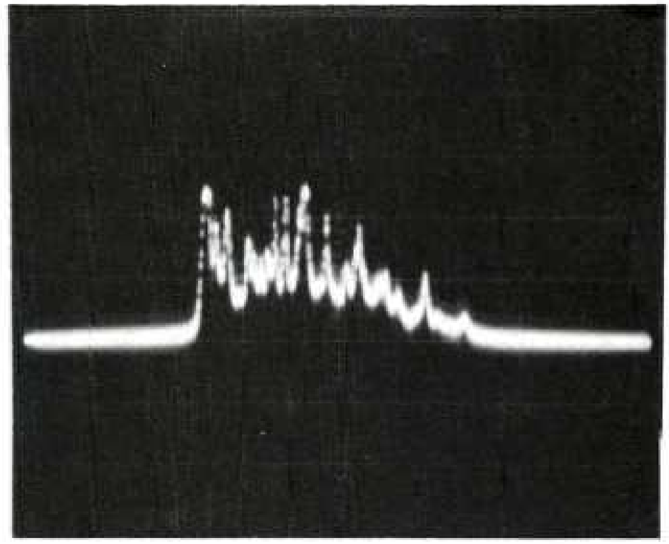


Figure 6. Optical calibration and adjustment

End View

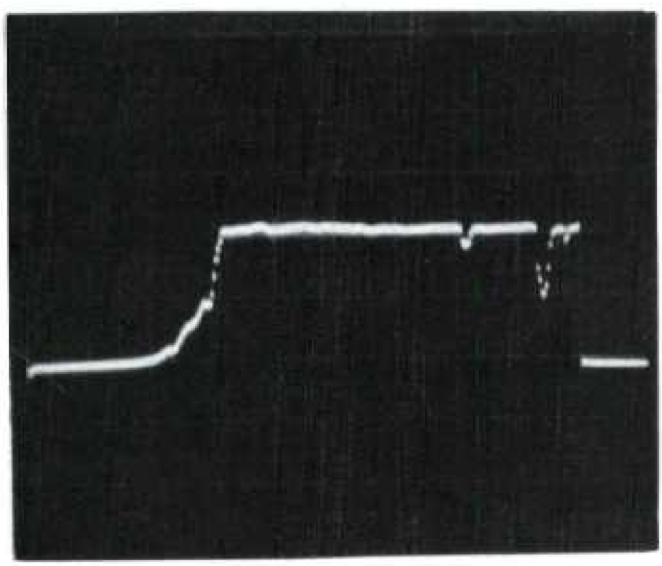


Aligned with peaks

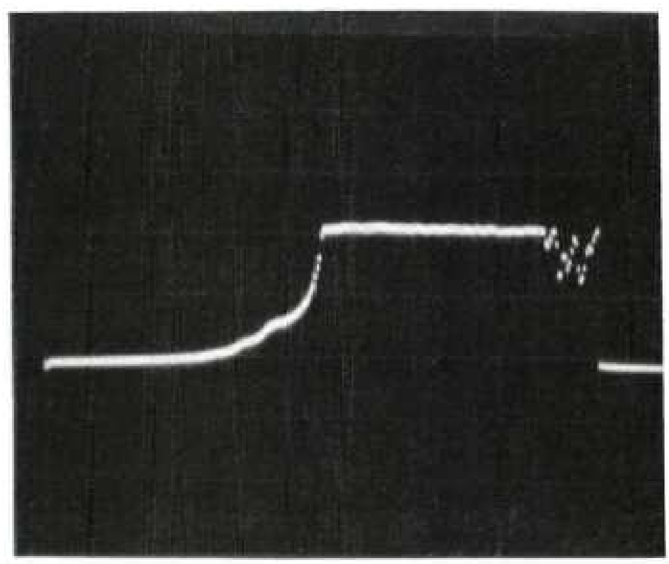


Aligned with valleys

Side View



Aligned with a peak



Aligned with a valley

Figure 7. Optical head output signals

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