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MEASUREMENT OF RIFLING
TWIST IN GUN TUBES

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DECEMBER 1976



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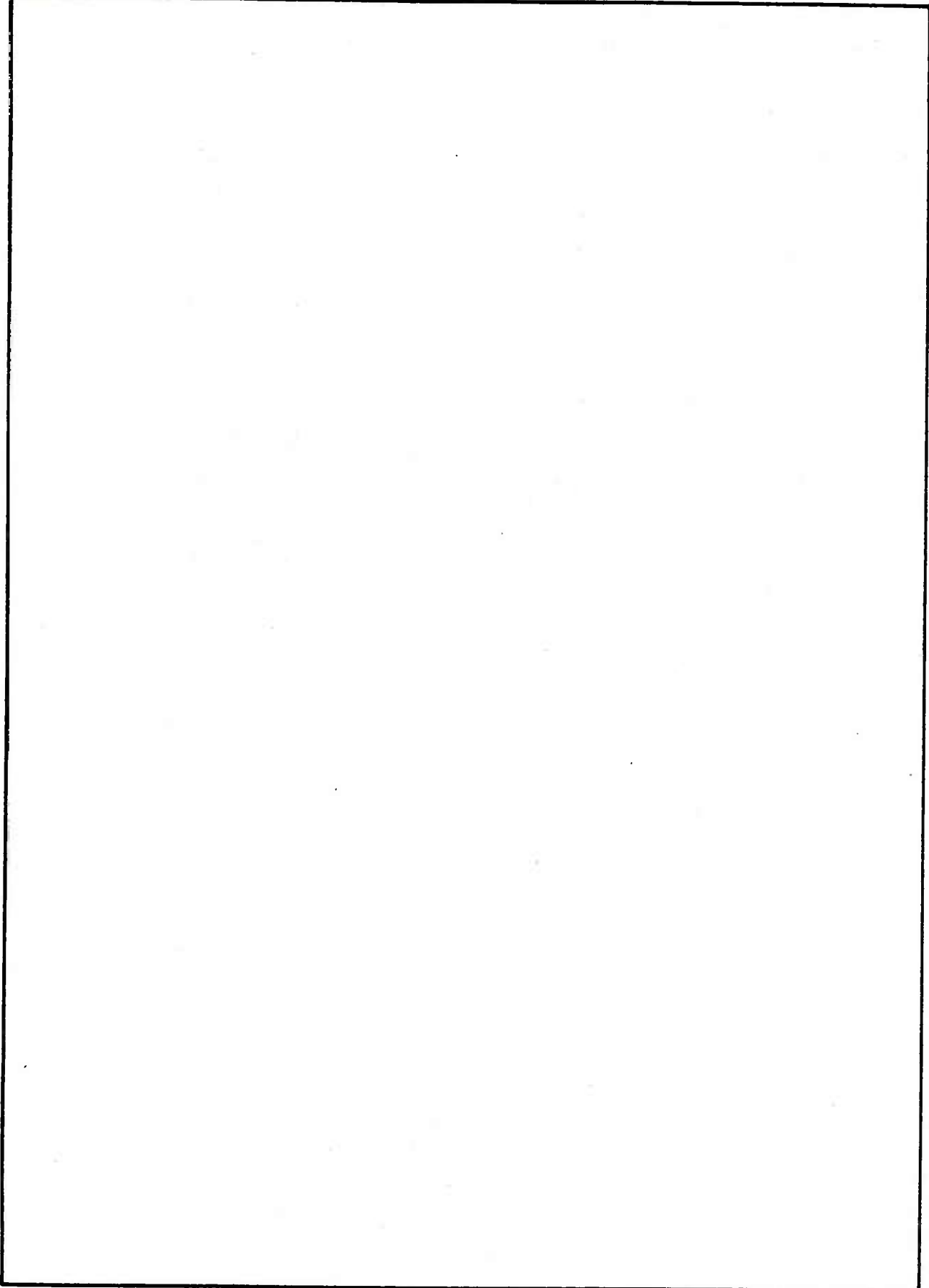
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Title: Measurement of Rifling
Twist in Gun Tubes

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ABSTRACT

Methods presently employed for determining conformance of rifling twist in gun tubes do not provide for direct measurement. The machine tooling used in manufacturing is calibrated and it is assumed the rifling twist produced in the gun tube is an acceptable reproduction of the machine tooling.

New inspection equipment has been designed and developed which provides a practical and effective means for direct measurement of rifling twist in gun tubes.

CROSS-REFERENCE DATA

Rifling Twist
Rotary Forging
Broaching
Rotary Encoder
Linear Encoder

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I. INTRODUCTION.

Rifling in a gun tube consists of a number of equally spaced helical grooves cut in the bore of a gun, beginning in front of the powder chamber and extending to the muzzle. These grooves impart rotation to the projectile which is necessary to insure stability in flight (see figure 1). Because projectiles must have a particular spin or rotation, deviations in the rifling twist can cause variations in the projectiles performance.

The rifling twist at any point is the inclination of a groove to the axis of the bore and is usually expressed in terms of calibers of length in which a groove completes one turn (360°), one caliber being the bore diameter. For example, the rifling twist for the 105mm. M68 is "1 turn in 18 calibers" or one turn in 74.412 inches. The tolerance on the twist is usually expressed as a linear zone in which one turn is completed, e.g. "one turn in $74.412 \pm .125$."

II. MANUFACTURING METHODS

Presently, at Watervliet Arsenal broaching is used to produce rifling in gun tubes.

Rifling produced by broaching utilizes a rotating rifling bar, pushing a series of progressively larger cutters through a gun tube. (see figure 2). The rotation is imparted to the rifling bar by a stationary pin which projects into a single helical groove on the bar whose path is the prescribed rifling twist of the cannon tube. As the rifling bar is moved longitudinally, rotation of the rifling bar occurs and a specific angle of rotation is generated for a given distance traveled longitudinally.

In the near future "Rotary Forging" will also be used to produce the rifling in gun tubes.

"Rotary Forging" is a forming process in which the workpiece or tube is rotated as it passes through four symmetrically located hammers (see figure 3,4) pounding the workpiece around a precision mandrel. The mandrel used has the rifling form on its outside diameter.

III. PRESENT METHOD OF INSPECTION

In both methods, broaching or rotary forging, a form tool is used to produce the rifling. The present method of calibrating the rifling machine utilizes a laser interferometer to measure the cutters linear displacement and a rotary encoder to measure the angular rotation. The mandrels for the rotary forge are checked on precision rotating centers at accurately controlled linear increments. Both methods give an accurate representation of what twist is expected from the rifling machine or mandrel.

Until recently there has not been a convenient or accurate method of inspecting the twist in a finished machined gun tube. It was assumed that the twist was a reproduction of the rifling bar groove or the rifling profile on the outside diameter of the mandrel.

However, many factors influence the machining process which cause changes in the actual rifling twist machined or formed. These changes are caused by:

1. Torqueing-up of the rifling bar.
2. Changes caused by the loading-up of the cutters.

3. Geometry changes due to changing distances between the key in the rifling bar and the cutters.
4. Keyway or key wear.
5. Manufacturing tolerances.
6. Variations in the movement of the tube over the mandrel causing incorrect rifling helix.

IV. SYSTEM DESIGN AND CONSTRUCTION

The object of the rifling twist project was to design and build an inspection system to accurately measure the rifling twist in the finished tube. (see figure 5)

The system designed is basically a two part system. Part one consists of a head assembly (see figure 6) with an angular measuring encoder mounted internally and a spring loaded drive pin on its outside diameter. As the head assembly is pushed through the gun tube, it is rotated by the spring loaded drive pin engaged in a rifling groove. (see figure 7). A lead pendulum inside the head assembly is mounted to the angular measuring encoder's shaft. As the body of the encoder is rotating with the head assembly, the pendulum remains stationary relative to gravity. The relative rotational displacement is a measurement of the groove twist over a given linear distance.

Part two is a linear distance measuring device which is a commercial item. (see figure 8). Basically, it consists of a rotary encoder attached to an output drum wound with an invar tape. This assembly is mounted on a fixture which attaches to the muzzle end of the tube. (see figure 9). The head assembly is pushed through the

tube to the muzzle end and the invar tape is attached to the head assembly. As the head assembly is pulled back, the invar tape unwinds off the drum and the resulting rotation of the drum is converted to the linear distance traveled and displayed.

A thermal printer is interfaced to the angular and linear readouts. At each prescribed position along the bore both angular and linear measurements shown on the displays are recorded by means of a remote switch. Recording of data can then be filed for future reference or analysis.

The angular and linear measurements recorded are then used to determine linear locational error at each point inspected.

The formula used to determine linear locational error is shown below:

Linear Error equals:

$$\text{Distance Reading} - \left(\frac{\text{Bore Dia} \times \text{No. of Calibers in } 360^\circ}{360^\circ} \right) \times \text{Angular Reading}$$

As the tube is being checked, twist measurements are taken at linear increments; the linear being the easier of the two variables to establish and the linear display being of the greater resolution than the angular display. At each linear position it is necessary to impart a slight shock to the tube to assist the pendulum in overcoming all bearing drag on the encoder which may keep the pendulum from settling to its zero rest position.

During the design of the head, it was decided to centralize in the rifling groove using a spring loaded tapered drive pin thereby eliminating variations in the measured helix angle due to changing groove widths.

V. TEST AND EVALUATION RESULTS

The accuracy of the rotary encoder was inspected using a highly accurate metrology indexing instrument ("VINCO"). The accuracy of the encoder $\pm .02^\circ$ was checked using a pendulum attached to the encoder shaft as the zero reference.

The linear measurement system was checked using a coordinate measuring machine over a 100 inch range and was within $\pm .0025$ inches.

The entire system was then set-up and a series of runs were made in a 105mm., M68 gun tube.

Representative data obtained is shown and plotted in figure 10. The data is based on the 105mm., M68 cannon tube which has a prescribed twist of 1 turn in 18 calibers or 360° in 74.412 inches (18 x 4.134) of down bore travel. Four readings were taken starting at the muzzle end at 12, 3, 6, and 9 o'clock positions.

As an example, the chart shows that at 30 inches downbore, the rifling groove which started at the 3 o'clock position contained a rotational error that equated to a .025 inch downbore error. That is, it was necessary to advance the head assembly .025 inches to achieve the prescribed 145.13° angular reading at 30 inches.

$$\text{Angle} = \frac{30 \text{ inches} \times 360^\circ}{74.412 \text{ inches}} = 145.13$$

The system was also used to measure the rifling twist in an 8 inch How., M201 cannon tube. (see figure 11). The outside diameter of the head assembly was increased by pressing chimes over the ball bearing

outside diameter. The spring loaded drive pin was replaced by a solid driving pin designed to only contact the driving side of the rifling groove as requested by Product Engineering for this check.

The twist data was sent to Product Engineering for evaluation to determine if the rifling twist machined in the gun tube using a suspect rifling bar could be accepted.

At the beginning of the equipment test in the 105mm., M68 gun tube, it became evident that the spring loaded drive pin was not performing its design function, that is, rotating the head assembly relative to the center of the rifling groove. The small clearance between the head assembly diameter and the bore diameter plus the weight of the head assembly produces greater drag than the spring loaded drive pin is capable of overcoming.

To eliminate this problem, the diameter or chimes that contact the cannon bore were mounted on ball bearings (see figure 6). This greatly reduced the rotational drag and allowed the drive pin to accurately rotate the head assembly in respect to the centerline of the rifling groove.

Also noted during these tests was that the pendulum did not always overcome all bearing drag to settle at a zero rest position by imparting shock to the gun tube, especially on a large gun tube like the 8 inch. This problem was overcome for the testing and evaluation segment of the project by taking special precautions and compensating for this error in the data.

Refinements will be required prior to the procurement of additional systems for production inspection to insure the return of the pendulum to the zero rest position.

VI. CONCLUSION

Based on the testing and evaluation results it is concluded that the inspection equipment developed and designed under this project provides a practical and effective means for measuring rifling twist in gun tubes. With a design refinement to insure return of the pendulum to a zero rest position, the equipment will be adapted to measure rifling twist in a variety of different cannon tubes.

VII. RECOMMENDED IMPLEMENTATION

It is recommended that work be continued on design refinements and upon completion, a large population of gun tubes be inspected for rifling twist to determine the magnitude of variations.

Studies could then be undertaken to evaluate the effects of rifling twist variations upon projectile performance.

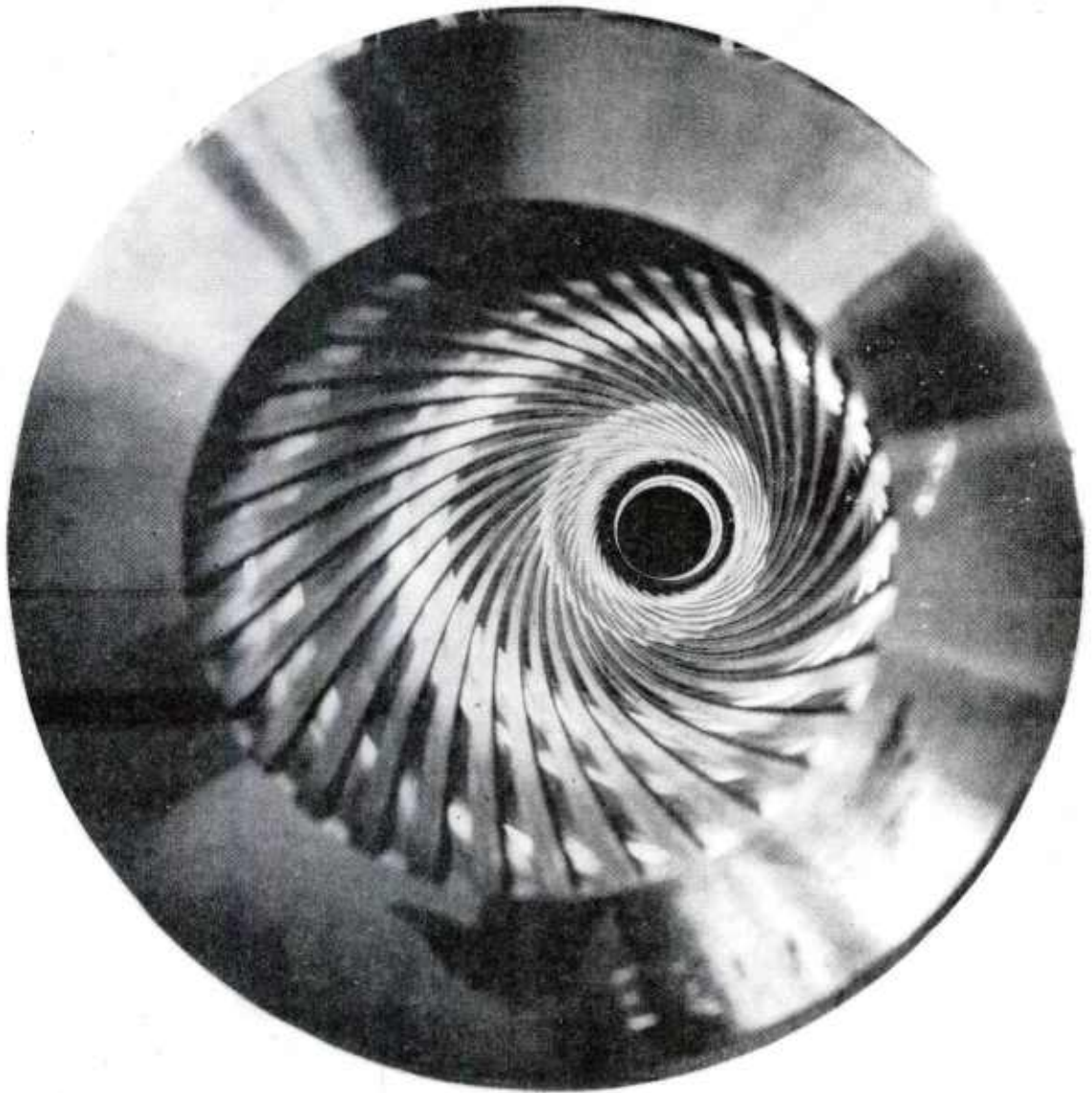


FIGURE 1. RIFLING TWIST IN GUN TUBE

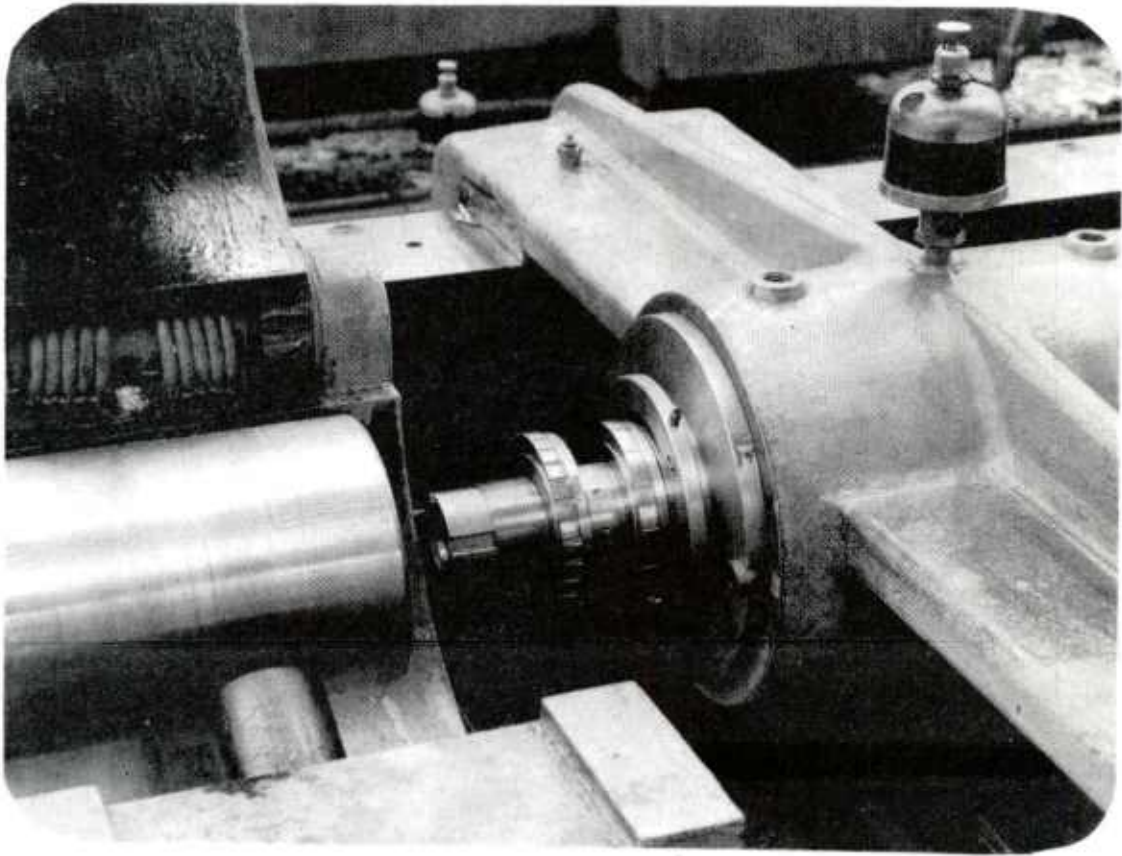


FIGURE 2. BROACHING CUTTER

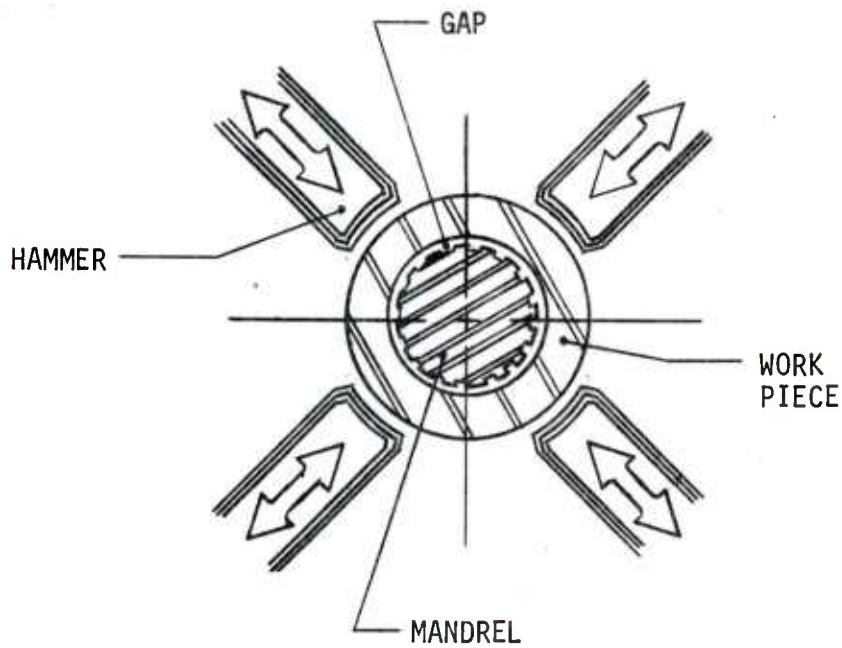


FIGURE 3. ROTARY FORGING - LOCATION OF HAMMER, MANDREL AND WORKPIECE

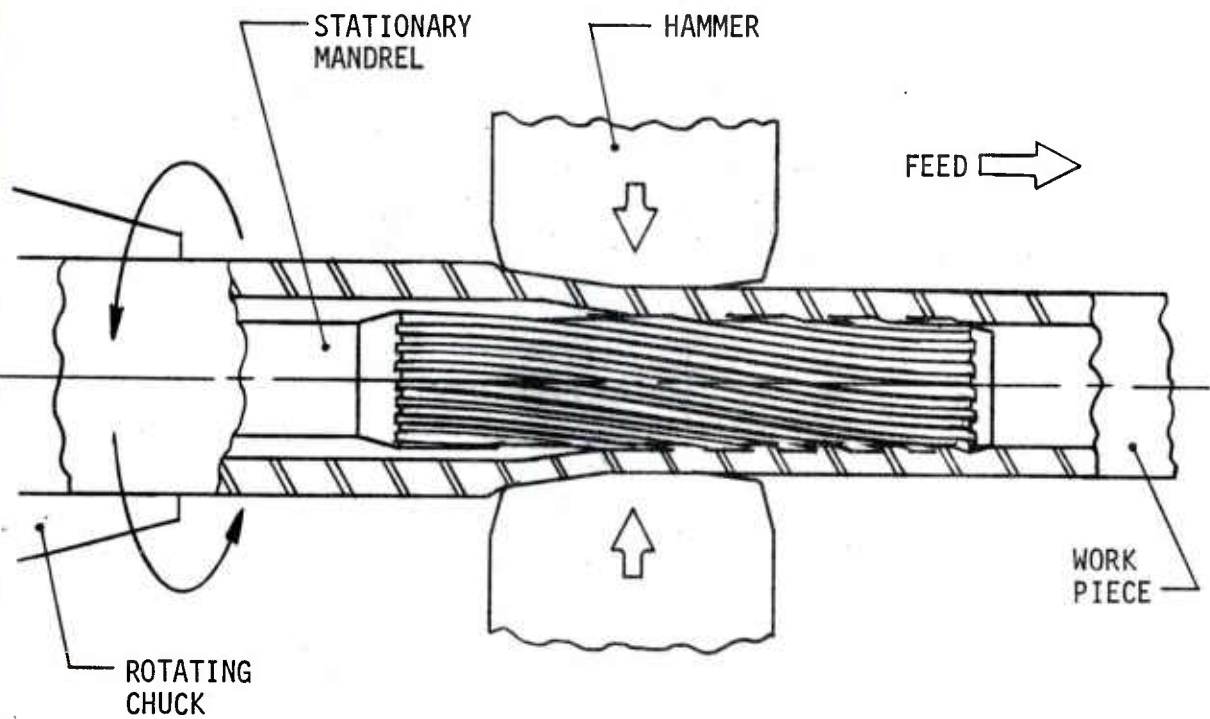


FIGURE 4. ROTARY FORGING - SCHEMATIC OF FORGING OVER MANDREL

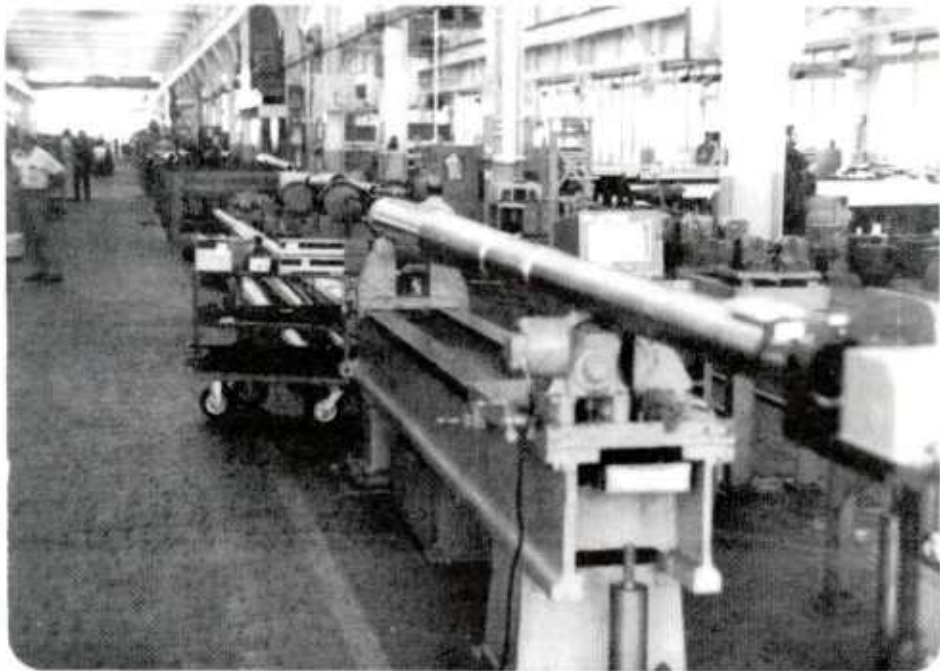


FIGURE 5. RIFLING TWIST MEASURING SYSTEM

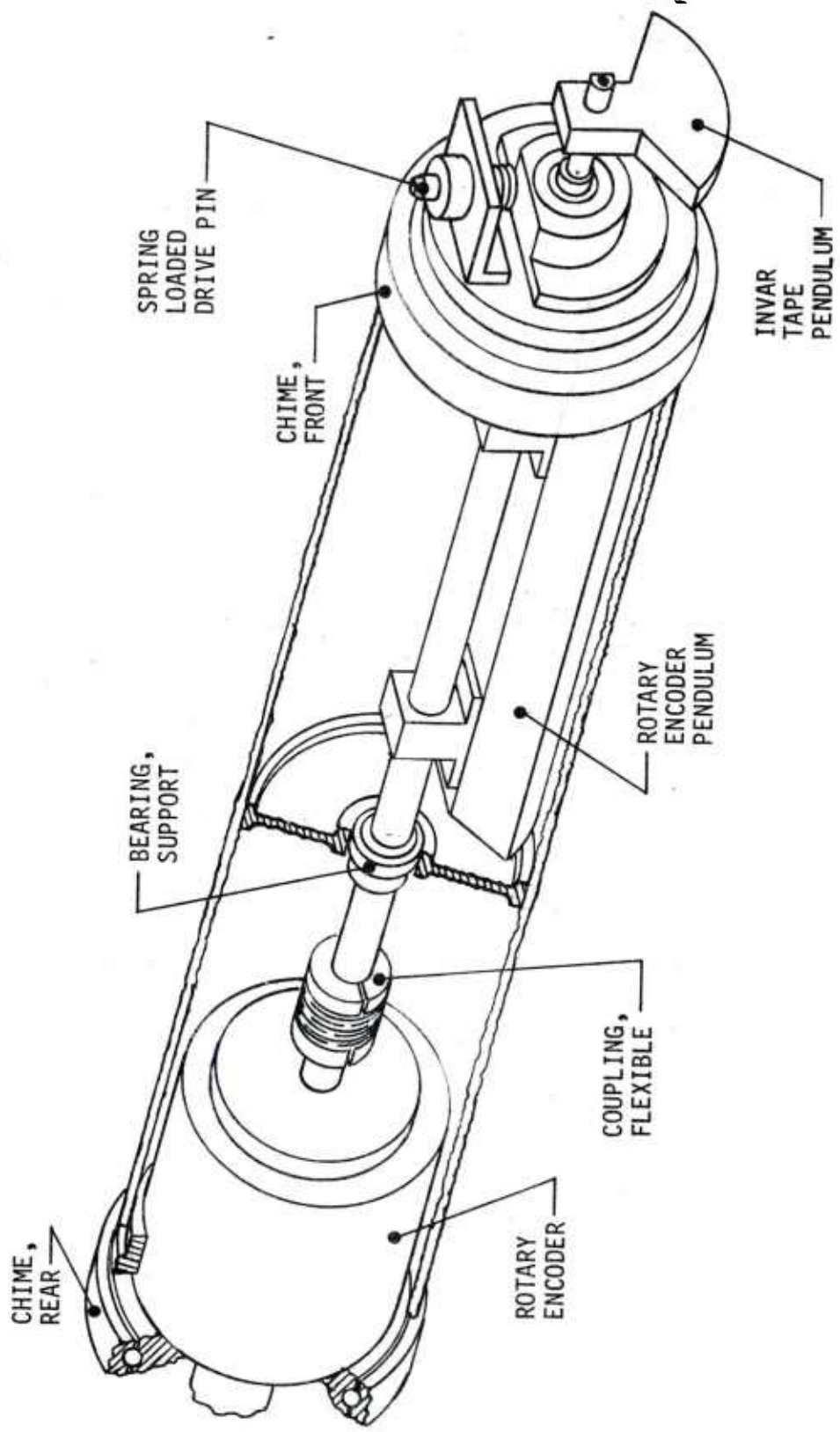


FIGURE 6. HEAD ASSEMBLY

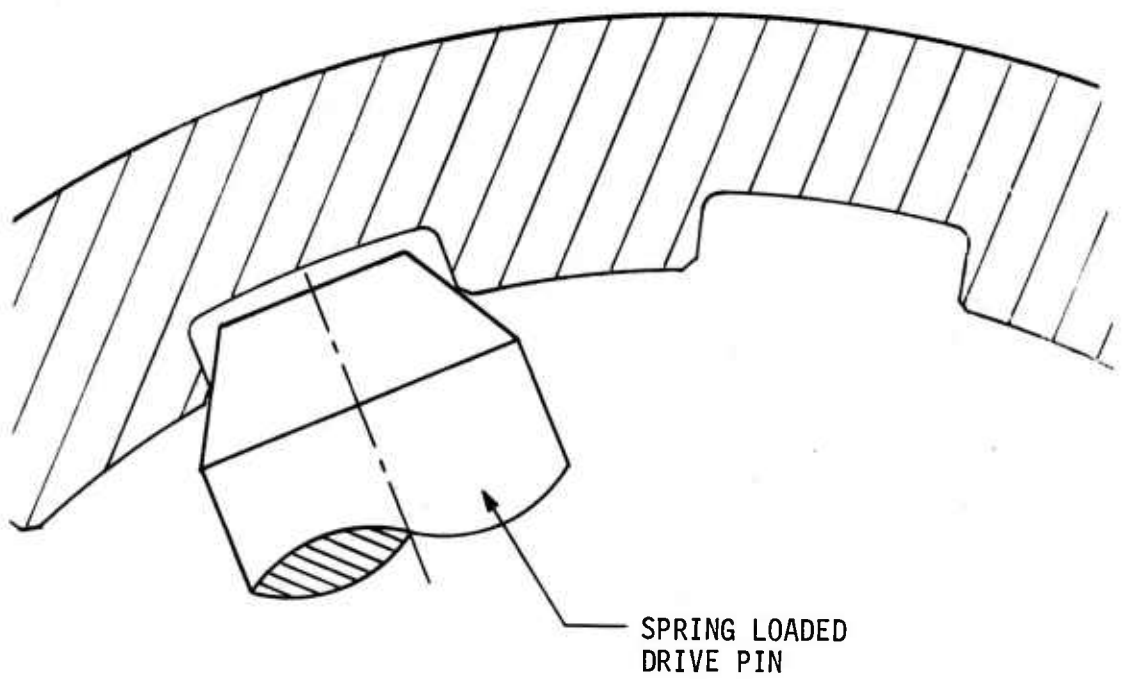


FIGURE 7. SPRING LOADED DRIVE PIN

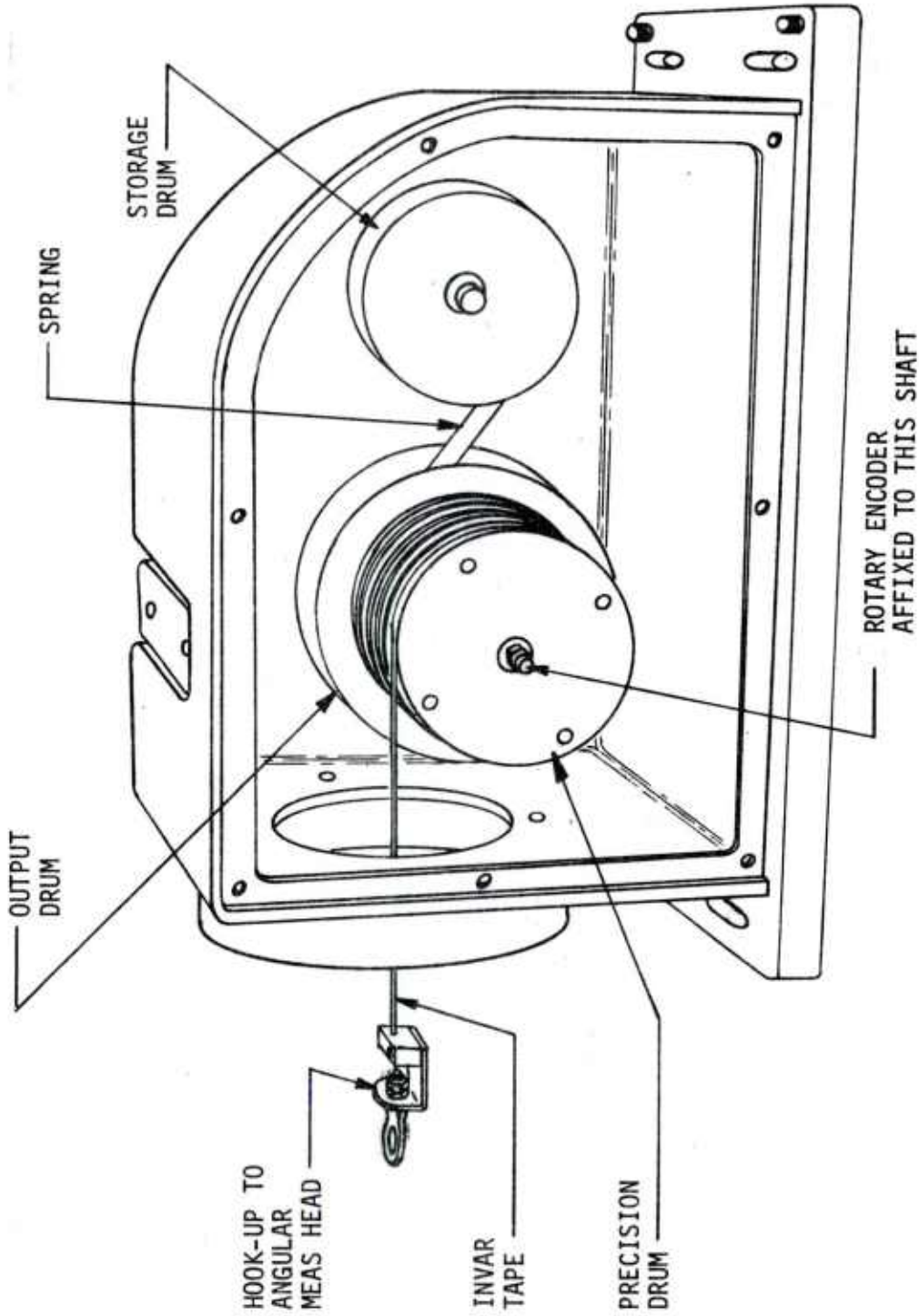


FIGURE 8. LINEAR MEASURING DEVICE HOUSING

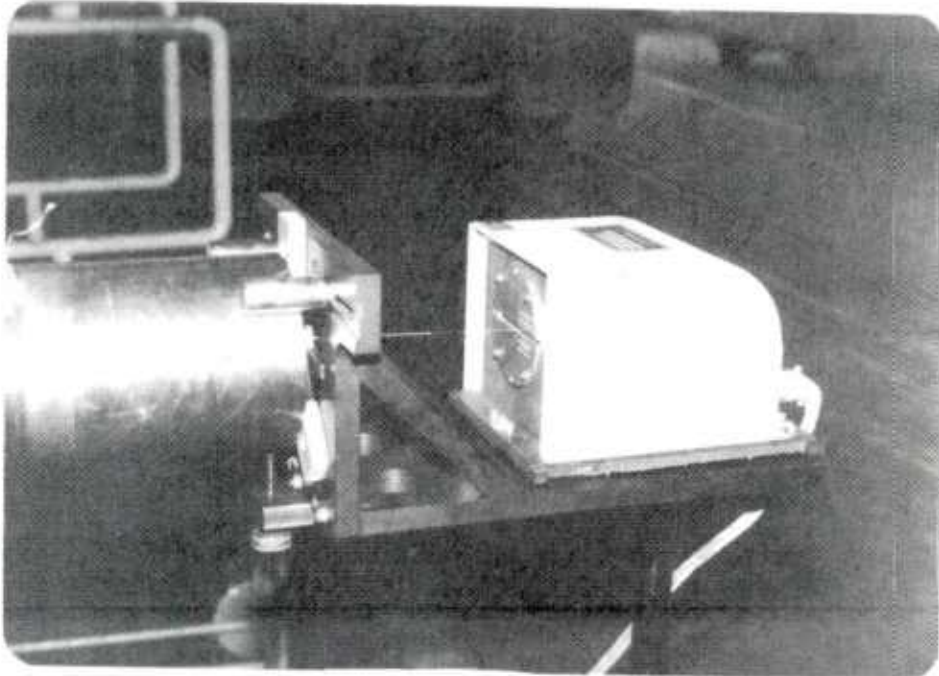


FIGURE 9. LINEAR MEASURING DEVICE AND HOLDING FIXTURE

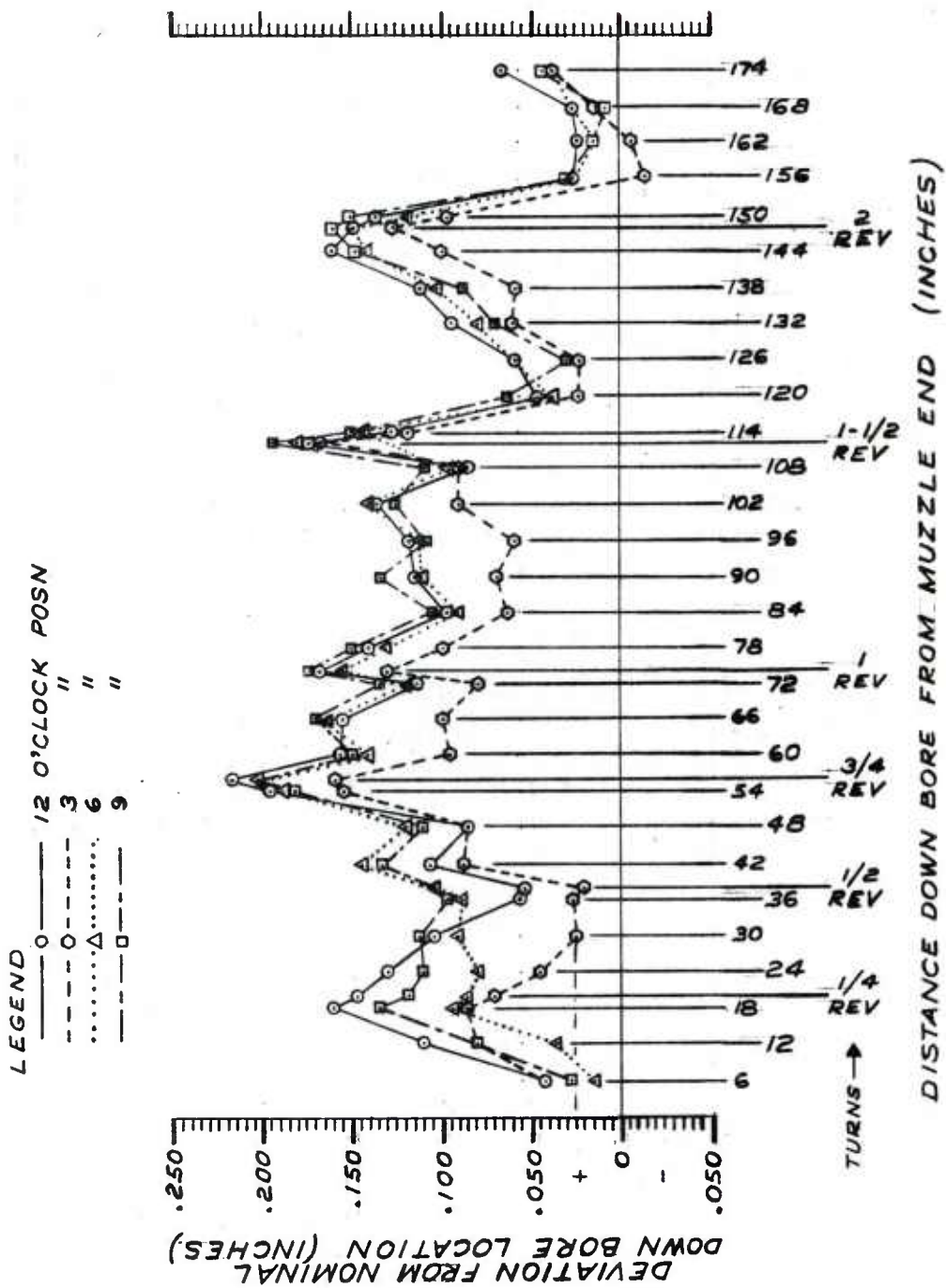


FIGURE 10. PLOT OF RIFLING TWIST MEASUREMENTS

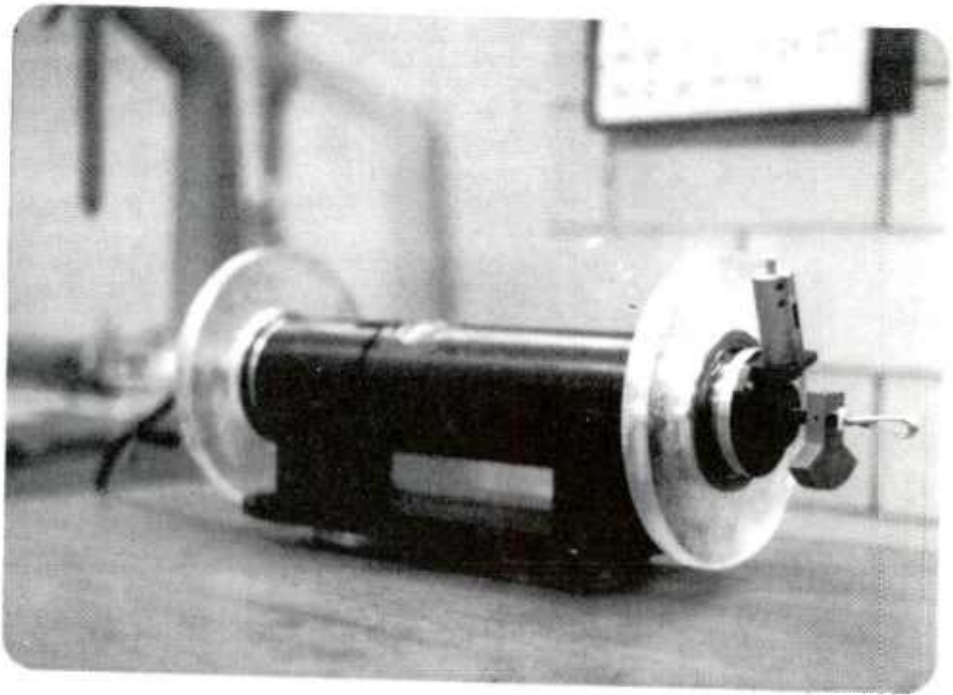


FIGURE 11. HEAD ASSEMBLY MODIFIED FOR INSPECTION OF 8 IN. HOW., M201

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