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FRANKFORD ARSENAL, PHILADELPHIA, PA.

REPORT NO. R-662

A RECORDING BALL BEARING TEST UNIT

SECOND REPORT

PROJECT 1/26

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First Report
R-661

REPORT NO. 232/3
WATERTOWN ARSENAL

November 1945

OBJECT

To develop a ball bearing test unit capable of measuring slight changes in the frictional characteristics of ball bearings at low speeds and torques.

SUMMARY

This report describes the development and operation of a ball bearing test unit which will measure torque changes in ball bearings of the order of 0.06 g. cm.

Tests may be run rapidly and conveniently, the data are recorded, and the method is non-destructive.

The unit is useful for a number of applications, including selections of new ball bearings, study of lubricants for synchronous unit bearings, and measurement of change of operation of ball bearings during long term storage or corrosive processes.

AUTHORIZATION

O.O. 412.2/12755; F.A. 412.2/11548.

I. INTRODUCTION

In connection with an investigation on lubricants for synchronous unit bearings, it was found necessary to use some testing device to determine the frictional characteristics of high precision ball bearings. The maximum torque under which these bearings must operate smoothly in service is of the order of 5 g. cm. The maximum torque for new bearings is much lower (of the order of one g cm.) in order to allow for traces of corrosion during the assembly process, storage, and use. The only applicable method in the past was to assemble the bearings into synchronous units and to measure the angular error of these units. The errors associated with such measurements have been described in detail elsewhere(1). The procedure is quite cumbersome when many determinations are being made and the errors are increased enormously when a set of bearings is repeatedly assembled into a synchronous unit in order to study the time rate of changes during some exposure. The use of synchronous units for quantitative measurement of bearing friction is not entirely satisfactory because the angular errors obtained with new bearings are quite close to the maximum permissible angular error of the synchronous unit. In addition, the use of a standard synchronous unit as a bearing test device automatically fixes all of the dimensions of the bearings under test.

Briefly stated, the problem consists of the development of a test unit which will enable determination of the frictional characteristics of precision ball bearings under small loads and low speeds and change in these characteristics within the range in which the bearing is still serviceable. For synchronous unit bearings this range is particularly small. Experience has indicated that synchronous unit bearings become unserviceable before any corrosion or other change takes place that may be detected with the unaided eye.

Laboratory bearing test fixtures described in the literature involve measurements of wear, and temperature increase at high loads and speeds(2). These are obviously not applicable to the problem. Commercial torque meters cannot be used because they are not intended for the low torques involved.

In 1943, Mr. John L. Everett of the Fire Control Laboratory at this Arsenal suggested that the change in resistance due to strain of a short length of resistance wire might be used for bearing friction measurements since the small torques involved cause appreciable strain in sufficiently fine wire. It appeared therefore that a satisfactory unit might be obtained by mounting the bearing on a rotating shaft in such a way that the bearing torque causes continuous strain in a resistance wire. The resulting unbalance in a resistance bridge could then be amplified and recorded. After calibration, the unit would supply a continuous record of the torque required to turn the bearing during an entire revolution.

This report describes the development, construction, calibration, and use of a recording bearing test unit embodying the above principle.

II. APPARATUS

A. Assembly

The commercial SR-4 strain gage obtained from the Baldwin Locomotive Works was used as the resistance element. This gage consists of a flattened coil of resistance wire cemented between sheets of paper. The delicate set-up that would result from the use of a length of fine wire suspended in air is thus avoided. Strain gages have been used industrially to determine strains on beams(3) and are readily available.

In the final set up, four type A-14 (500 ohm) SR-4 strain gages were mounted on a strip of spring bronze 4 1/2 in. x 5/8 in. x 0.013 in; two gages on each side of the spring. The four gages were assembled as the arms of a resistance bridge. A brass holder with two projections was made to fit a no. 37 bearing (this size was used throughout the work). The strain spring, drive motor and shaft were assembled in a single-unit as illustrated in Fig. 4 (the unit included a drive motor for 3 rpm.).

A commercial oscillator, amplifier, and balancing unit was used with the above fixture (SR-4 Single Channel Balancing Unit and SR-4 Oscillator-Amplifier obtained from the Instrument Division of the Baldwin Locomotive Works, Phila. Pa.). In use, the bridge was balanced, the bearing rotated, unbalance amplified, and amplifier output recorded on a recording d.c. milliammeter (Esterline-Angus 5 ma d.c. range). The input to the bridge was 12 volts at 1000 cycles. Details of assembly are illustrated in Figs. 1-5. The gain of the amplifier was checked periodically and adjusted when required. (This was done by shunting one of the gages with a calibration resistor built into the bridge balancing unit and determining the current output due to unbalance)

B. Calibration

A small hole (4 mm dia.) was drilled in the end of the bronze spring. The bridge was electrically balanced, the unit placed on its side so that the spring was horizontal and a wire hook suspended from the spring. The weight of the spring and hook was counterbalanced with a sufficient weight to rebalance the bridge electrically (Fig. 6). Weights were then hung from the spring and the resulting currents recorded.

The data, Table I, were fitted to a straight line, Fig. 7, by the method of least squares. The equation for this line was found to be

$$I = 0.0016W - 0.0525$$

where I is the current in milliamperes and W is the weight in milligrams. By reference to Figure 7 it will be seen that the calibration curve departs from linearity at weights over 800 mg (Corresponding to currents greater than 1.25 ma) for the particular spring used.

III. OPERATION

Typical data obtained with the bearing tester are illustrated in Figures 8, 9, and 10. Nine standard No. 37 precision ball bearings (A-H) were tested in two counter-clockwise and two clockwise revolutions. The bearings were then subjected to salt spray for one hour and then retested. In most instances, the corrosion of the balls and races were of such magnitude that it could not be readily detected by hand rotation.

The zero lines given in the figures were drawn in after the data were recorded. Each curve represents one revolution (at one rpm) of the bearing.

Reference to Figures 8-10 indicates clearly the differences among new bearings. Bearings A-H all appeared to be equivalent when turned by hand, but had widely different frictional characteristics when subjected to test. Thus bearings D and H have much poorer characteristics than the other bearings. It may also be seen that the frictional characteristics may be different when the bearing is rotated in different directions. This is illustrated by the data on bearings A, D, and G. It should be noted that this is not due to entrance or exit of dirt after the first two revolutions because the clockwise and counter-clockwise revolutions were alternated during all tests.

Figure 10 illustrates the frictional characteristics of two No. 37 bearings (J and K) specially processed for use in synchronous units. The differences between these bearings and standard No. 37 bearings is apparent. The average torque of bearings J and K is 0.17 g. cm. The sensitivity of the bearing tester is approximately 0.05 ma corresponding to a torque of 0.056 g. cm. The unit is therefore suitable for study of changes in synchronous unit bearings.

III. DISCUSSION

The bearing test unit described has the following advantages:

- a. Tests may be made in a short period of time.
- b. Results are automatically recorded.
- c. The method is non-destructive.

Although the unit was developed primarily for determining the change in operation of precision ball bearings during exposure or use, it is applicable as a device for selecting unserviceable ball bearings from a manufactured lot.

In assembling the unit difficulty was at first experienced with the mechanical system. Since the torques encountered in synchronous unit bearings are very low, the spring must be quite thin in order to obtain appreciable strain. On the other hand, decreasing the thickness of the spring decreases the sensitivity of the gage. At a spring thickness of 0.008 in. it was found that the lead wires were sufficiently stiff to cause maximum spring strain above the strain gages. The first lead wires used were no. 20 stranded hookup wire (synthetic insulation) but these were changed to a double silk covered specially flexible wire. In spite of this it was found necessary to increase the spring thickness since the lead wires still contributed to stiffness in the gage area. A more rigid mechanical system resulting from the use of a thicker spring was also considered desirable to avoid damage in handling. At first only two strain gages were used, one on each side of the spring. The sensitivity was materially increased by the use of four rather than two gages. The material used to protect the gages from injury was also found to exert an appreciable effect. A thin flexible vinylite sheet used at first was abandoned in favor of a flexible felt.

The unit described was intended only for No. 37 bearings. A new unit has been designed having replaceable springs and spring holders for different size bearings. The new unit is inclosed in a box to prevent difficulties due to even slight drafts or temporary changes in atmospheric temperature in the neighborhood of the equipment, and is much more resistant to injury by shock or mishandling.

IV. CONCLUSIONS

A bearing test unit has been developed that is capable of determining changes in the frictional characteristics of ball bearings within the range in which the bearings are still serviceable. The unit can measure changes in torque of the order of 0.06 g. cm. and is satisfactory for study of synchronous unit bearings.

V. RECOMMENDATIONS

It is recommended that the bearing test unit described be used to study the changes in operation of ball bearings during long term storage and in other applications involving slight frictional changes.

REFERENCES

(1) Frankford Arsenal Ordnance Laboratory Report R-661

(2) L. W. Sproule, The Institute Spokesman, National Lubricating Grease Institute, VIII, No. 11, Feb. 1945.

(3) D. M. Nielson, Electronics 16, 106 (Dec. 1943)

TABLE I

CALIBRATION

Weight, mg.	Current, ma.	Std. deviation (10 readings)
100	0.12	0.0454
200	0.28	0.0595
300	0.40	0.0768
400	0.59	0.0467
500	0.74	0.0458
600	0.90	0.0329
700	1.07	0.0471
800	1.24	0.147
1000	1.58	0.0451

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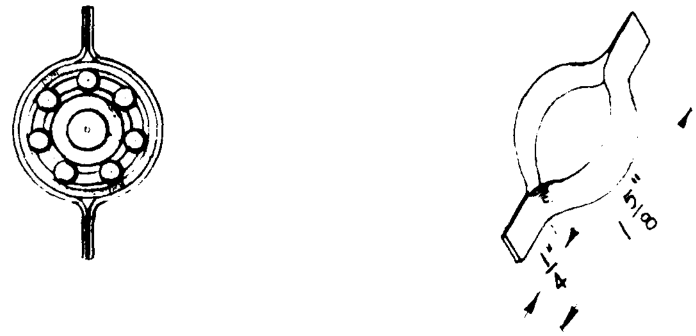


FIG. 1 BEARING & HOLDER

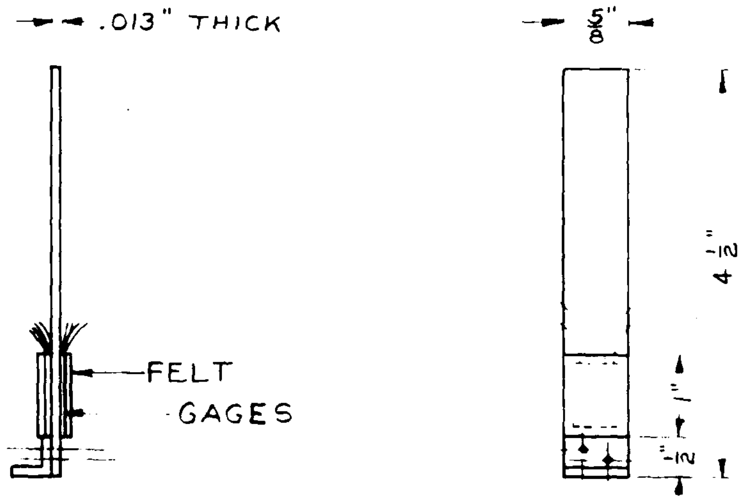


FIG. 2 SPRING & STRAIN GAGES

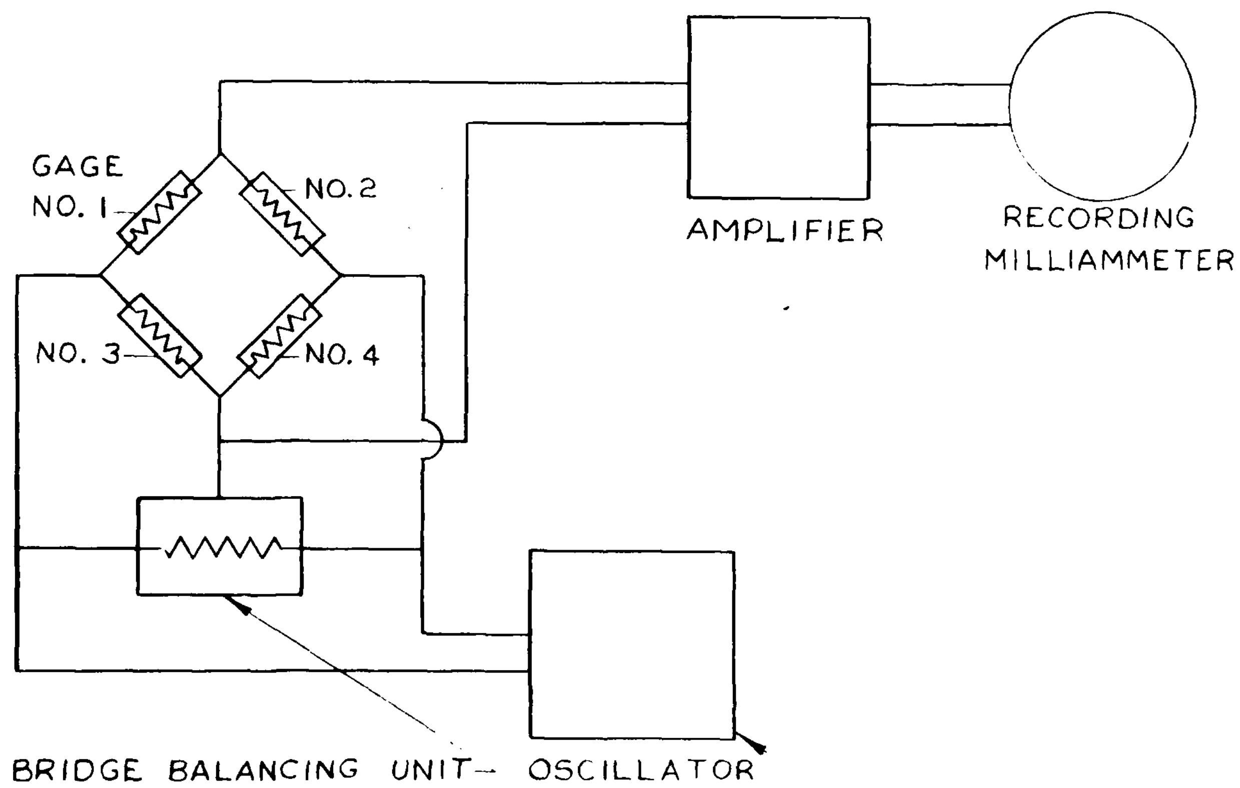
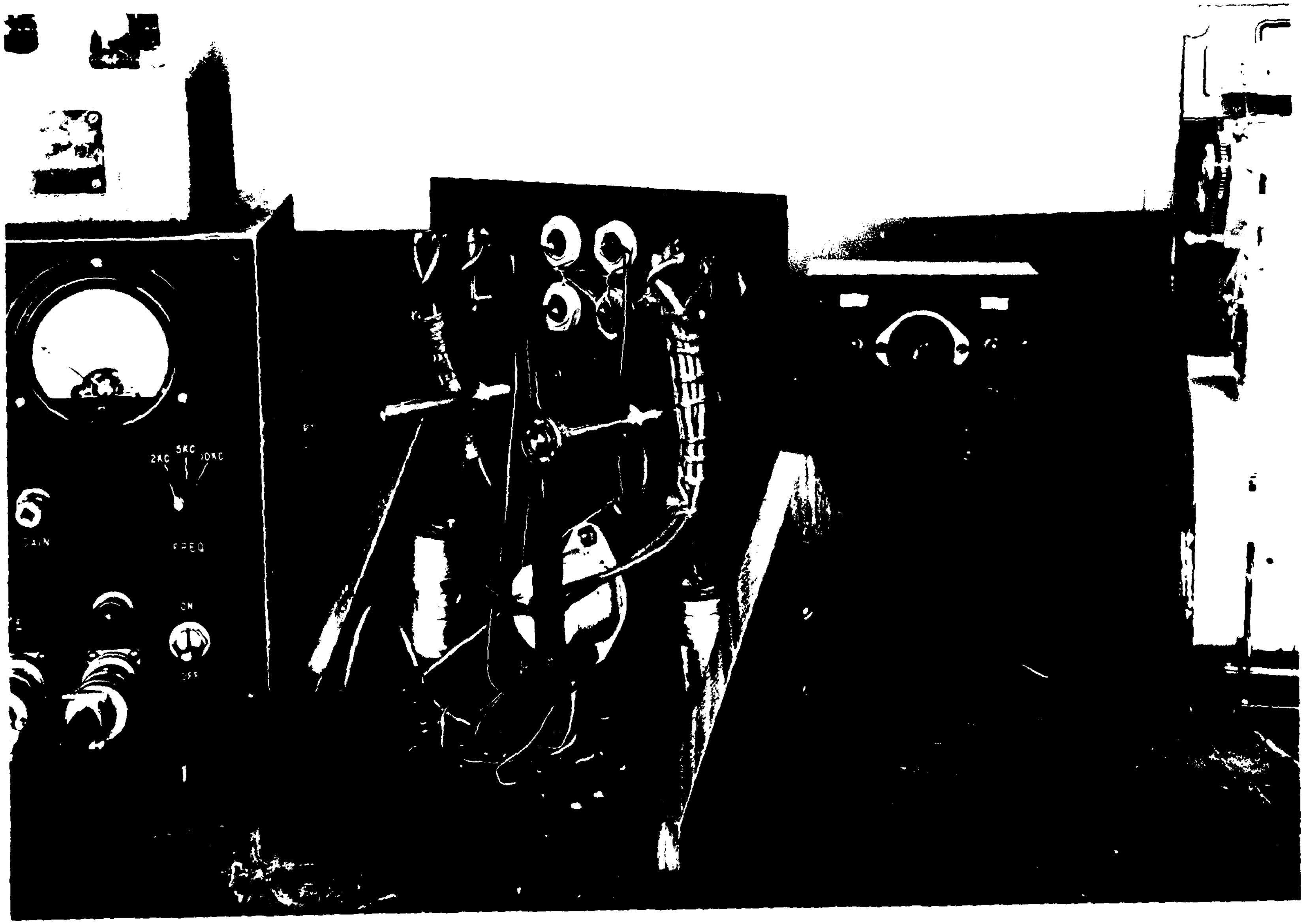


FIGURE 3 - WIRING DIAGRAM



NEG. #16281-1 14 SEPT. 1945 FRANKFORD ARSENAL FIG. 4 ORDNANCE DEPARTMENT

BEARING TEST UNIT, DETAILS OF ASSEMBLY.

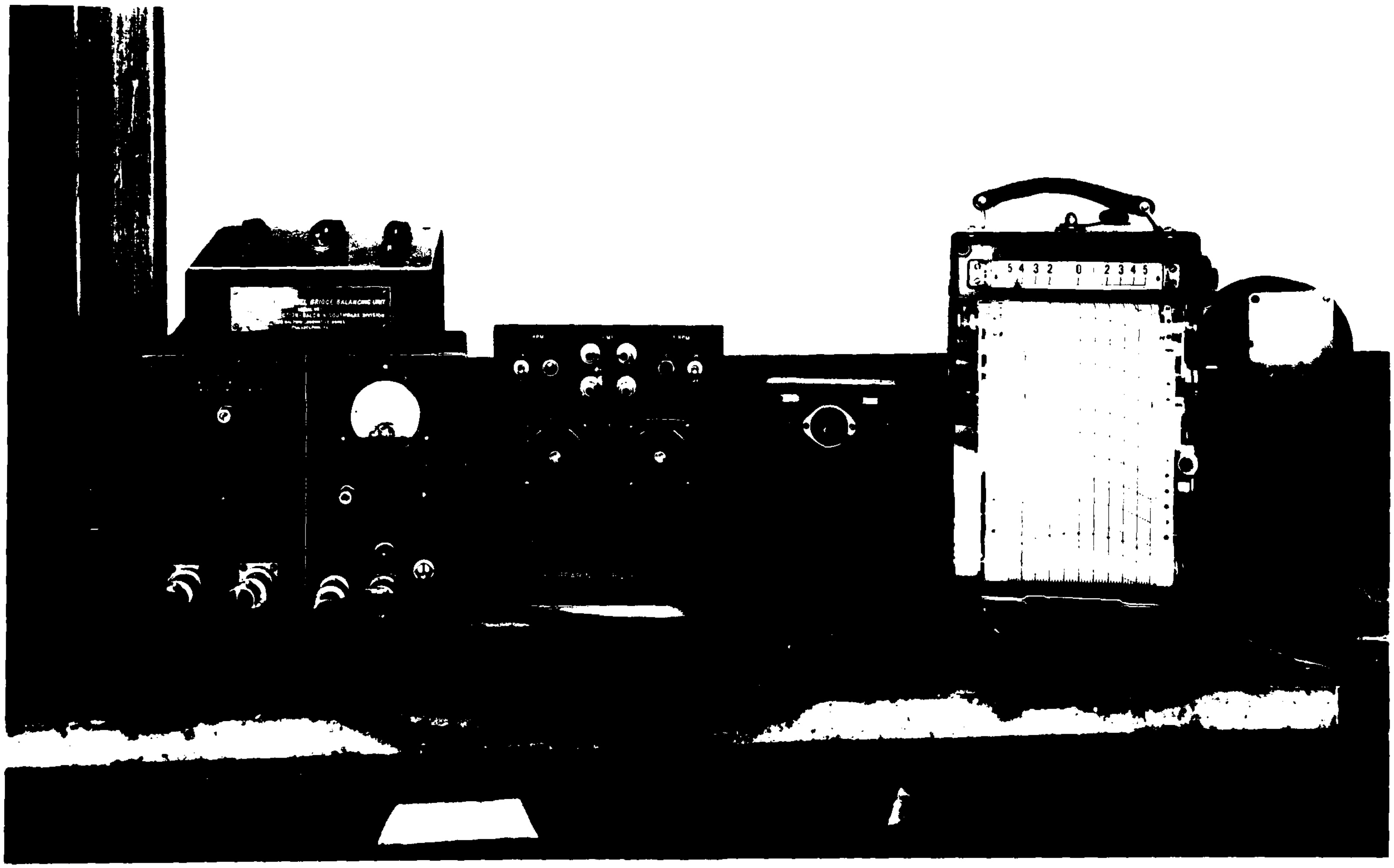


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FIG. 5

BEARING TEST UNIT, OSCILLATOR - AMPLIFIER AND RECORDING METER.

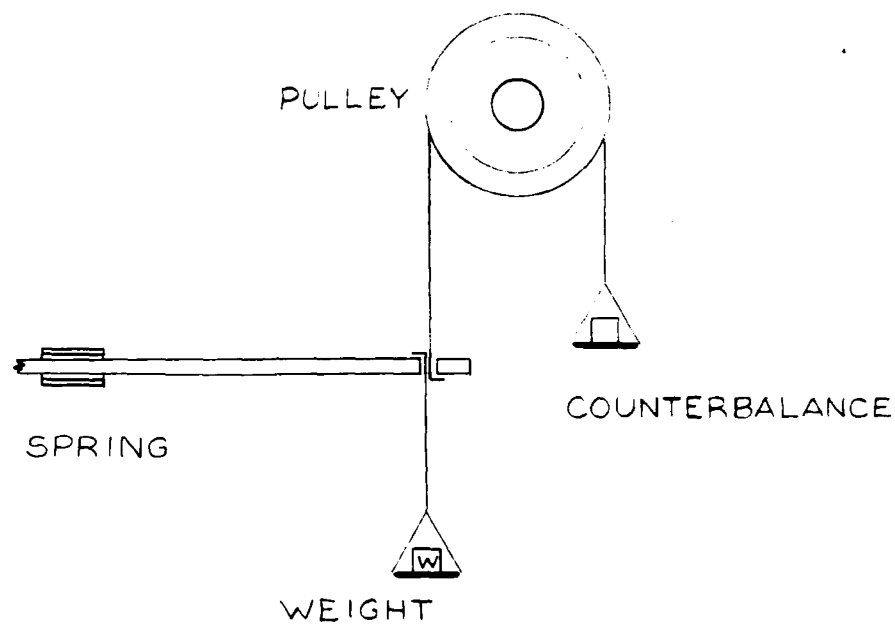

FIGURE 6 - CALIBRATION

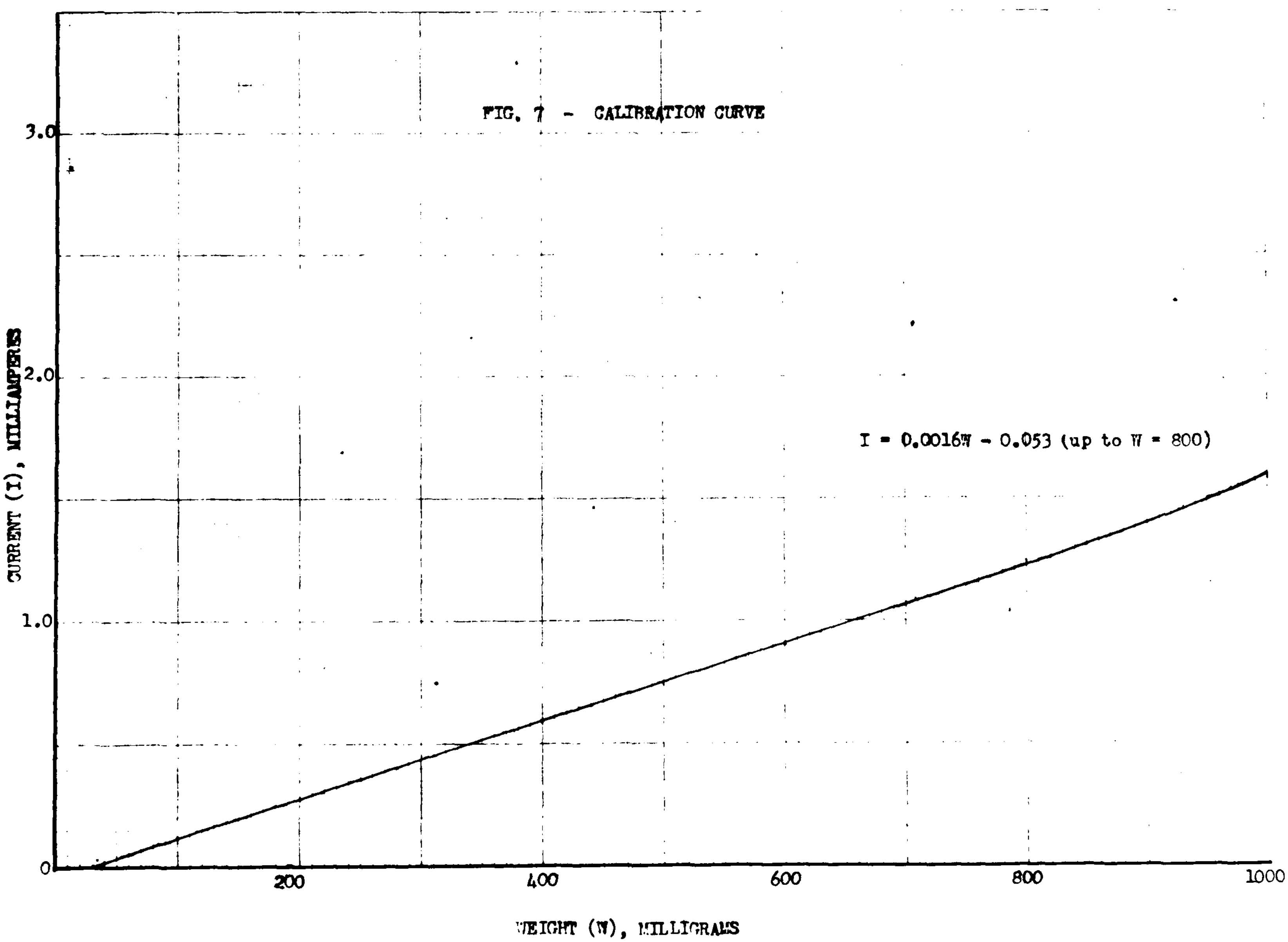

FIG. 7 - CALIBRATION CURVE

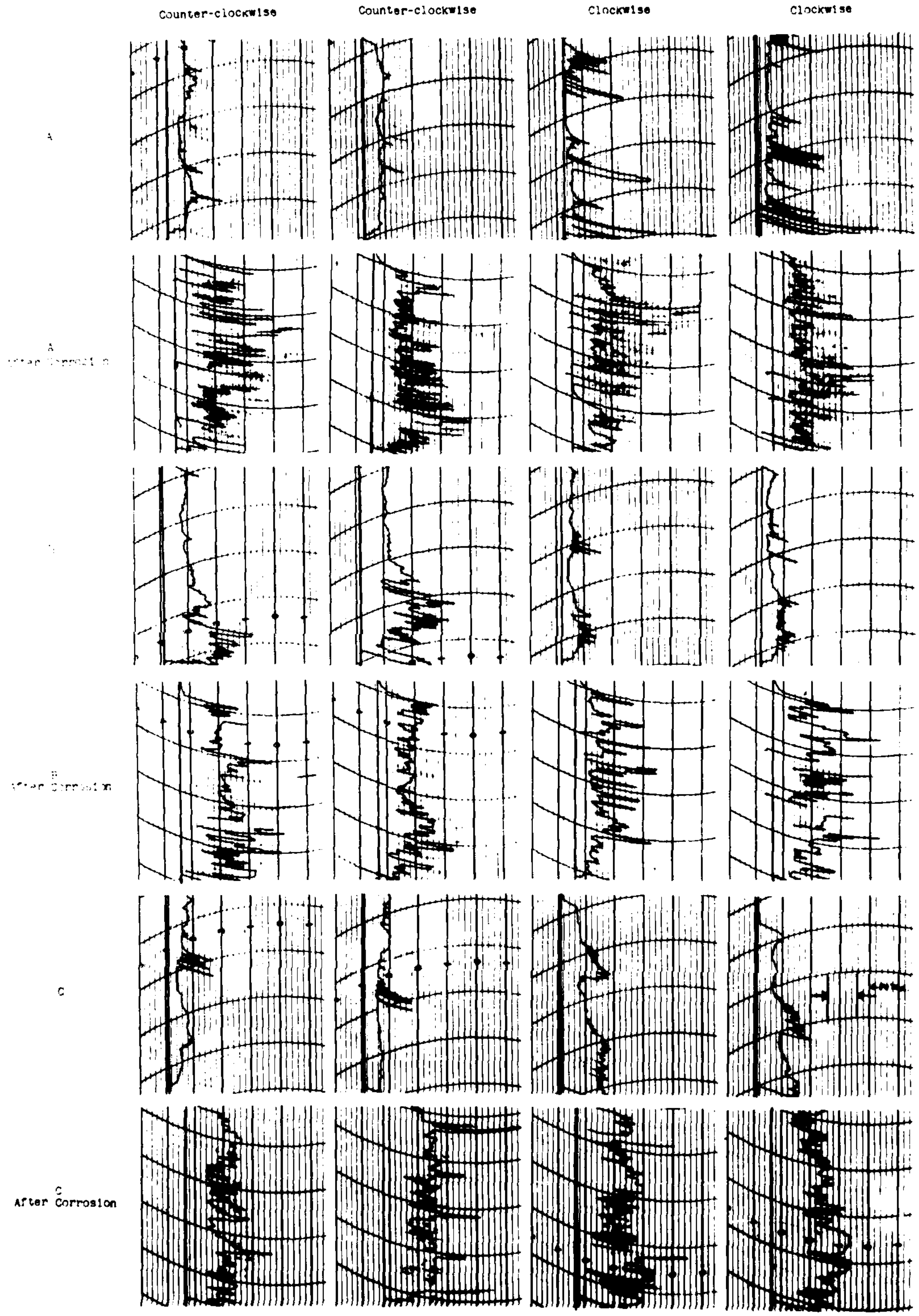

Fig. 8. TYPICAL NO. 37 BEARINGS BEFORE AND AFTER CORROSION

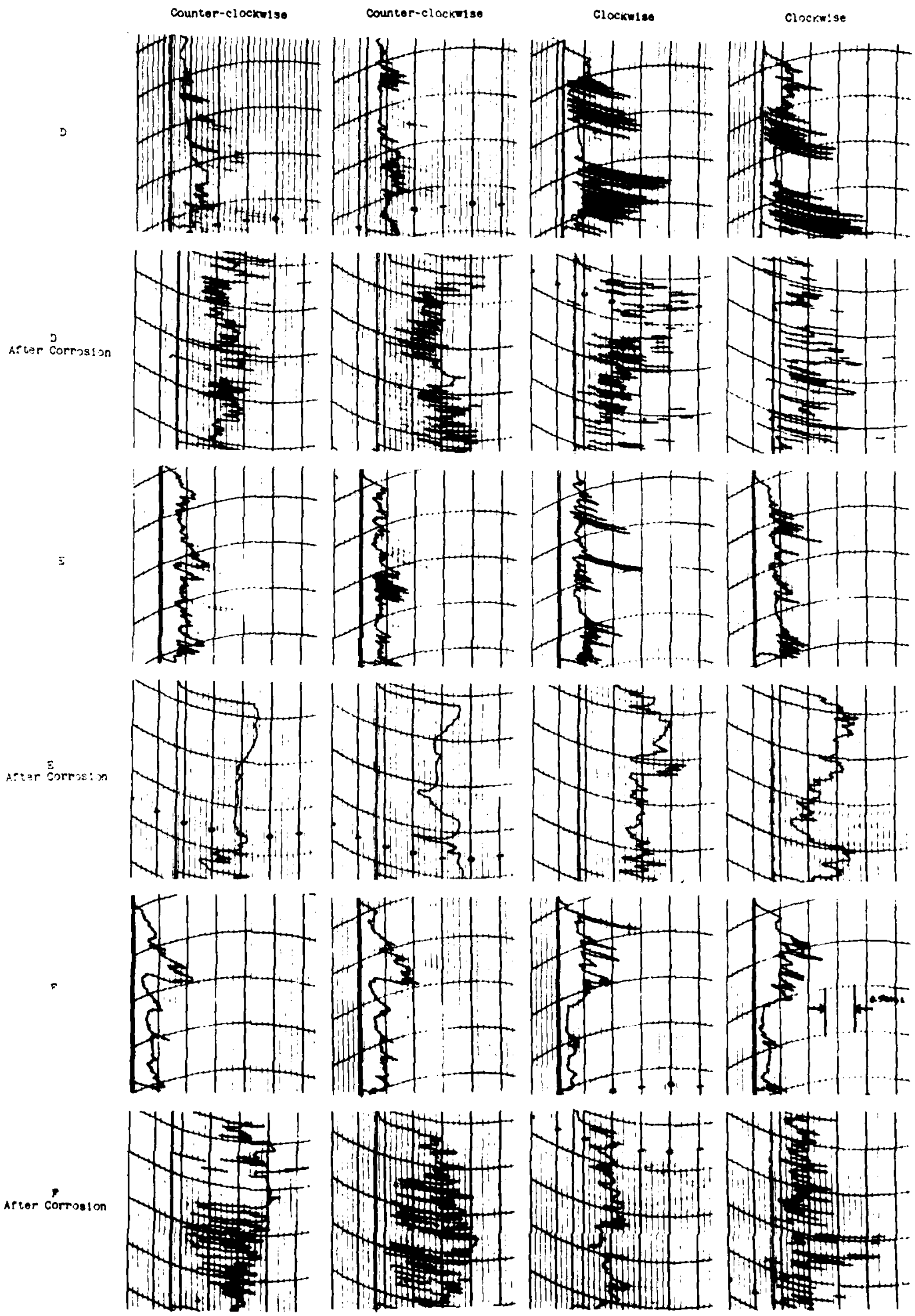

Fig. 9. TYPICAL NO. 37 BEARINGS BEFORE AND AFTER CORROSION

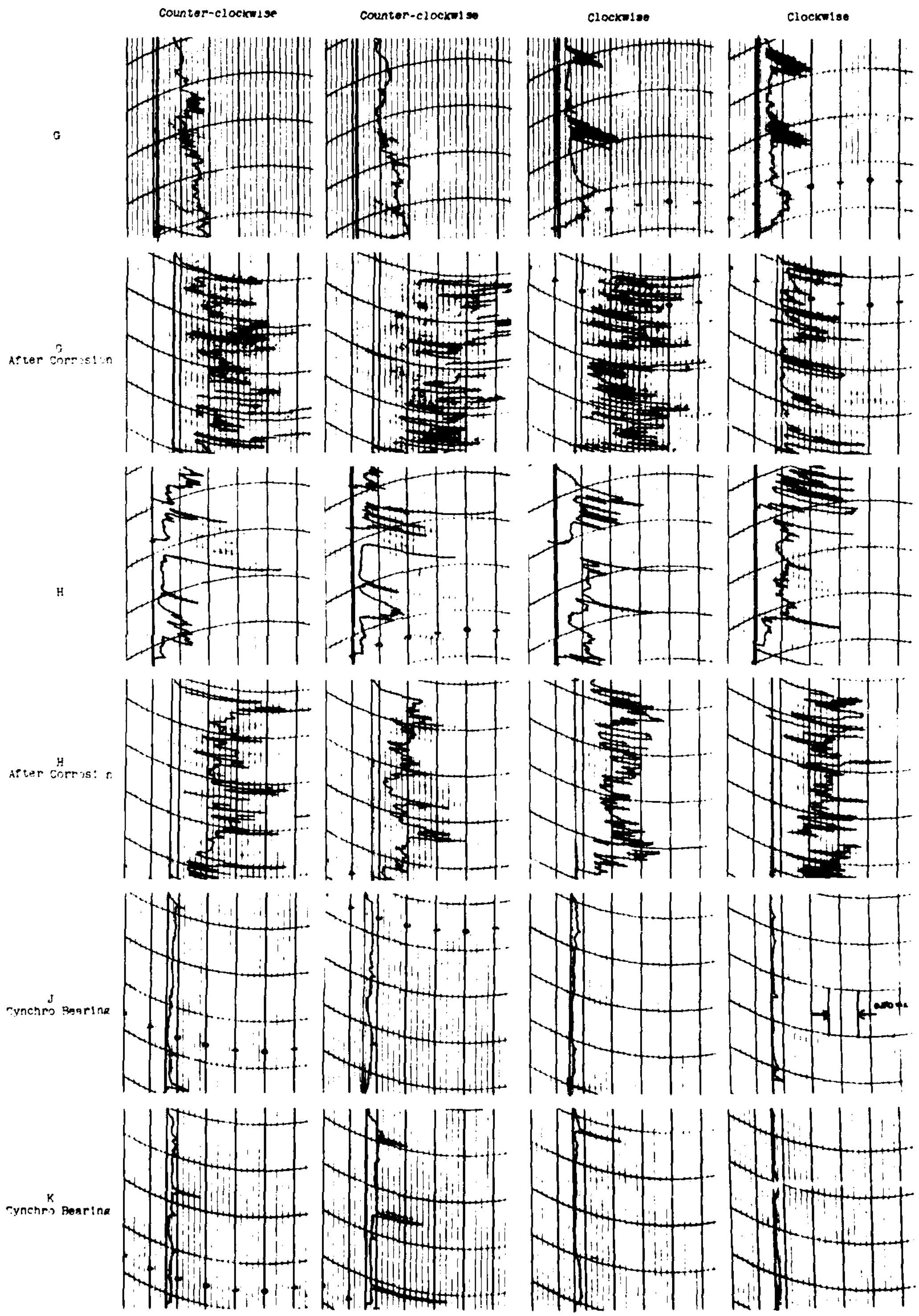

Fig. 10. STANDARD NO. 37 BEARINGS AND NO. 37 BEARINGS SPECIALLY PROCESSED FOR USE IN SYNCHRONOUS UNITS