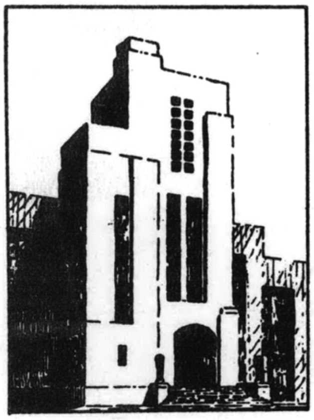
4-6

NAVY DEPARTMENT
THE DAVID W. TAYLOR MODEL BASIN
WASHINGTON 7, D.C.

PROPELLER DYNAMOMETER INSTRUMENTATION AT THE DAVID TAYLOR MODEL BASIN

By

G.J. Norman, M.W. Wilson, and F.B. Bryant



Prepared for the
American Towing Tank Conference
Washington, September 1956

July 1956

Report 1068

PROPELLER DYNAMOMETER INSTRUMENTATION AT THE DAVID TAYLOR MODEL BASIN

By

G.J. Norman, M.W. Wilson, and F.B. Bryant

Prepared for the
American Towing Tank Conference
Washington, September 1956

July 1956 Report 1068

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

ABSTRACT

A new transmission propeller dynamometer for ship model testing is described. It features differential transformer transducers of a special design, which permit the measurement of torque and thrust in the shaft without the use of sliprings. The associated instrumentation provides for either indicating or graphic recording of the torque and thrust quantities. Additional instrumentation provides for measurement and automatic tabulation on a digital printer of shaft revolution, carriage speed, and test time interval data.

The paper also describes briefly other propeller dynamometers designed and developed at the Taylor Model Basin, leading up to the present transmission dynamometer design.

INTRODUCTION

During the past several years, a continuing program of design and development of propeller dynamometer instrumentation has been underway at the David Taylor Model Basin. Several new designs have evolved from this program, and a number of new dynamometers and associated instrumentation systems have been produced and placed in operation. The latest of these designs is a compact and versatile transmission dynamometer, which measures torque, thrust, and rpm in the propeller shaft without the use of sliprings, and which is suitable for either steady-state or transient measurements. The dynamometer may be used with remote indicating or graphic recording instrumentation. Several models of this dynamometer have been built in various ranges.

It is the purpose of this paper to describe this transmission dynamometer and the associated instrumentation. In addition some of the history and descriptions of earlier dynamometers leading up to this present design will be given briefly, so as to present a general over-all picture of propeller dynamometer instrumentation available and in use at the Taylor Model Basin today.

PROPULSION DYNAMOMETER DEVELOPMENT

The newer dynamometers designed and built at DTMB have not necessarily replaced the older ones, but have, in most cases, supplemented them, providing different features and characteristics, and making possible a wider variety of test programs in the various facilities at the Model Basin. In each new design, we have, of course, attempted to overcome certain limitations of previous designs or to provide certain features of operation not previously available. It would seem appropriate, then, at this time to review the various propeller dynamometers which have been developed at DTMB in the past, leading up to the latest transmission dynamometer.

Gravity (Pendulum) Dynamometer

The earliest propulsion dynamometer used at DTMB is the familiar gravity or pendulum dynamometer (Figure 1). This is a reaction-type dynamometer with a self-contained propulsion motor. In this design, torque and thrust forces displace pendulums from their initial positions. The angular displacement of the pendulum is read by means of an optical lever which deflects a light beam along a calibrated scale. These dynamometers are currently in use on a routine basis for propulsion tests of surface models in still water.

1/2 HP Submarine Dynamometer

About 1948, requirements arose for remote indicating dynamometers for use in submerged model tests. About the same time, the need was felt for a graphic recording dynamometer which would produce a permanent time-history record of torque and thrust and which would be suitable for transient measurements such as crash-backs. These requirements led to the development of two types of dynamometers utilizing electrical gaging elements, or transducers, for the measurement of torque and thrust.

The first of these designs was the 1/2 HP submarine dynamometer shown in Figure 2. This is a reaction dynamometer with its self-contained motor. The unit is enclosed in a watertight case for use submerged. The torque and thrust forces are applied to flexures and the resulting deflections are detected by means of differential transformers. In the remotely-located indicating instrument, the cores of matching differential transformers are displaced a similar amount to produce an electrical null with the gaging transformer, and the magnitude of this displacement is a measure of the torque or thrust.

In the first indicating instrumentation this was done manually through a crank and a lead-screw. Later, an automatic system was designed in which a stepping servo positioned the balancing transformer to the nearest of 100 fixed positions and the remaining unbalance was recorded on a graphic recorder. A means was provided also to record an indication of which step the stepping servo had homed to, so that the complete record of magnitude was on the chart. This system was built up in a four channel unit, known as the Four-Channel Magnigage Recorder.

Strain Gage Reaction Dynamometer

Another reaction dynamometer design was also completed at about this time. In this design, shown in Figure 3, torque and thrust forces are restrained by cantilever-type flexures, and SR-4 strain gages bonded to these flexures constitute the electrical gaging element. These gages form a Wheatstone resistance bridge, which is unbalanced electrically by the torque and thrust. Balance is restored by a servo-system actuating a slide wire in an automatic-balancing graphic recorder, which gives a chart record of torque or thrust.

This strain-gage-type dynamometer introduced a number of new features in propeller dynamometer instrumentation. One of these, a characteristic of strain-gage transducers, was a secondary calibration. A precision resistance shunting one arm of the strain gage bridge constituting the transducer produces an electrical signal which can be chosen to simulate any desired torque or thrust, and can thus be used for standardizing (i.e., setting the scale or range of) any associated indicating or recording instrumentation.

Another feature introduced with this dynamometer was a new type of revolution counter. A disk with ten radial slots rotates with the shaft between two coils forming arms of an inductance bridge. As each slot passes, it changes the reluctance of the magnetic path and a pulse is produced which is counted and displayed by electronic counters. Since ten pulses are produced per revolution, shaft turns are measured to a tenth of a revolution. If these pulses are counted for an exact six second interval the resulting count is a direct RPM reading; or if they are counted for one second or for ten seconds, the resulting count is a direct RPS reading, to tenths or hundredths of RPS.

The instrumentation associated with this strain-gage dynamometer provided for automatic operation for each test. An initiating push-button starts several functions simultaneously: (a) graphic recording of torque and thrust; (b) counting of shaft revolutions; (c) measurement of distance traveled by carriage; and (d) measurement of time, in milliseconds. At the end of a pre-selected fixed distance, the measuring operations are automatically stopped. The total revolutions and the time are displayed on counters, so that RPM and speed can be calculated. In later instrumentation, the automatic operation provides for measurements over a fixed time interval rather than a fixed distance, so that shaft revolutions per second and carriage speed in feet per second are measured and displayed directly; this instrumentation is described more thoroughly later in this paper. The dynamometer is described in the forthcoming DTMB Report 1072 entitled "A Reaction Type Propeller Dynamometer with Strain Gage Transducers," by Vernon E. Benjamin.

Transmission Dynamometers

These reaction dynamometers, while generally satisfactory for their intended purposes, have a number of disadvantages. Since the propulsion motor is an integral part of the assembly, the over-all size of the dynamometer is frequently a problem, particularly in small multiple screw models. Procurement of special motors to meet design requirements is usually necessary and is usually expensive and time consuming. It is difficult to change motors to obtain different propulsion unit characteristics for different tests, such as the "constant speed" characteristic of shunt motors or the "constant torque" characteristic of series motors. And it is difficult to synchronize the speeds of different shafts in multiple shaft models.

The answer to these problems of the reaction dynamometer appears to lie in a transmission dynamometer design, in which torque, as well as thrust, is measured in the propeller shaft system independent of the motor. With transmission dynamometers, two or more shafts may be geared together and driven by one motor, so that synchronization of shafts is thus taken care of. The dynamometers may be placed close to the stern tube, reducing the difficulties of alignment and universal couplings, and the motor, which is usually the heaviest unit of the system, may be located in the model as desired.

In the earlier considerations of transmission dynamometer designs, the use of slip rings appeared to be a necessary evil; however, because of the feeling that slip rings would be too much of a maintenance problem for routine basin testing, no dynamometers were actually constructed using such a design. The development of a torque-measuring device known as the "magni-torque" provided a solution to the slip ring problem. The magni-torque is a special type of differential transformer which permits the measurement of torque in a rotating shaft without the use of sliprings. It will be described in more detail later in this paper.

Submarine Transmission Dynamometer MK I

Utilizing the magnitorque, the MK I submarine transmission dynamometer was designed and built. (See Figures 4, 5, and 6) This is a compact dynamometer about 12 inches long and 4 inches diameter, with the gaging elements entirely encapsulated in plastic so that the dynamometer can be operated free-flooded. This dynamometer has been used in most of the submarine model testing for the past four years. The instrumentation used with this dynamometer is the Four-Channel Magnigage Recorder described previously.

As with the strain gage dynamometer instrumentation, this recorder operates with the revolution-speed-time measurement unit to provide similar automatic operation.

The need for still further reductions in size and weight of the dynamometer unit led to the development of a smaller thrust measuring element known as the "magni-thrust." This too is a special differential transformer not requiring slip rings for the measurement of thrust in rotating shafts. In this element, the gage armature and the thrust flexure form an integral assembly permitting a much smaller and much stiffer thrust flexure than in previous designs.

THE TMB TRANSMISSION DYNAMOMETER

The "magni-torque" and the "magni-thrust" elements form the basis of the present basic design for the TMB transmission dynamometers. Several different dynamometers have now been constructed to this general design, in various ranges of horsepowers, torques, thrusts, and RPM.

A typical transmission dynamometer of this design, as illustrated in Figures 7 and 8, is made up of two basic assemblies; the housing assembly, and the shaft assembly. The housing assembly consists of a cylindrical body which contains the differential transformers, the revolution counter pickup, and miscellaneous spacers. The shaft assembly is made up of the torque and thrust flexural elements, the revolution counter disc, and three bearings. When assembled there are no mechanical connections or restraints between the shaft assembly and housing assembly except for the bearings, which center the shaft in the housing.

Magnitorque

The torque transducer or magnitorque is shown in Figure 9. Two necked-down sections of the shaft, A and A', having the same diameter and length form the flexural elements. Three rings made from magnetic material are fastened to the shaft over these flexural elements; one ring "B" is fastened to the land between the two flexural sections, and the other two rings "C" and "D" are fastened to the shaft at the ends of the flexural sections. The rings have configurations such that a series of longitudinal air gaps "E" and "F" are formed between the center ring and the two end rings.

With no torque applied to the shaft, the active gaps "E" and "F" are equal and the net output of the differential secondary coils is zero. When a clockwise torque is applied, as shown, the flexural elements deflect, resulting in air gaps "F" increasing and air gaps "E" decreasing, thereby, weakening one magnetic circuit and strengthening the other. This results in a net output from the secondary coils which is proportional to the applied torque. Similarly, counterclockwise torque results in a secondary output proportional to torque, but in opposite phase from clockwise torque.

The shaft is made from a non-magnetic spring material such as beryllium copper or K-monel to avoid magnetic short circuiting of the differential transformer.

Magnithrust

The thrust transducer or "magnithrust" is shown in Figure 10. The flexural element consists of an annular section of the shaft in which a series of slots are cut perpendicular to the centerline of the shaft, thus forming a type of compression spring. The shaft extension on one side of the spring carries a ring "A." This ring is centered between two similar rings "B" and "C" which are secured to a sleeve "S" which is fastened to the shaft on the opposite side of the spring.

With no thrust applied to the shaft, the active air gaps "D" and "E" formed by rings "A," "B," and "C" are equal and the net output of the differential secondaries is zero. When a positive thrust is applied as shown, the spring is deflected, thereby allowing ring "A" to move to the left. This movement decreases air gap "D" and increases air gap "E" resulting in an output from the differential secondaries. The output is proportional to applied thrust for either positive or negative loading.

Revolution Counter Pickup

The revolution counter consists of a copper disc, having ten radial slots, which is mounted on the shaft and rotates with the shaft. Two iron core coils are mounted in the housing, one on each side of the copper disc. One coil is energized with a 10 kc supply and induces a voltage in the coil on the opposite side of the copper disc. When the shaft rotates the induced voltage is pulsed by the slots in the copper disc. The pulses are counted over measured time intervals by suitable instrumentation to obtain either RPM or RPS.

Features of the TMB Transmission Dynamometer

The principal operational advantages of this type of transmission dynamometer are as follows:

1. The small size of the dynamometer made possible by the use of the magnitorque and magnithrust transducers permits the use of dynamometers in smaller models than was practicable heretofore.

2. Slip rings are not used to transmit measured values of torque and thrust. This simplifies the mechanical design and manufacture, eliminates signal errors due to slip rings, conserves space, eliminates frictional torque of slip rings, and eliminates frequent servicing which slip ring assemblies generally require.

3. The dynamometers are independent of the driving motors. Since any motor having the required torque and speed characteristics can be used for driving the dynamometers, the following benefits can be derived:

   a. Motor failure does not render the dynamometer inoperative.

   b. Different types of motors may be used with the dynamometers if it is desired to simulate full scale power plant characteristics.

   c. Motors need not be trunnionized, thereby reducing the cost of motor procurement.

d. Dynamometers may be located close to propellers, thereby minimizing shafting installation and frictional difficulties.

4. Shafts may be mechanically synchronized. By using the transmission type dynamometers, the shafts may be synchronized by: (a) gear head motor with two output shafts, and,(b) cross coupling by means of gear boxes interposed between motors and dynamometers. This mechanical synchronization is not practicable with the reaction type dynamometers because of the indeterminate torque transfer through the mechanical coupling.

5. Relatively high natural frequency in torque and thrust compared with the pendulum type dynamometers makes the transmission dynamometer suitable for transient type test work, such as testing in waves and crashbacks.

6. The torque transducer is insensitive to changes in pitch, roll, and yaw. The thrust transducer is insensitive to changes in roll and yaw, and is sensitive to changes in pitch by the amount of the gravity component of the shaft and propeller. In contrast, the pendulum dynamometers are highly sensitive to changes in pitch, and moderately sensitive to changes in roll (scale factor change).

ASSOCIATED INDICATING AND RECORDING INSTRUMENTATION

In present and anticipated designs, the instrumentation associated with the various propeller dynamometers in use at DTMB performs a variety of functions. This instrumentation, located on the towing carriage, serves not only for the indicating or recording of torque, thrust, and revolutions, but also as a control center for the test operation. It provides for complete automatic operation of the test instrumentation over a pre-selected time interval, during which propeller revolutions per second and carriage speed are measured and their average values indicated at the end of the test interval. During this same interval, torque and thrust values are recorded graphically or indicated on digital indicators. At the end of the test interval (which is usually 5 seconds) the average RPS for each of the shafts, average carriage speed, the time duration of the run, and a sequential test number are all automatically tabulated on an adding-machine type printer. In the present instrumentation, torque and thrust values are read manually, from the indicators or graphic recorders; however, the equipment is adaptable to automatic read-out and printing of these channels also.

The Null-Balance Measurement System

There are two basic types of transducers which have been used in the various dynamometer designs described previously: (a) the differential transformer, and (b) the SR-4 strain gage bridge. In addition to the propeller dynamometer, a variety of drag dynamometers, multi-component force balances, and other instruments utilize one or the other of these transducers. For measuring the outputs of these transducers, an automatic null balancing system, in which the transducer and the indicator or recorder form a closed-loop servo system, is used. The transducer output is balanced by a potentiometer. Any error signal from the transducer, resulting from torque, thrust, or other force, is amplified and drives a servo motor which positions the potentiometer to restore an electrical balance, or null, to the system. The amount that the potentiometer is moved is a measure of the force.

The differential transformer transducers are, of course, excited with a-c, usually at 400 cycles per second in the TMB instrumentation. The strain gage bridge transducers usually have d-c excitation, primarily because it simplifies the controls and operation somewhat.

A block diagram of the measurement system used with the differential transformer type dynamometers is shown in Figure 11. A gage control unit provides means for initial balancing of resistive and reactive components of the gage output, ("Voltage Null," "Phase Null," and "Load Phase"). It also provides for a "sensitivity" adjustment and range changing. The 400 cps error signal from the transducer, coming through the gage control unit, is amplified, demodulated, and fed to a servo amplifier which actuates the servo motor. The servo motor positions the potentiometer to restore a null in the system and simultaneously positions a digital indicator or a recording pen.

It will be noted that the a-c signal from the gage is amplified, converted to d-c, then converted to a-c again in the chopper-type servo amplifier. There are several reasons for this seemingly roundabout procedure: (1) it permits the use of the same servo amplifier and recorder with either the differential transformer transducers or the d-c excited strain gage transducers; (2) it permits selecting the most appropriate frequency for the gage excitation, independent of servo motor considerations; (3) it permits simpler filtering and smoothing of the higher frequency fluctuations, or hash, in the dynamometer outputs.

A block diagram of the measurement system used with the d-c excited strain gage bridge transducer is shown in Figure 12. Since d-c excitation is used, no reactive balance or phasing controls are necessary in the Gage Control Unit. Also, the a-c amplifier and demodulator are not needed; the d-c error signal is fed directly to the chopper-type servo amplifier. In other respects the operation of the system is the same as that described above.

Automatic Digital Indicator

Two sets of instrumentation incorporating these measurement systems have been designed and built at TMB for use with the propeller dynamometers and also with the other balances and dynamometers used in model tests. One of these, the Automatic Digital Indicator, is shown in Figure 13. In this instrument, the servo motor, (a Minneapolis Honeywell "Brown" unit), drives the balancing potentiometer and simultaneously positions a mechanical rotation counter which provides a digital indication of the reading. The balancing potentiometer is a 10-turn helical potentiometer, and a 21 to 1 step up from that shaft to the counter shaft gives a scale range of plus or minus 1050 divisions. This was chosen specifically to give a full scale reading of 1000 units, with a little range to spare.

The response time of this instrument, with its present servo motor, is 4 seconds from zero to full scale. A certain degree of smoothing of the indicator readings with fluctuating inputs from the transducer is provided by a special inertia-loading wheel. This wheel normally rides free on the shaft, but by energizing an electromagnetic coil, the inertia wheel is coupled to the shaft, and the resulting flywheel system then reduces the high frequency variations which the indicator would otherwise follow.

Graphic Recorder

As shown in the block diagrams of Figures 11 and 12, the graphic recording system is basically the same as the digital indicating system. A Minneapolis Honeywell (Brown) graphic recorder with a 10-inch wide scale is used in this instrumentation; the unit currently in use has a response time of one second full scale. Several higher speed response recorders of 1/4 second full scale are currently on order and will permit more accurate recording of the higher speed transients. A complete 4-channel graphic recorder assembly is shown in the photograph of Figure 14.

Revolution-Speed-Time Recorder

An instrument which has assumed more and more importance in the model test programs at DTMB is the TMB Revolution-Speed-Time Recorder (RST). As the name implies, this instrument measures and records revolutions (of 4 shafts), carriage speed, and the time interval of the test. But it also does more than this. It is the RST Recorder which serves as the control center for the test instrumentation and which provides the features of automatic operation which have been mentioned earlier in this paper.

A block diagram of the instrument is shown in Figure 15 and a photograph of it in Figure 16. The detail design can best be understood by following through the block diagram, and will not be described in detail here. Instead, a functional and operational description follows.

Basically, the RST Recorder is a pulse-counting instrument combined with a control and programming system designed especially for model test operations on the towing carriages. The pulses to be counted originate from 3 sources:

1. A slotted disc shaft revolution pickup in the propeller dynamometer which produces 10 pulses per revolution; the output from 4 separate shafts are accommodated in the instrument.

2. An electromagnetic pulse generator on an idler wheel of the towing carriage, which produces 100 pulses per foot of travel of the carriage.

3. A precision tuning fork controlled oscillator which produces timing pulses at the rate of 1000 per second (referred to subsequently as millisecond pulses).

These pulses, after being operated on by various suitable control circuits, are counted and totals accumulated in sets of four-decade decimal counting units (d.c.u.) of the electronic decade counter type. There are, in the instrument, six of these four-decade d.c.u.'s: four for shaft revolutions, one for carriage speed, and one for time. Preceding each of these four-decade d.c.u.'s is a "gate"; when the gate is closed, no more pulses go in and the counters hold their reading until reset.

A selection of the time interval for the test is made in the control and timing system. This interval may be 1, 5, 6, or 10 seconds. The reason for these specific values will appear later. An indefinite manually-controlled interval is also available.

From this point on, the instrument can probably be best understood by following its operation. Let us assume that all is in readiness for a test. Pulses are being produced at the revolution pickups on the shafts, the speed pickup on the carriage wheel, and the millisecond timing oscillator, but are not going into the counters. The operator has selected the time interval for the test. When he wants to initiate the test, he pushes the "start" button which opens the gates to all counters, and the counting channels start accumulating their respective pulse counts. Simultaneously relay contact closures are provided which may be used for activating graphic recorders, digital indicators, or any other associated instruments. At the exact end of the pre-selected time interval, as indicated on the millisecond time counter, a pulse is produced which closes all gates and stops all counting, leaving the count displayed on each set of counters. Simultaneously, relays operate to turn off graphic recorders or perform other desired operations. A stepping-switch system then goes into operation to scan and read out each of the counters, in sequence, and these readings are automatically tabulated on an adding machine type printer. A test number which advances automatically for each data taking operation is also tabulated in this operation. This scanning and printing operation takes about 3 seconds for recording of the seven items (4 revolutions, 1 speed, 1 time, 1 run no.). The instrument is then ready for the next test. Pushing the "start" button for each test automatically and instantaneously resets all counters and gates.

It is evident, of course, that the counting of these revolution or speed pulses for a 1 second or 10 second interval results in readings directly in terms of revolutions per second or feet per second. It should also be noted that these are true average values over the time interval selected.

Similarly it is evident that counting pulse totals for a 6-second interval (at the rate of 10 pulses per revolution or 100 pulses per foot) results in readings directly in terms of revolutions per minute or feet per minute. This 6-second interval was made available (since it involved no extra complications) specifically for use on occasions when readings in terms of units per minute were desired.

The 5-second time interval was incorporated in the system because it appeared to be the most suitable interval for general test use. In order to retain the feature of direct reading in RPS or ft/second, it is necessary to double the number of pulses originating from the revolution and speed pickups. The doublers are automatically connected in the circuits when the time interval selector is thrown to "5 seconds."

One other feature of the RST Recorder is of interest. A "recycle" position is available on the time selector switch; in this position, all pulses are counted for one second, the readings displayed for one second, and the operation then automatically recycled. In this position, the instrument serves as a precision indicating tachometer and carriage speed meter; the printing operation does not take place in the "recycle" condition.

DYNAMOMETER PERFORMANCE

Probably the most important performance factor to be considered in propeller dynamometer design is that of accuracy. In general, dynamometer instrumentation design at DTMB has been based on an over-all accuracy requirement of ± 1/2 % of full scale, with a goal of improving the accuracy to 1/4 % or 1/10 %. Linearity, zero stability, and constancy of calibration factor should, of course, be consistent with the over-all accuracy of the instrumentation. Resolution of a part in a thousand is also a general requirement.

The TMB transmission dynamometer described in this paper is just getting into active use on a more or less regular basis. Laboratory tests and calibrations of this unit, with its associated instrumentation, have shown it to be capable of accuracies of about ± 1/4 % of full scale. In some of the model tests using this dynamometer, errors greater than this have been encountered, but at the time of this writing, the causes of these errors are gradually being found, and it is expected that they can be eliminated. The principal problem has been temperature effects, in the dynamometer transducer and in the associated instrumentation.

SPECIAL PURPOSE DESIGNS

In addition to the general purpose propeller dynamometers described above, special designs utilizing the same type of transducers have been made from time to time to meet other requirements for Basin tests. Some of these are described below.

Contra-Rotating Torpedo Dynamometer

This dynamometer (Figure 17) was designed to measure torque and thrust in the contra-rotating shafts of a full-scale torpedo. In this dynamometer, one torque and one thrust element are made hollow so that the other shaft can pass through. Loop thrust flexures are used and the deflections are measured by means of magnigage type elements.

Torque is measured by magnitorque elements. Shaft seals and body seals are provided to exclude water from the measuring elements. Torque and thrust ratings are 3300 pound-inches and 600 pounds at 3000 RPM per shaft.

Thrust Transient Dynamometer

The purpose of this dynamometer (Figure 18 and 19) is to measure thrust vibratory forces in model propeller shafts. In order to make its frequency response as high as possible, the flexure was made very stiff (about 60,000 lb/inch). Also, to permit installation immediately forward of the propeller, the dynamometer was made quite small (1.12 inches diameter by 4.5 inches long). A magnithrust type gage is used. The natural frequency with a 5-pound mass attached is about 240 cps.

For measuring amplitude of the thrust variations, a Consolidated carrier amplifier (3 kc carrier) is used, in conjunction with a vibration analyzer.

Hollow Shaft Dynamometer

This dynamometer was designed to operate in conjunction with a standard propulsion dynamometer to measure torque and thrust in contra-rotating propeller tests in models. Torque and thrust ratings are 50 pound inches and 50 pounds. Internal nylon sleeve bearings are provided to pass a 3/8 inch diameter inner shaft.

Figure 20 shows the complete assembly, using a 5-40 propulsion dynamometer on the inner shaft. Both shafts are driven from a common shaft at the same speed in opposite directions. The outer shaft is driven through a pair of gear boxes and a countershaft. Both gear boxes are sealed to exclude water and the one on the right has a hollow shaft to permit the inner shaft to pass through. The entire assembly is mounted on a base plate which can be mounted in the model as a unit.

CONCLUSIONS

The dynamometer instrumentation described in this paper, following the original pendulum dynamometers, has been developed at the Taylor Model Basin over a period of several years, to fulfill new and changing requirements for test instrumentation. This is a process which will no doubt go on indefinitely; there will always be new requirements and it is always possible to improve instruments or to design something new. However, the model testing programs require not only that there be new developments to meet new requirements, but also that we have reasonable periods of stability between changes so that new instrumentation can work its way into more or less routine use. Ideally, the development program should be underway on a continuing basis and new instruments not placed into use until significant advances have been made over a previous model and the new instrument thoroughly tested and proved. In laboratory applications, as contrasted with production, this is difficult to do. New instrumentation is never really thoroughly evaluated until it does get into routine use.

With the new transmission dynamometer described in the foregoing, it appears that we may have reached one of these desired periods of stability in design. The general features of this dynamometer appear to meet practically all of our current requirements. It is a compact light weight unit and can be designed in various sizes and capacities as required. It needs no sliprings. It can be used submerged, free flooded. Since it is relatively insensitive to attitude or accelerations it can be used for either steady state or transient tests, in waves, or maneuvering. It can be used with either indicating or graphic recording instrumentation. Although at the present time there are still some "bugs" to be worked out in the dynamometer, it appears that this can be done without changes in the basic design.

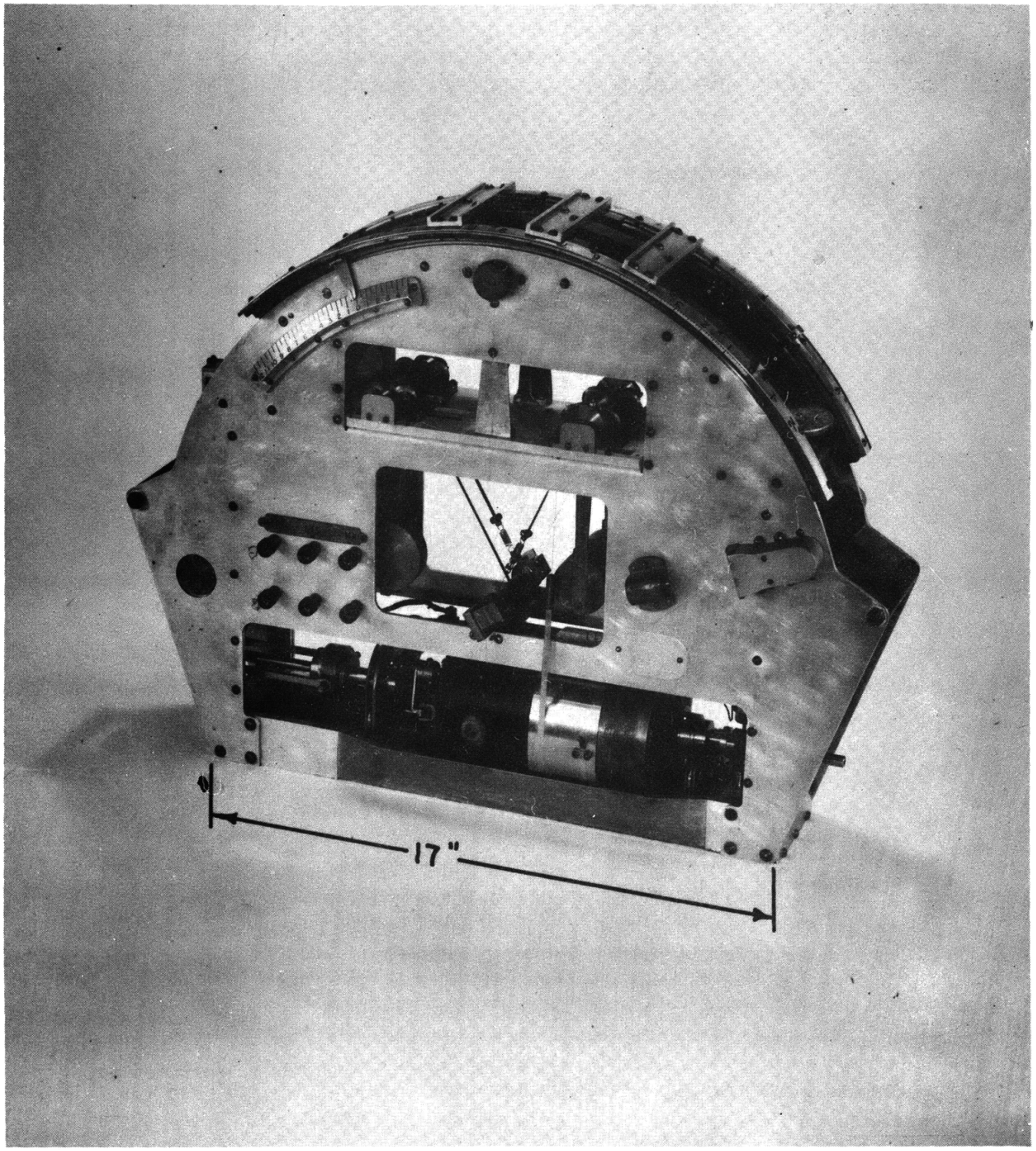
In the indicating and recording instrumentation now available, we have a very flexible system usable not only with the transmission dynamometer but also with other propeller dynamometers, force balances, and other transducers used in various model tests. This system is composed essentially of a number of "building-blocks" which together form an integrated measurement system but which are distinct enough so that modifications or improvements can be made in one portion of the system without necessarily affecting the other portions of the basic system design. The improvements most needed in the present instrumentation are along the lines of simplifying and improving the circuitry to increase stability and accuracy.

The obvious trend so far as future instrumentation developments are concerned is an increasing utilization of automatic data handling methods. Test data will be read out and logged automatically, in digital printed form for on-the-spot inspection and use, and on tape or punched cards for final analysis in a computer. There are several approaches which might be followed in applying these methods, and the planning of a suitable system requires careful study and consideration of many factors, from both the instrumentation and the test program viewpoints. For example, should the recording be made initially on magnetic tape, perforated paper tape, or IBM punch cards? Should a data point represent an average value for a test interval, or should data be sampled and read out rapidly and repeatedly during the interval? How long should the test interval be to assure a valid test? All of these and many other questions are currently being studied, and their answers will dictate the choice of methods to be used.

In our present instrumentation, we have a start toward an automatic data handling system. Shaft revolution and carriage speed data are now automatically read out and printed; in each case the printed reading is a true average value of the quantity over the test interval (usually 5 seconds). We can, without to much difficulty, also provide digital recording of torque and thrust data, by using analog-to-digital converters on the shafts of the balancing servo motors in the dynamometer indicators or recorders. The problem here, however, is in insuring that the quantities are steady enough over the test interval so that a single data point is accurate and representative. The more rapid fluctuations can be filtered and smoothed out in the servo amplifier system, but longer term variations over a test interval can be averaged only by some form of integrating system.

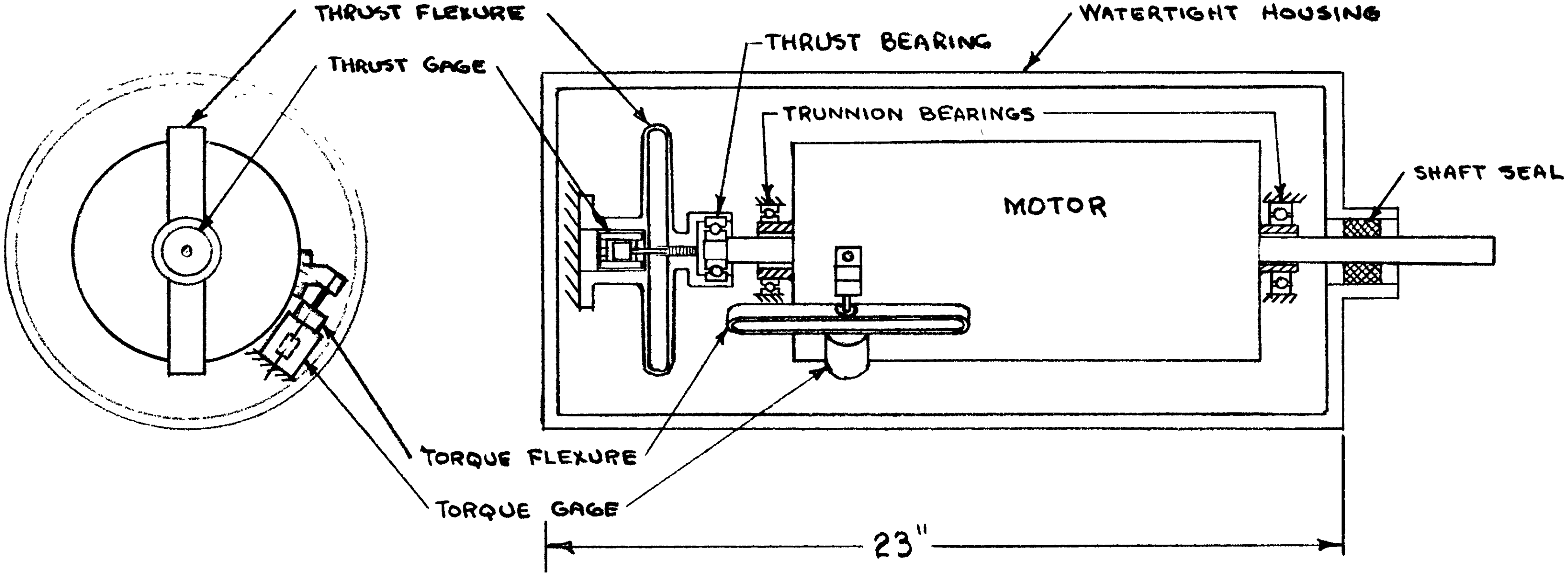
A project is now underway to incorporate a digital read-out system into the automatic digital indicators described earlier, and to provide the accessory equipment for scanning out ten channels of such data into an IBM card punch. This is intended for use with a multi-component balance in some of the stability test programs; the same system, of course, may be adapted to use in propulsion tests and can serve to evaluate its suitability for such tests.

Another trend in the future will inevitably be toward miniaturization of the instrumentation. Even now the size and weight of instruments required on the towing carriages constitutes a problem, and the problem could become more acute as requirements expand. Fortunately, however, developments in miniaturization are proceeding rapidly, in practically all components of the instrumentation system, so that we can hope to keep the size and weight problem under control.



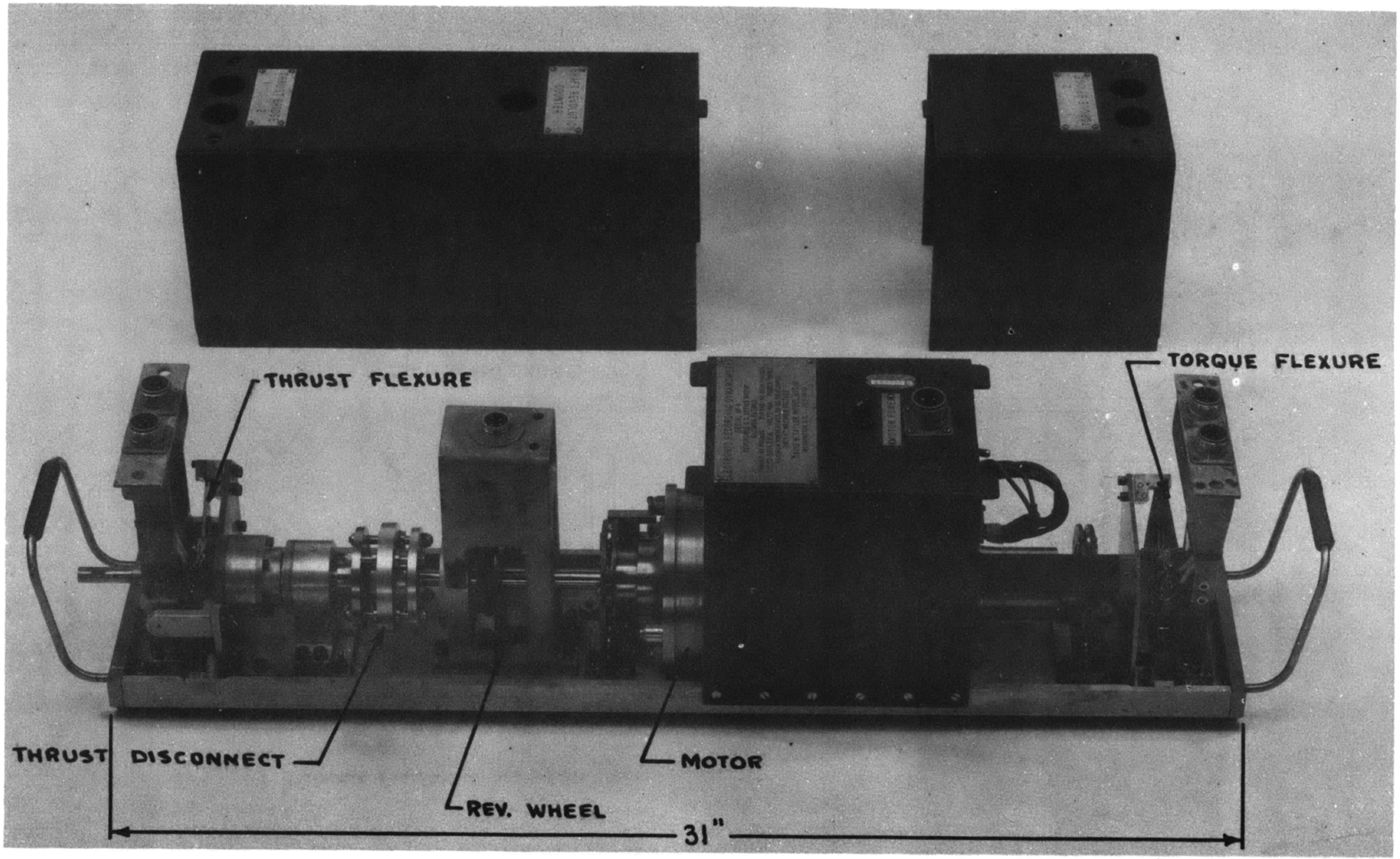
TMB 26538

Figure I - Pendulum Dynamometer



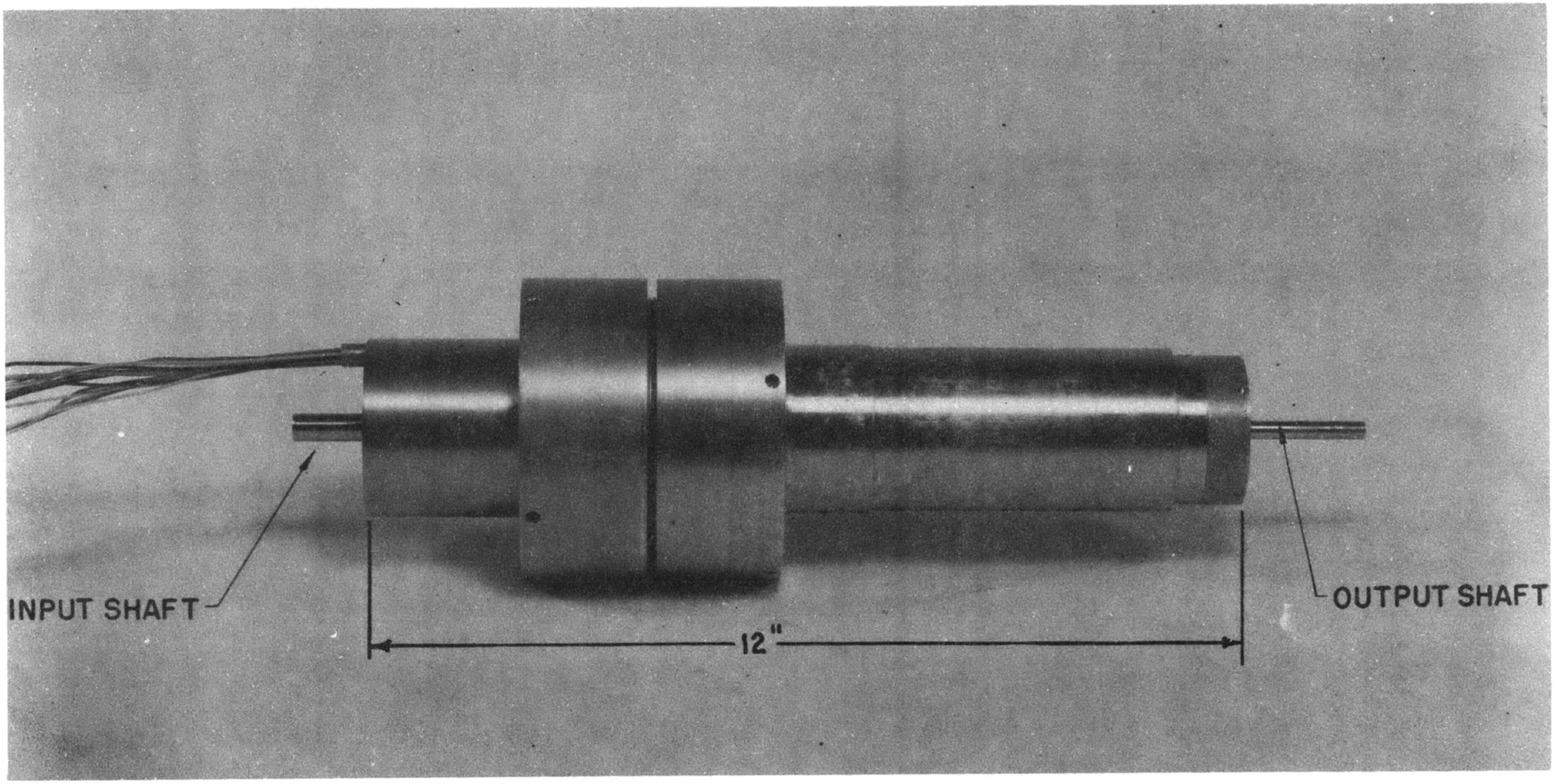
1/2 HP SUBMARINE DYNAMOMETER

FIGURE 2



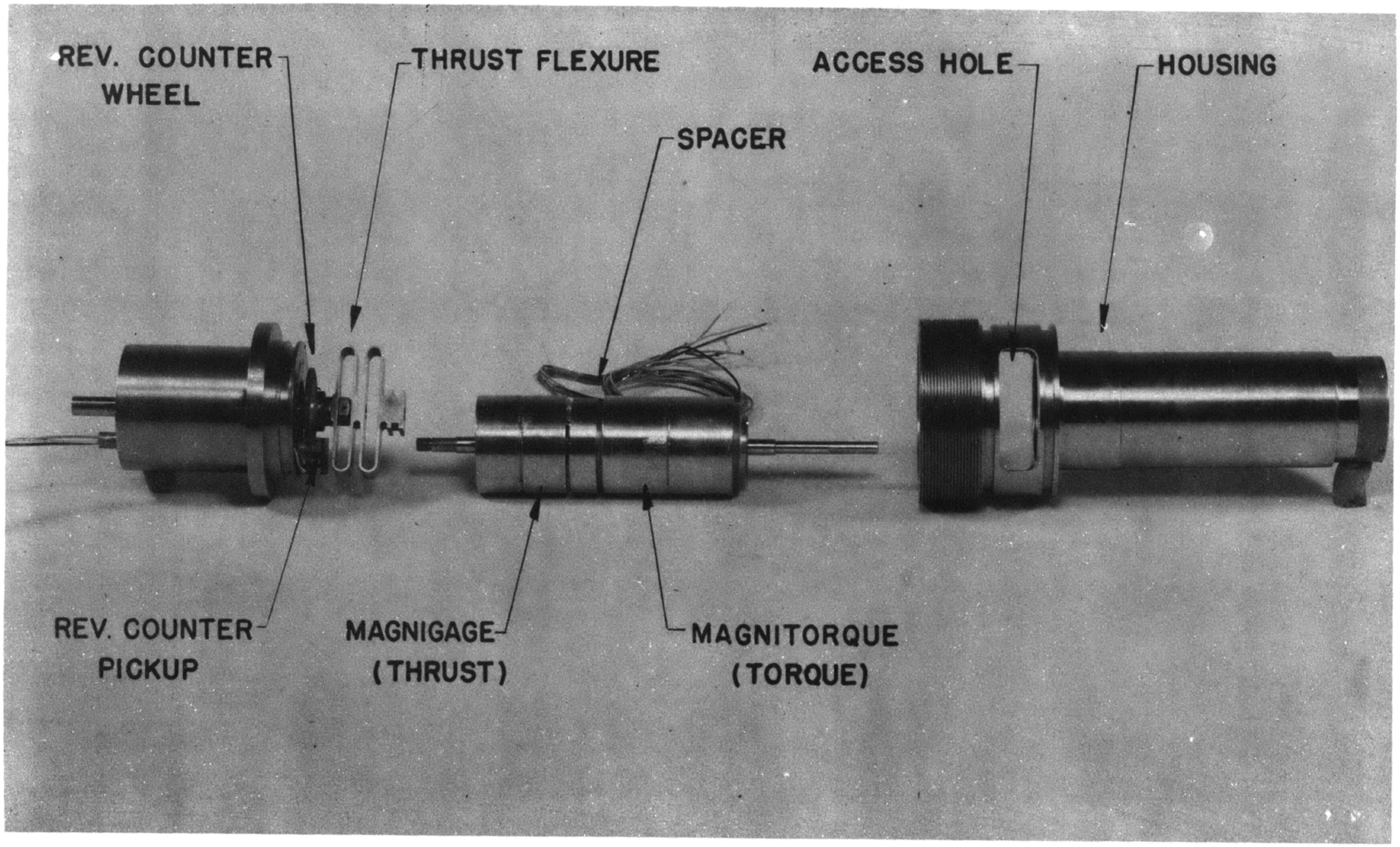
NP21-57643

Figure 3 - Strain Gage Dynamometer-Reaction Type



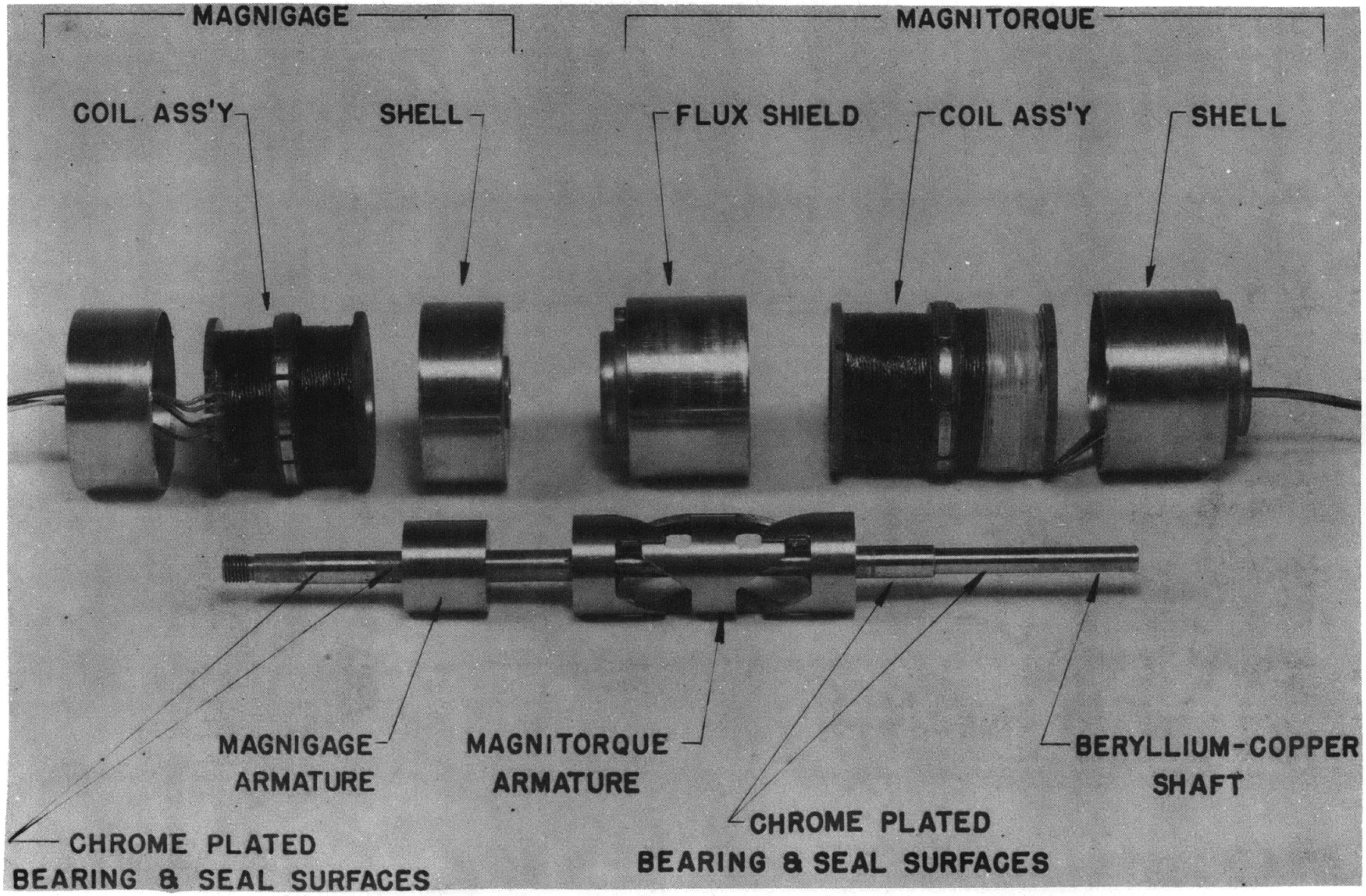
NP21-49434

Figure 4 - Submarine Transmission Dynamometer - Assembled



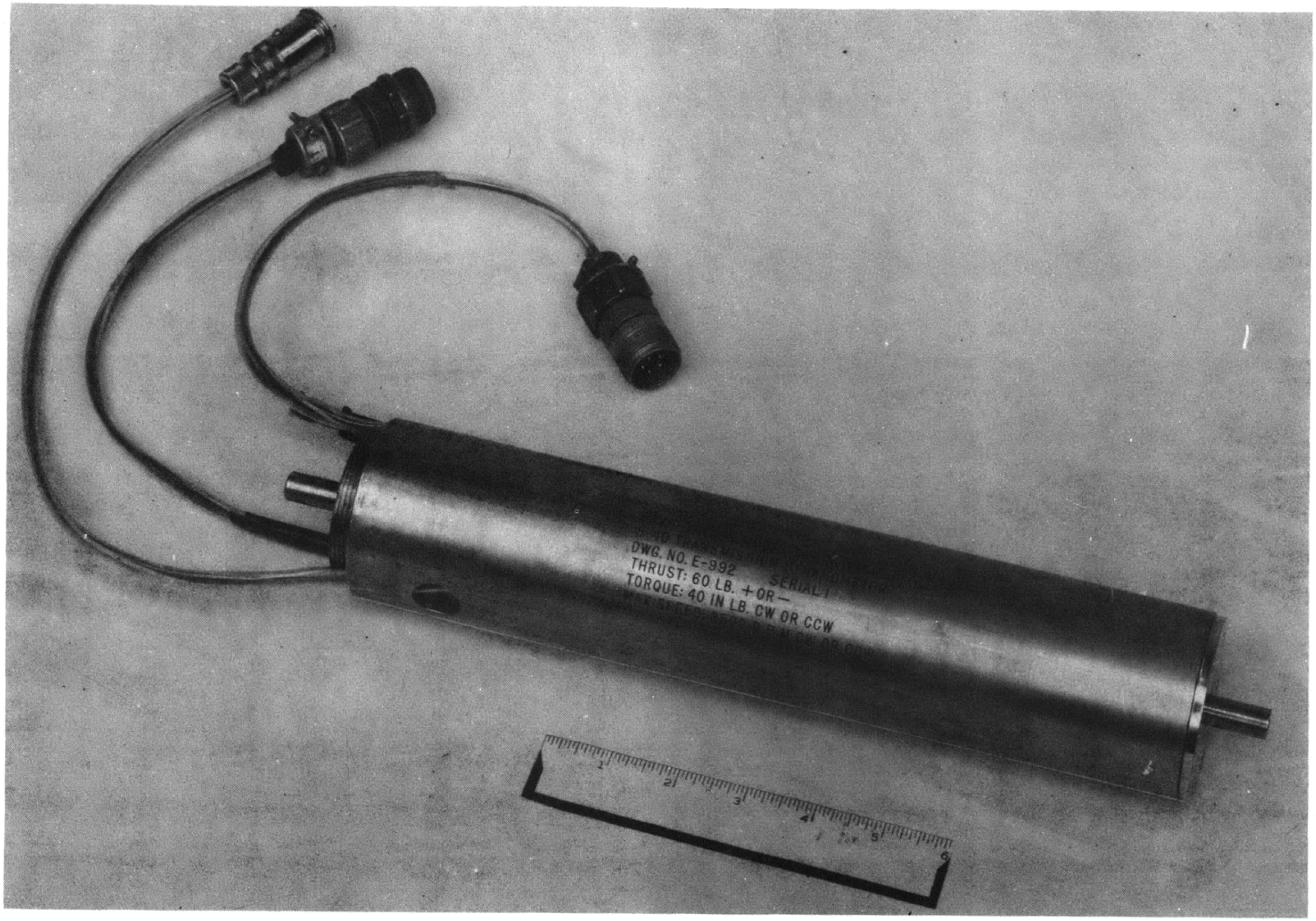
NP21-49436

Figure 5-Submarine Transmission Dynamometer - Disassembled



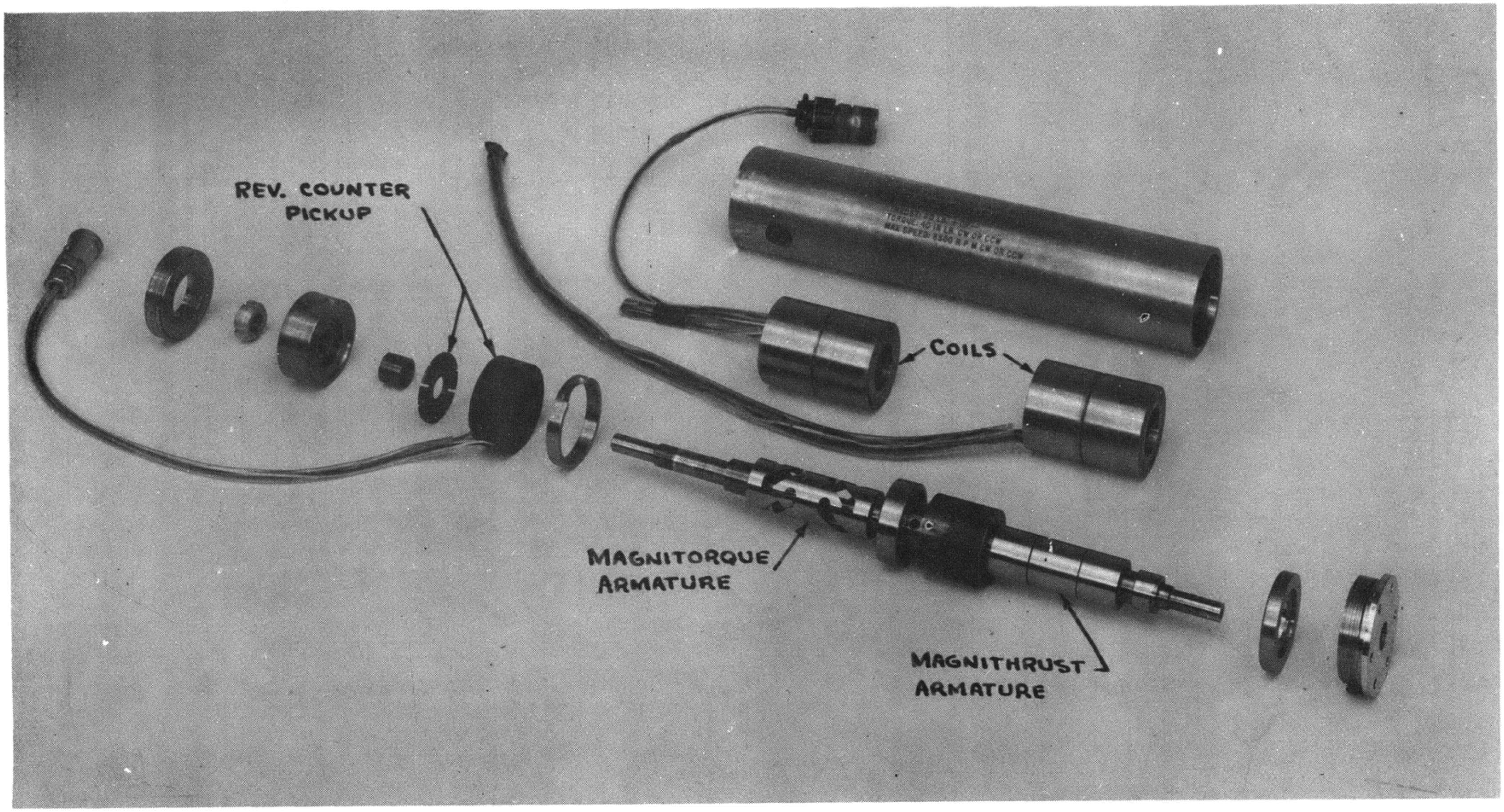
NP21-49437

Figure 6 - Submarine Transmission Dynamometer - Transducers



NP21-64339

Figure 7 - 5-40 Transmissions Dynamometer-Assembled



NP21-64338

Figure 8 - 5-40 Transmission Dynamometer-Exploded View

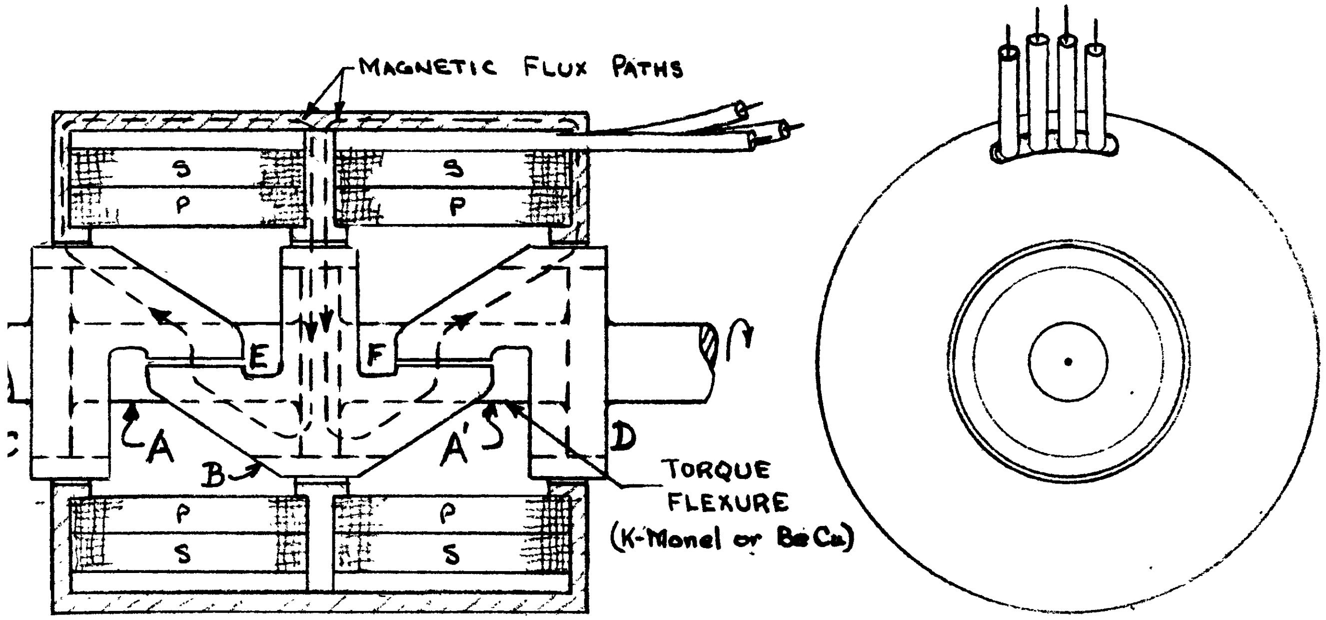


FIGURE 9 - TORQUE TRANSDUCER - "MAGNITORQUE"

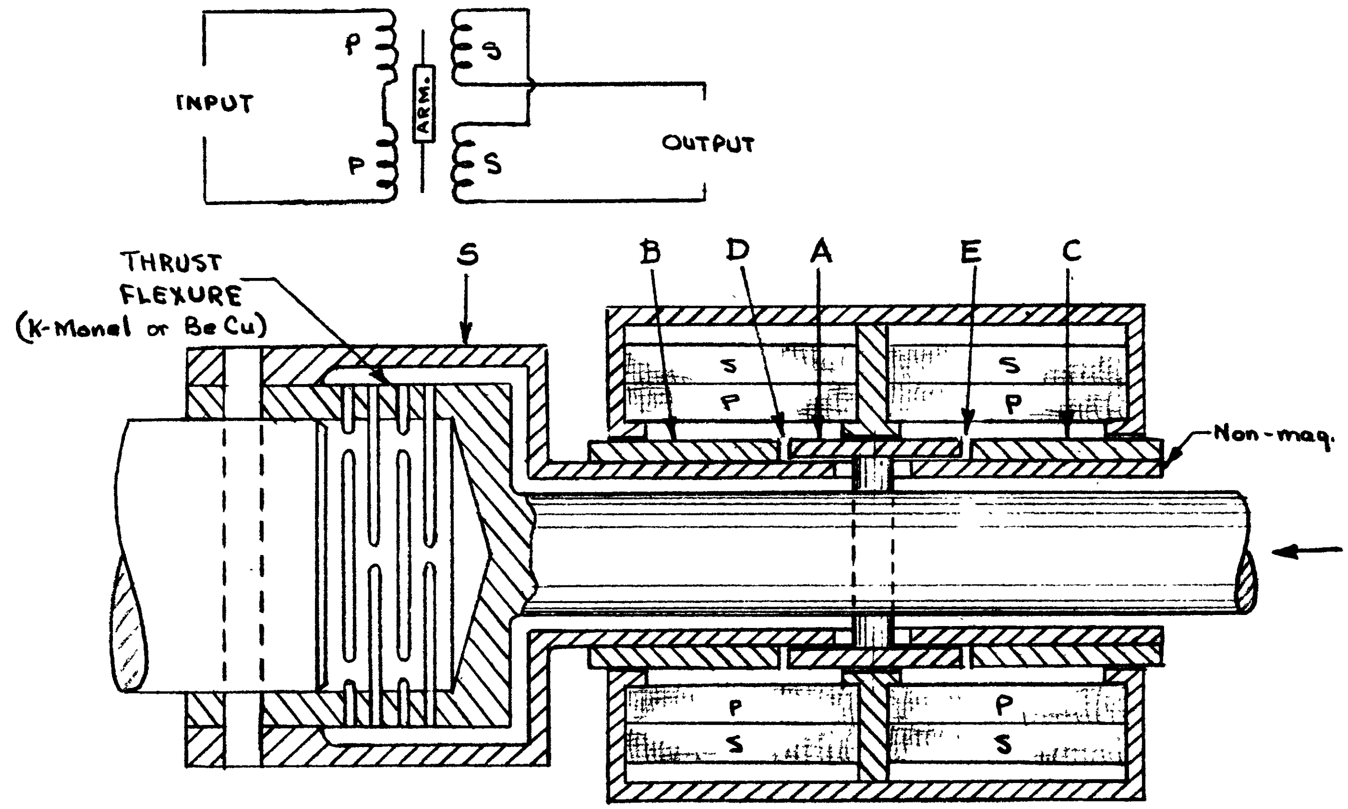
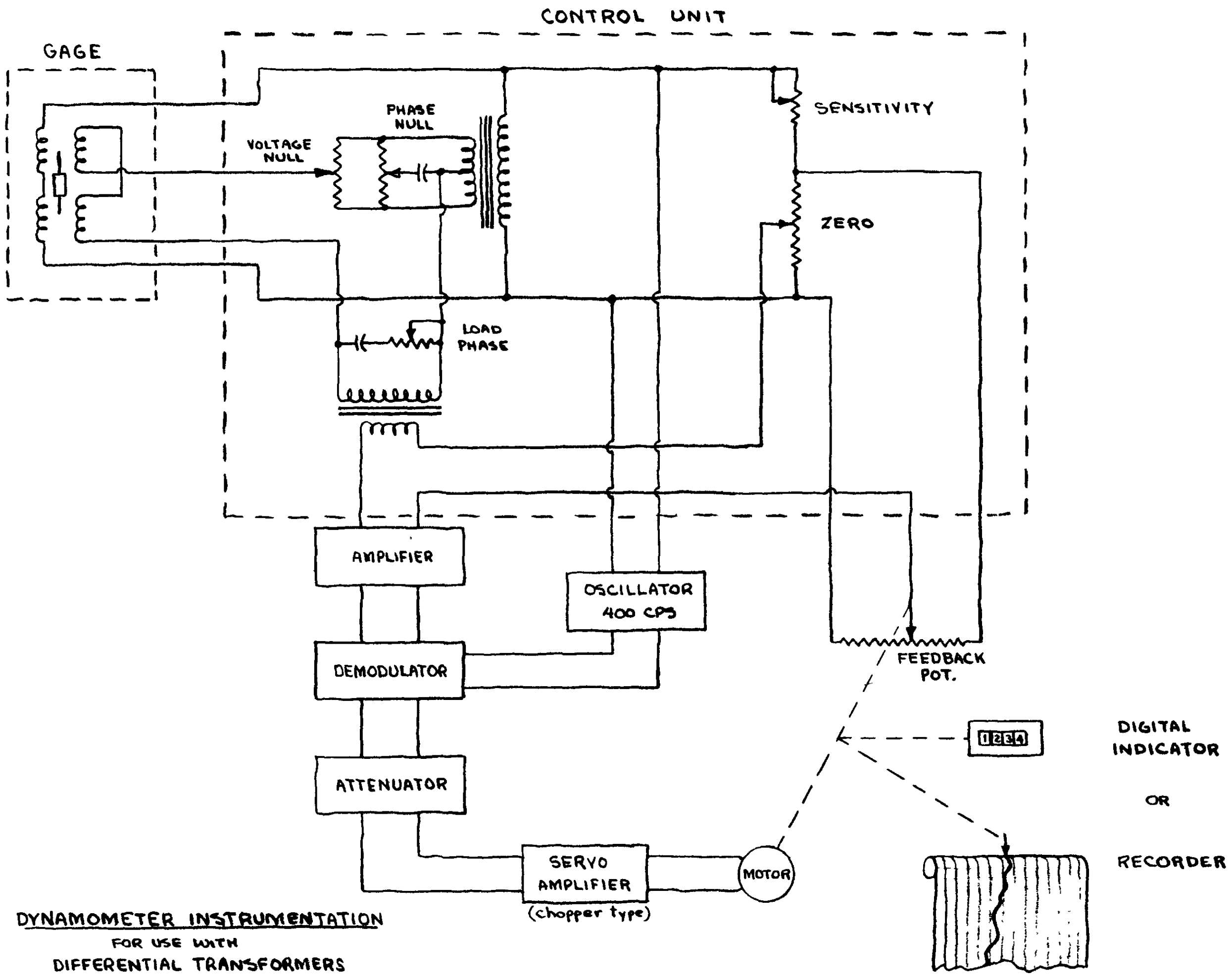
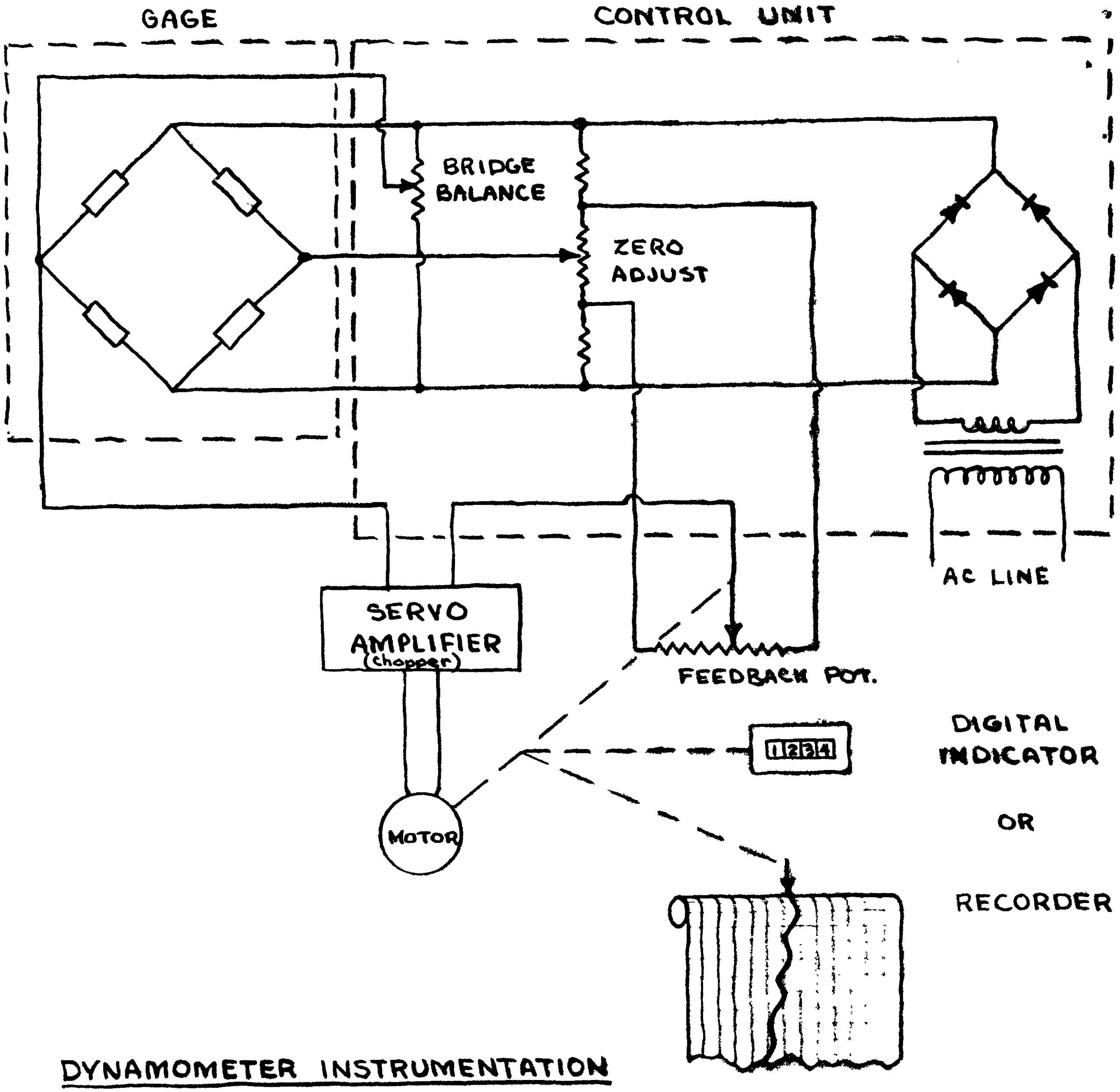


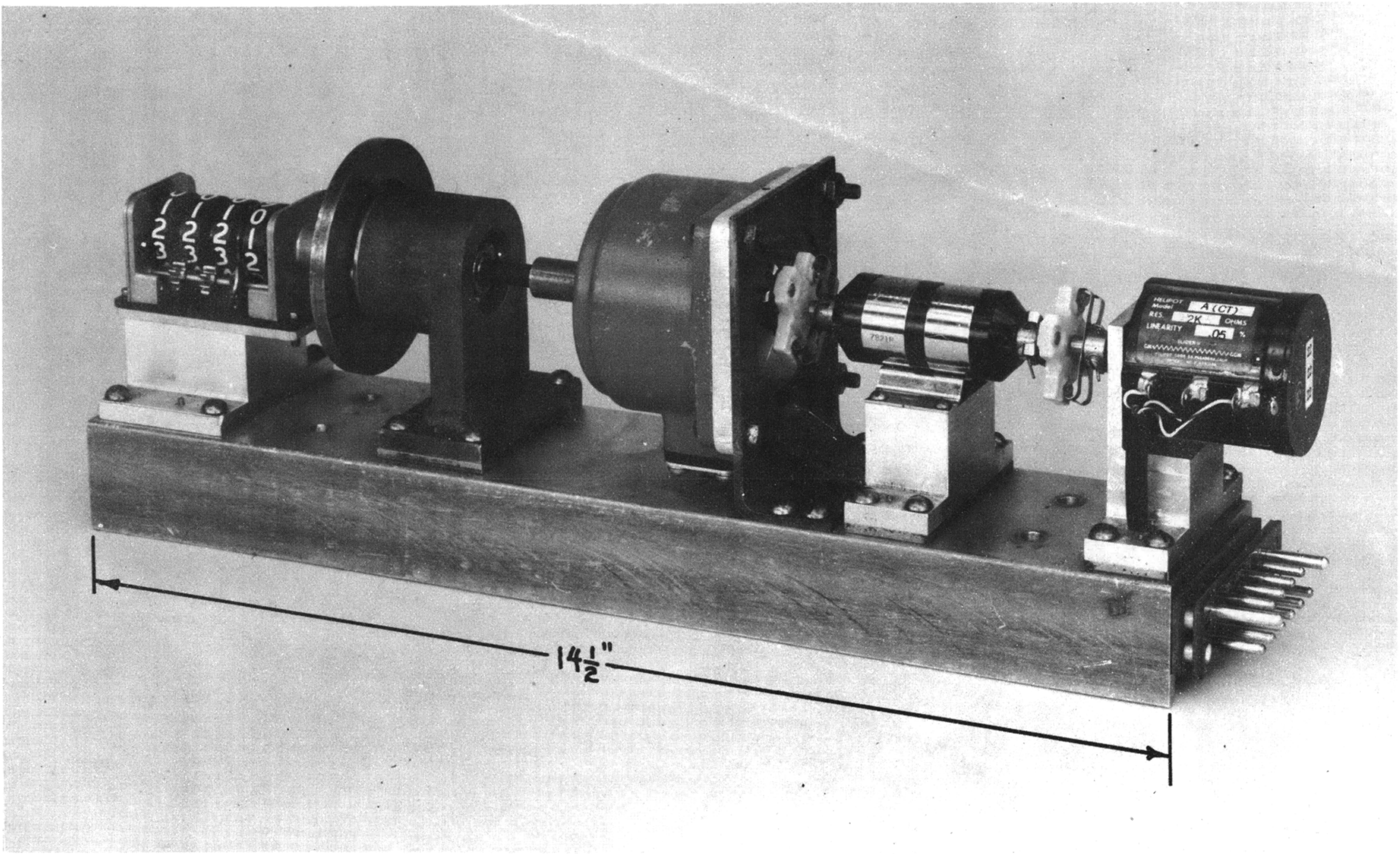
FIGURE 10 - THRUST TRANSDUCER - "MAGNITHRUST"



DYNAMOMETER INSTRUMENTATION
FOR USE WITH
DIFFERENTIAL TRANSFORMERS
FIGURE 11

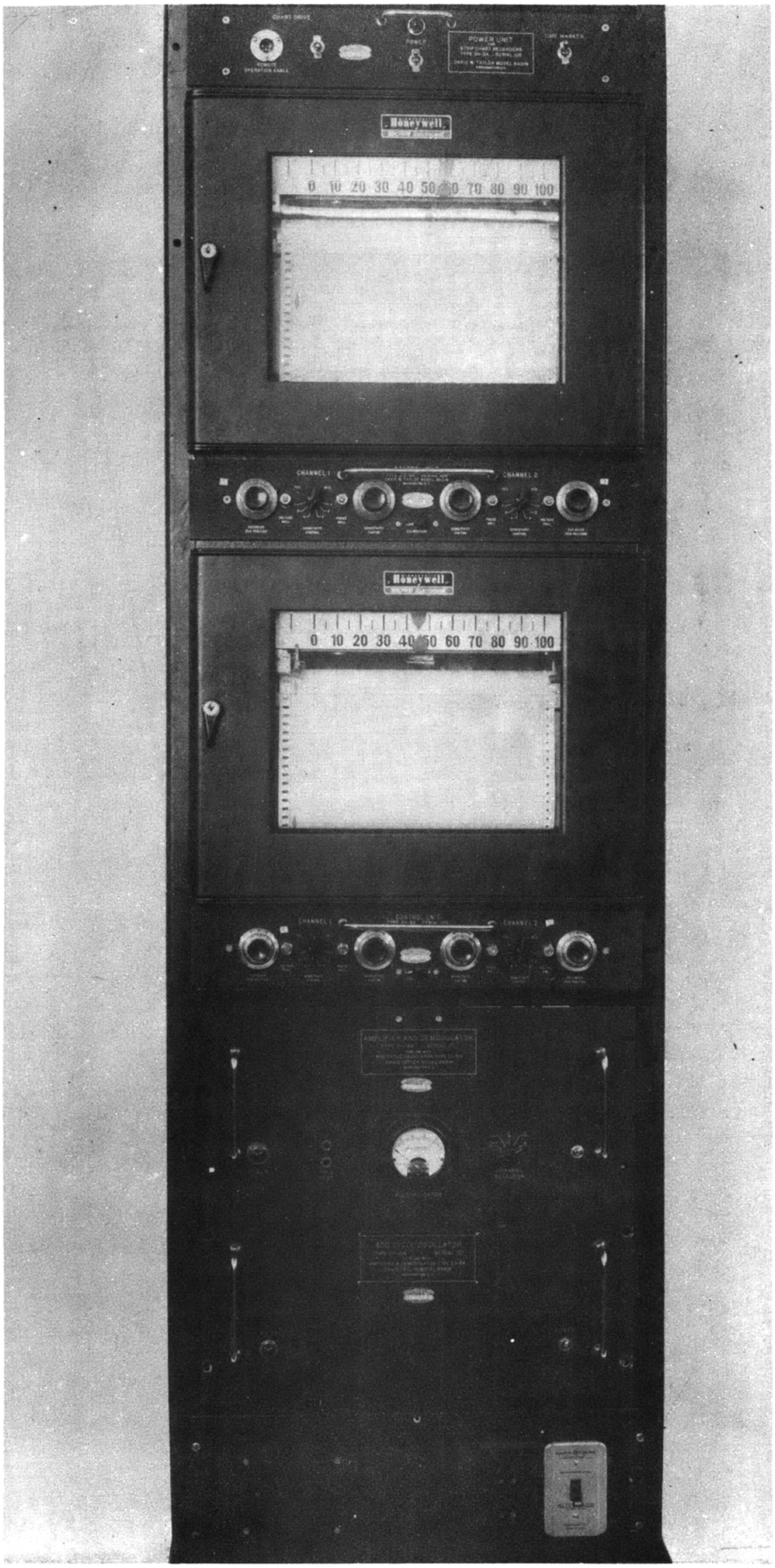


DYNAMOMETER INSTRUMENTATION
FOR USE WITH
STRAIN GAGE BRIDGES
FIGURE 12



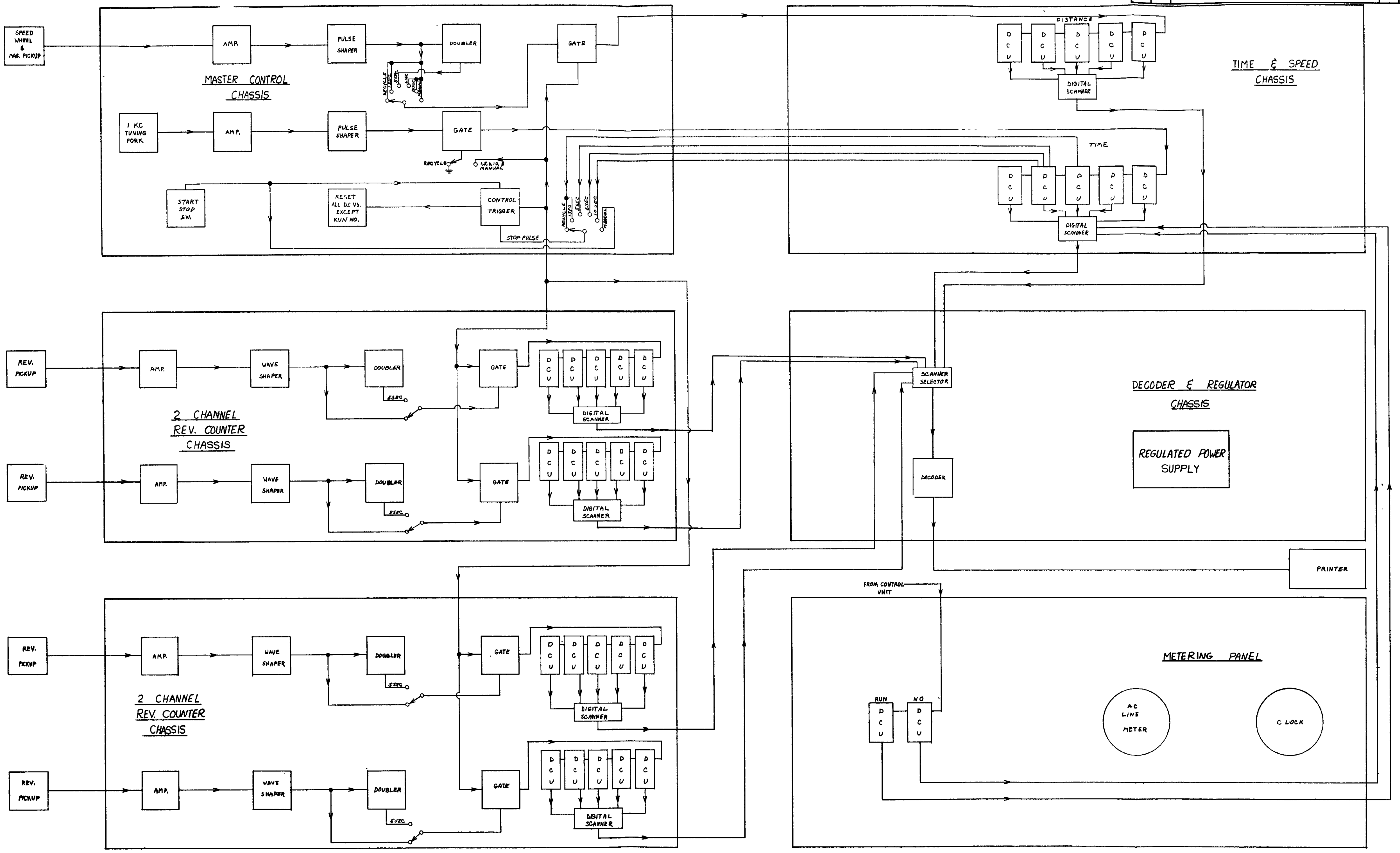
NP21-64340

Figure 13 - Digital Indicator



NP21-61700

Figure 14. 4 Channel Wide Scale Graphic Recorder



REVISIONS

REV.	ZONE	DESCRIPTION	BY	DATE	APPD.

PC. NO.	NAME OF PIECE	NO. REQD.	MATERIAL	MATL. SPEC	STD. NAVY STOCK NO.	SOURCE

LIST OF MATERIAL — QUANTITIES FOR ONE

TOLERANCES: DECIMAL DIMENSIONS AS SPECIFIED. MACHINED FRACTIONAL DIMENSIONS ± 1/64 INCH UNLESS OTHERWISE SPECIFIED.
FINISHES ARE RMS VALUES EXPRESSED IN MICROINCHES.

REFERENCES

DRAWN EES
CHECKED J.T.K.
REVIEWED
APPROVED
DATE
FOR DIRECTOR

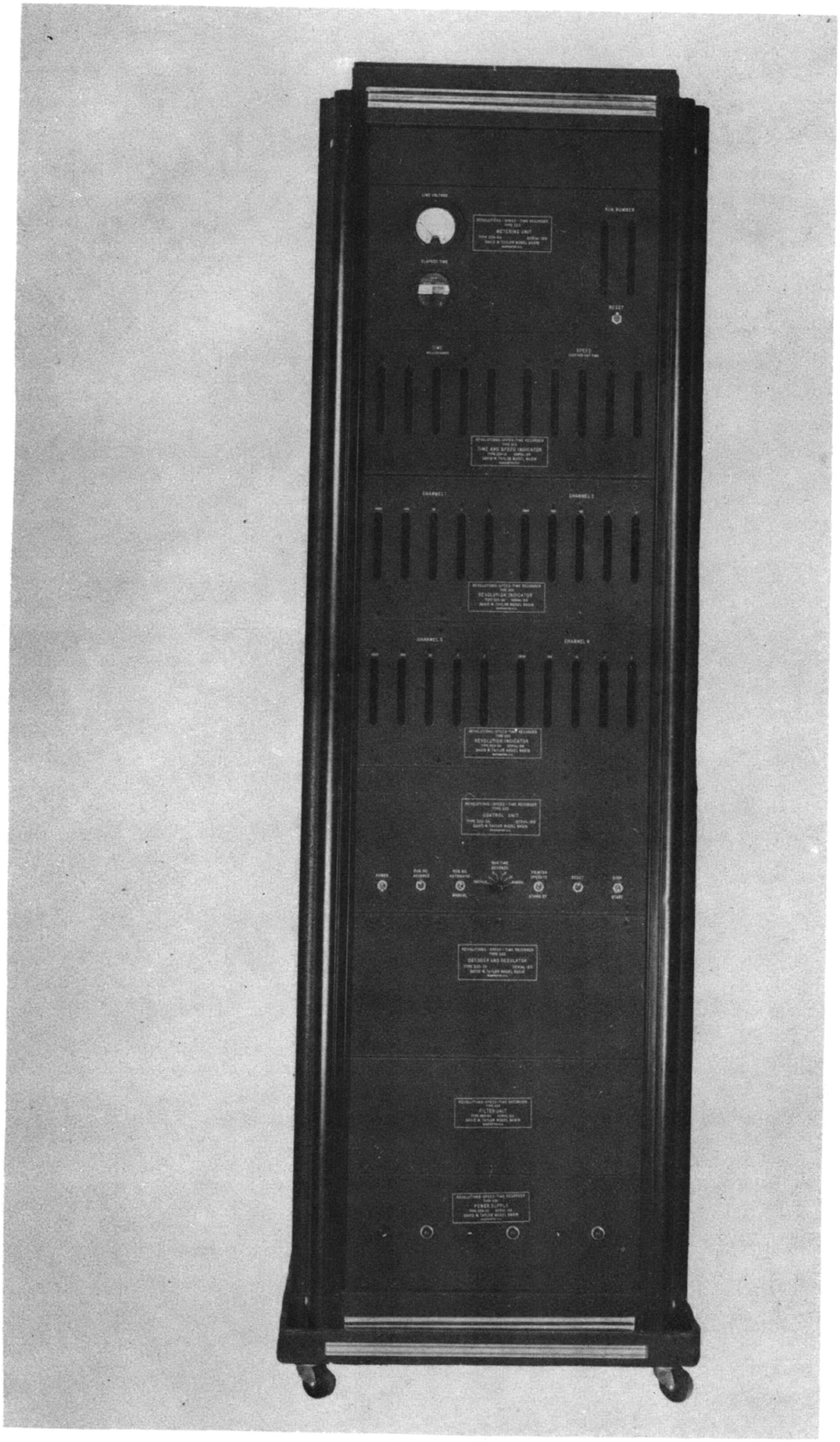
REVOLUTION-SPEED-TIME
RECORDER
TYPE 223

SCALE

NAVY DEPT. WASHINGTON, D. C.
DAVID W. TAYLOR MODEL BASIN

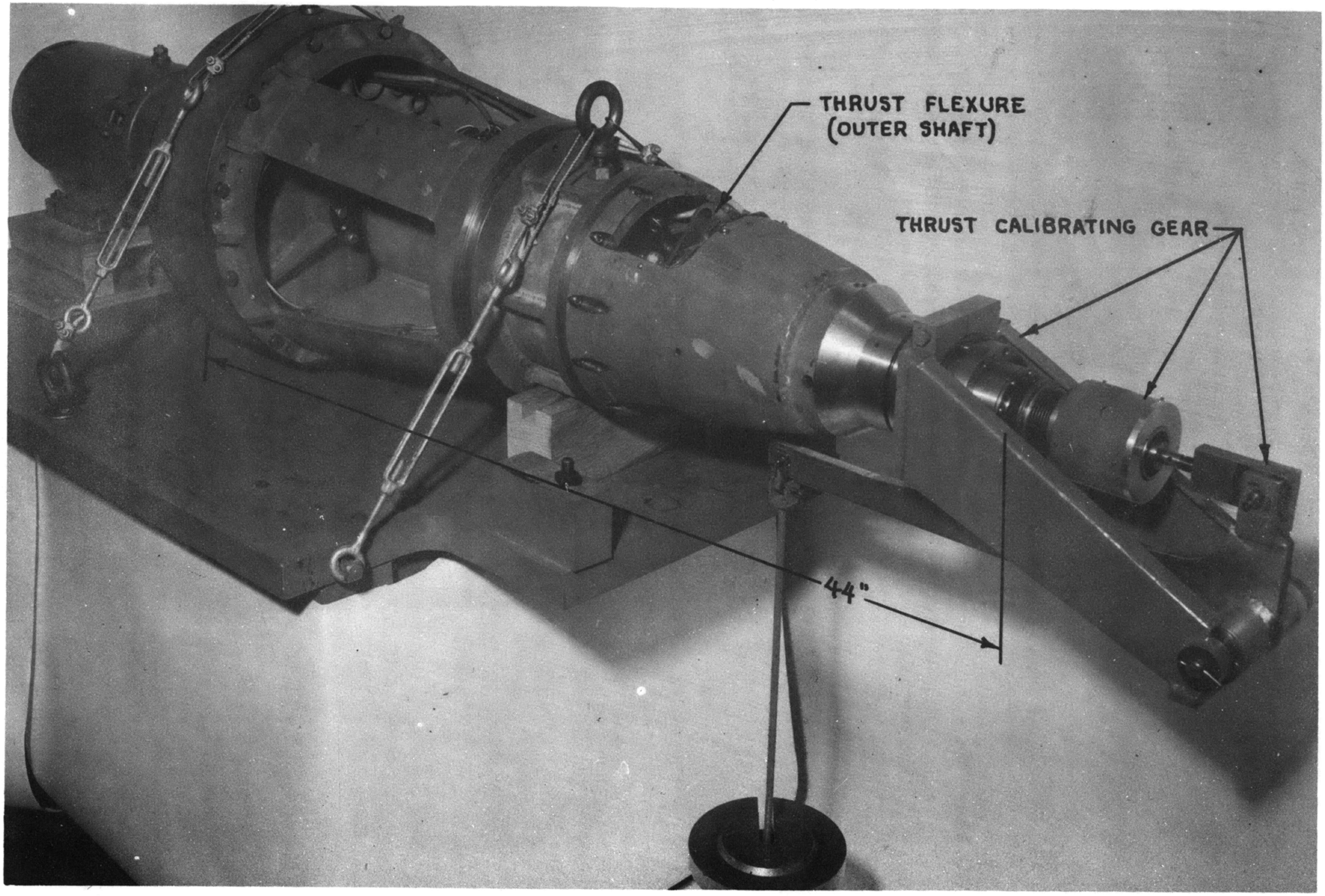
TAYLOR MODEL BASIN NUMBER E 1305
REV.
TOTAL NO. SHEETS

FIG. 15



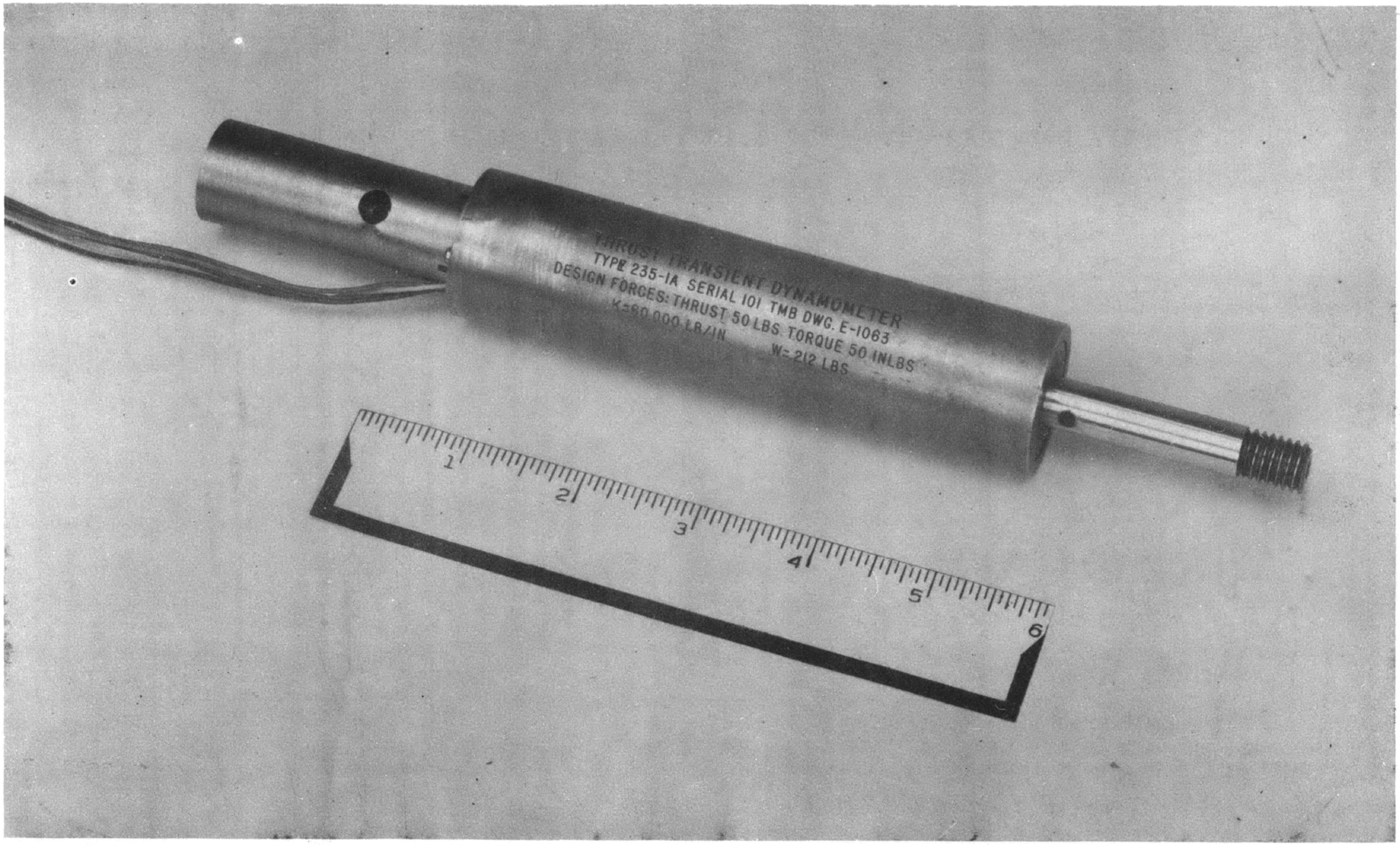
NP21-65032

Figure 16 Revolution - Speed - Time Recorder Instrument Rack



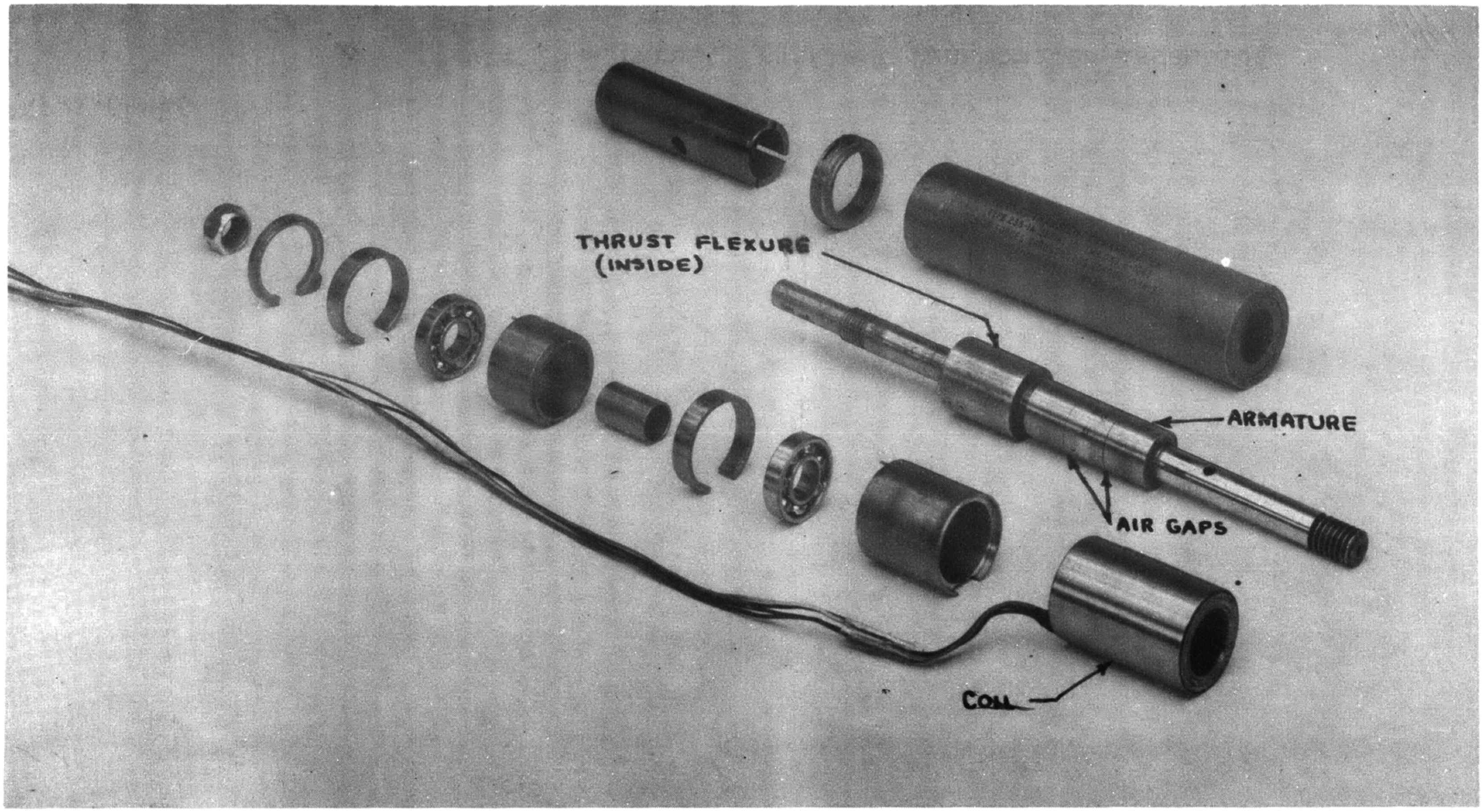
NP21-61695

Figure 17 - 300 HP. Contra-Rotating Torpedo Dynamometer
(with thrust calibrating apparatus)



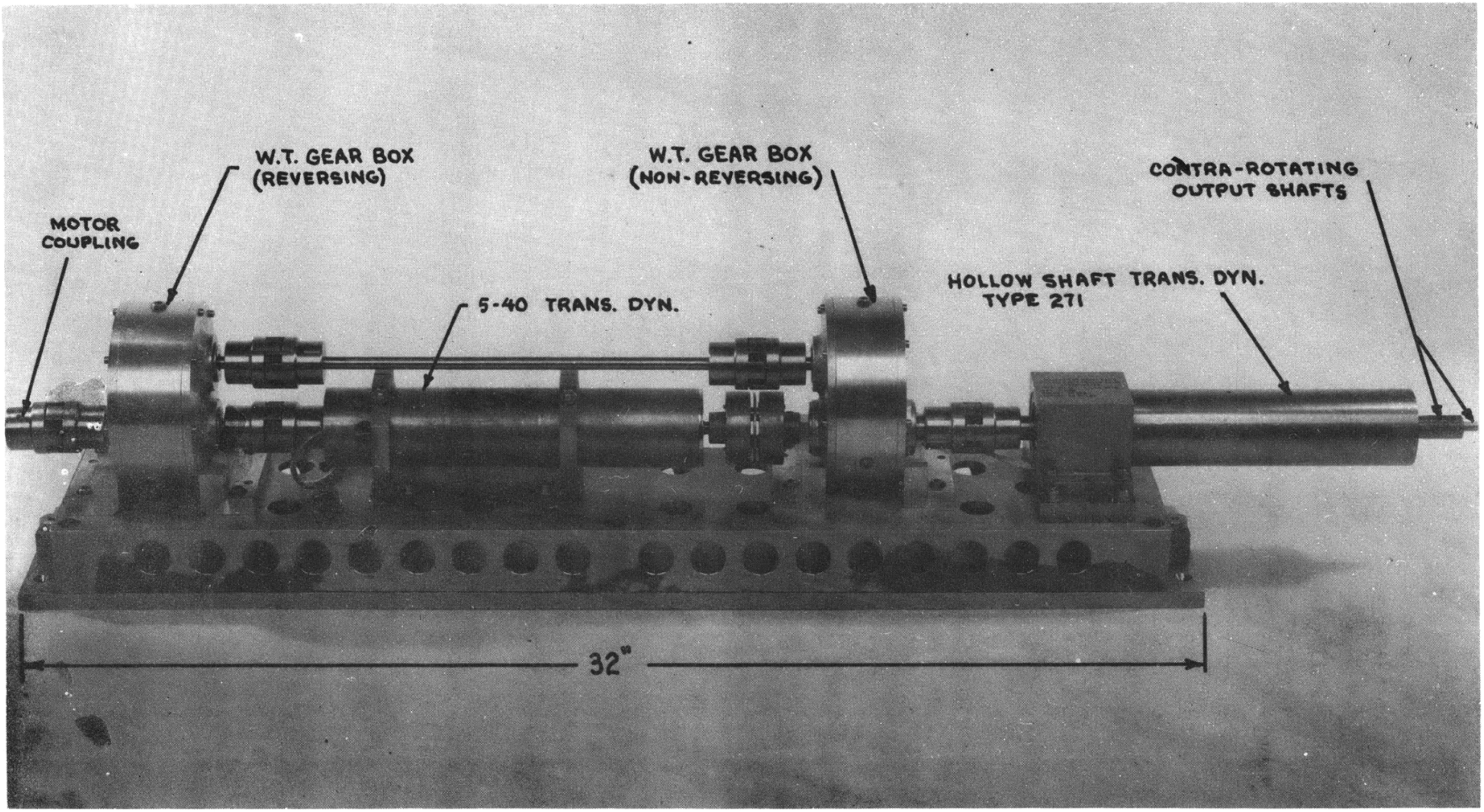
NP21-64346

Figure 18 - Thrust Transient Dynamometer-Assembled



XP21-64345

Figure 19 - Thrust Transient Dynamometer-Exploded View



NP21-65082

Figure 20 - Contra Rotating Propeller Dynamometer

David W. Taylor Model Basin. Rept. 1068.
PROPELLER DYNAMOMETER INSTRUMENTATION AT THE DAVID TAYLOR MODEL BASIN, by G.J. Norman [and others] July 1956. iii, 35 p. incl. figs. (Prepared for the American Towing Tank Conference, Washington, September 1956)
UNCLASSIFIED

A new transmission propeller dynamometer for ship model testing is described. It features differential transformer transducers of a special design, which permit the measurement of torque and thrust in the shaft without the use of sliprings. The associated instrumentation provides for either indicating or graphic recording of the torque and thrust quantities. Additional instrumentation provides for measurement and automatic tabulation on a digital printer of shaft revolution, carriage speed, and test time interval data.

1. Transmission dynamometers – David W. Taylor Model Basin
2. Transmission dynamometers – Instrumentation
3. Propellers (Marine) – Torque – Measurement
4. Propellers (Marine) – Thrust – Measurement
5. Ship models – Testing equipment

I. Norman, George J.
II. Wilson, Meredith W.
III. Bryant, Frederick B.

David W. Taylor Model Basin. Rept. 1068.
PROPELLER DYNAMOMETER INSTRUMENTATION AT THE DAVID TAYLOR MODEL BASIN, by G.J. Norman [and others] July 1956. iii, 35 p. incl. figs. (Prepared for the American Towing Tank Conference, Washington, September 1956)
UNCLASSIFIED

A new transmission propeller dynamometer for ship model testing is described. It features differential transformer transducers of a special design, which permit the measurement of torque and thrust in the shaft without the use of sliprings. The associated instrumentation provides for either indicating or graphic recording of the torque and thrust quantities. Additional instrumentation provides for measurement and automatic tabulation on a digital printer of shaft revolution, carriage speed, and test time interval data.

1. Transmission dynamometers – David W. Taylor Model Basin
2. Transmission dynamometers – Instrumentation
3. Propellers (Marine) – Torque – Measurement
4. Propellers (Marine) – Thrust – Measurement
5. Ship models – Testing equipment

I. Norman, George J.
II. Wilson, Meredith W.
III. Bryant, Frederick B.

David W. Taylor Model Basin. Rept. 1068.
PROPELLER DYNAMOMETER INSTRUMENTATION AT THE DAVID TAYLOR MODEL BASIN, by G.J. Norman [and others] July 1956. iii, 35 p. incl. figs. (Prepared for the American Towing Tank Conference, Washington, September 1956)
UNCLASSIFIED

A new transmission propeller dynamometer for ship model testing is described. It features differential transformer transducers of a special design, which permit the measurement of torque and thrust in the shaft without the use of sliprings. The associated instrumentation provides for either indicating or graphic recording of the torque and thrust quantities. Additional instrumentation provides for measurement and automatic tabulation on a digital printer of shaft revolution, carriage speed, and test time interval data.

1. Transmission dynamometers – David W. Taylor Model Basin
2. Transmission dynamometers – Instrumentation
3. Propellers (Marine) – Torque – Measurement
4. Propellers (Marine) – Thrust – Measurement
5. Ship models – Testing equipment

I. Norman, George J.
II. Wilson, Meredith W.
III. Bryant, Frederick B.

David W. Taylor Model Basin. Rept. 1068.
PROPELLER DYNAMOMETER INSTRUMENTATION AT THE DAVID TAYLOR MODEL BASIN, by G.J. Norman [and others] July 1956. iii, 35 p. incl. figs. (Prepared for the American Towing Tank Conference, Washington, September 1956)
UNCLASSIFIED

A new transmission propeller dynamometer for ship model testing is described. It features differential transformer transducers of a special design, which permit the measurement of torque and thrust in the shaft without the use of sliprings. The associated instrumentation provides for either indicating or graphic recording of the torque and thrust quantities. Additional instrumentation provides for measurement and automatic tabulation on a digital printer of shaft revolution, carriage speed, and test time interval data.

1. Transmission dynamometers – David W. Taylor Model Basin
2. Transmission dynamometers – Instrumentation
3. Propellers (Marine) – Torque – Measurement
4. Propellers (Marine) – Thrust – Measurement
5. Ship models – Testing equipment

I. Norman, George J.
II. Wilson, Meredith W.
III. Bryant, Frederick B.

The paper also describes briefly other propeller dynamometers designed and developed, leading up to the present transmission dynamometer design.

The paper also describes briefly other propeller dynamometers designed and developed, leading up to the present transmission dynamometer design.

The paper also describes briefly other propeller dynamometers designed and developed, leading up to the present transmission dynamometer design.

The paper also describes briefly other propeller dynamometers designed and developed, leading up to the present transmission dynamometer design.

David W. Taylor Model Basin. Rept. 1068.
PROPELLER DYNAMOMETER INSTRUMENTATION AT THE DAVID TAYLOR MODEL BASIN, by G.J. Norman [and others] July 1956. iii, 35 p. incl. figs. (Prepared for the American Towing Tank Conference, Washington, September 1956)
UNCLASSIFIED

A new transmission propeller dynamometer for ship model testing is described. It features differential transformer transducers of a special design, which permit the measurement of torque and thrust in the shaft without the use of sliprings. The associated instrumentation provides for either indicating or graphic recording of the torque and thrust quantities. Additional instrumentation provides for measurement and automatic tabulation on a digital printer of shaft revolution, carriage speed, and test time interval data.

1. Transmission dynamometers – David W. Taylor Model Basin
2. Transmission dynamometers – Instrumentation
3. Propellers (Marine) – Torque – Measurement
4. Propellers (Marine) – Thrust – Measurement
5. Ship models – Testing equipment
I. Norman, George J.
II. Wilson, Meredith W.
III. Bryant, Frederick B.

David W. Taylor Model Basin. Rept. 1068.
PROPELLER DYNAMOMETER INSTRUMENTATION AT THE DAVID TAYLOR MODEL BASIN, by G.J. Norman [and others] July 1956. iii, 35 p. incl. figs. (Prepared for the American Towing Tank Conference, Washington, September 1956)
UNCLASSIFIED

A new transmission propeller dynamometer for ship model testing is described. It features differential transformer transducers of a special design, which permit the measurement of torque and thrust in the shaft without the use of sliprings. The associated instrumentation provides for either indicating or graphic recording of the torque and thrust quantities. Additional instrumentation provides for measurement and automatic tabulation on a digital printer of shaft revolution, carriage speed, and test time interval data.

1. Transmission dynamometers – David W. Taylor Model Basin
2. Transmission dynamometers – Instrumentation
3. Propellers (Marine) – Torque – Measurement
4. Propellers (Marine) – Thrust – Measurement
5. Ship models – Testing equipment
I. Norman, George J.
II. Wilson, Meredith W.
III. Bryant, Frederick B.

David W. Taylor Model Basin. Rept. 1068.
PROPELLER DYNAMOMETER INSTRUMENTATION AT THE DAVID TAYLOR MODEL BASIN, by G.J. Norman [and others] July 1956. iii, 35 p. incl. figs. (Prepared for the American Towing Tank Conference, Washington, September 1956)
UNCLASSIFIED

A new transmission propeller dynamometer for ship model testing is described. It features differential transformer transducers of a special design, which permit the measurement of torque and thrust in the shaft without the use of sliprings. The associated instrumentation provides for either indicating or graphic recording of the torque and thrust quantities. Additional instrumentation provides for measurement and automatic tabulation on a digital printer of shaft revolution, carriage speed, and test time interval data.

1. Transmission dynamometers – David W. Taylor Model Basin
2. Transmission dynamometers – Instrumentation
3. Propellers (Marine) – Torque – Measurement
4. Propellers (Marine) – Thrust – Measurement
5. Ship models – Testing equipment
I. Norman, George J.
II. Wilson, Meredith W.
III. Bryant, Frederick B.

David W. Taylor Model Basin. Rept. 1068.
PROPELLER DYNAMOMETER INSTRUMENTATION AT THE DAVID TAYLOR MODEL BASIN, by G.J. Norman [and others] July 1956. iii, 35 p. incl. figs. (Prepared for the American Towing Tank Conference, Washington, September 1956)
UNCLASSIFIED

A new transmission propeller dynamometer for ship model testing is described. It features differential transformer transducers of a special design, which permit the measurement of torque and thrust in the shaft without the use of sliprings. The associated instrumentation provides for either indicating or graphic recording of the torque and thrust quantities. Additional instrumentation provides for measurement and automatic tabulation on a digital printer of shaft revolution, carriage speed, and test time interval data.

1. Transmission dynamometers – David W. Taylor Model Basin
2. Transmission dynamometers – Instrumentation
3. Propellers (Marine) – Torque – Measurement
4. Propellers (Marine) – Thrust – Measurement
5. Ship models – Testing equipment
I. Norman, George J.
II. Wilson, Meredith W.
III. Bryant, Frederick B.

The paper also describes briefly other propeller dynamometers designed and developed, leading up to the present transmission dynamometer design.

The paper also describes briefly other propeller dynamometers designed and developed, leading up to the present transmission dynamometer design.

The paper also describes briefly other propeller dynamometers designed and developed, leading up to the present transmission dynamometer design.

The paper also describes briefly other propeller dynamometers designed and developed, leading up to the present transmission dynamometer design.