GALVANOMETERS AND DYNAMOMETERS

L&N

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1946

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Central Staff
R.C. Swanson

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LEEDS & NORTHRUP COMPANY
4907 STENTON AVENUE
PHILADELPHIA 44, PA.

GALVANOMETERS AND DYNAMOMETERS

CATALOG ED

1946

CONTENTS

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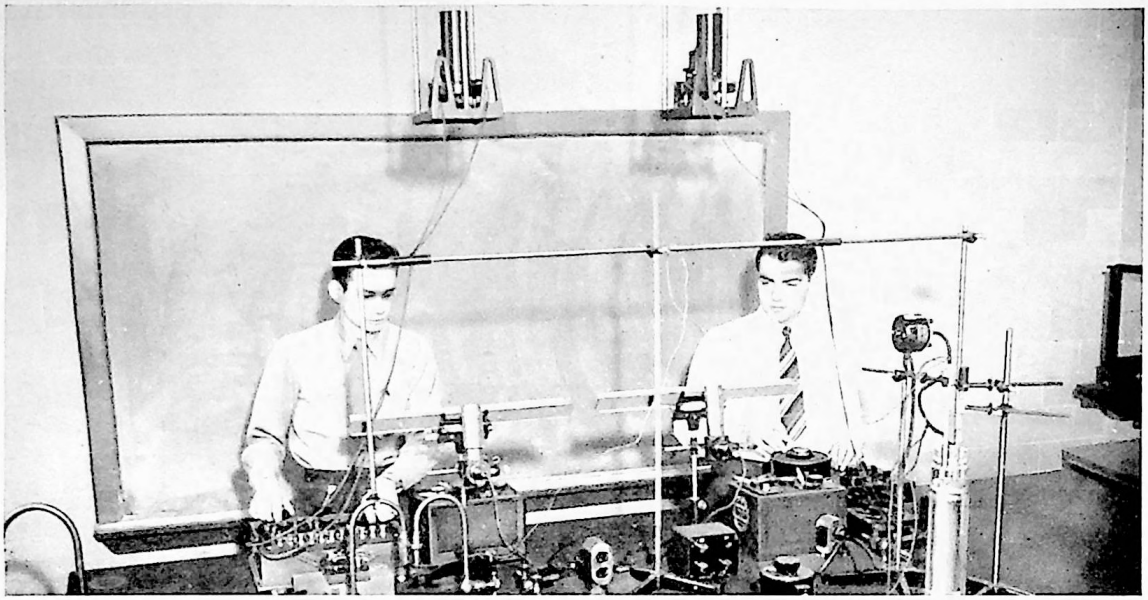
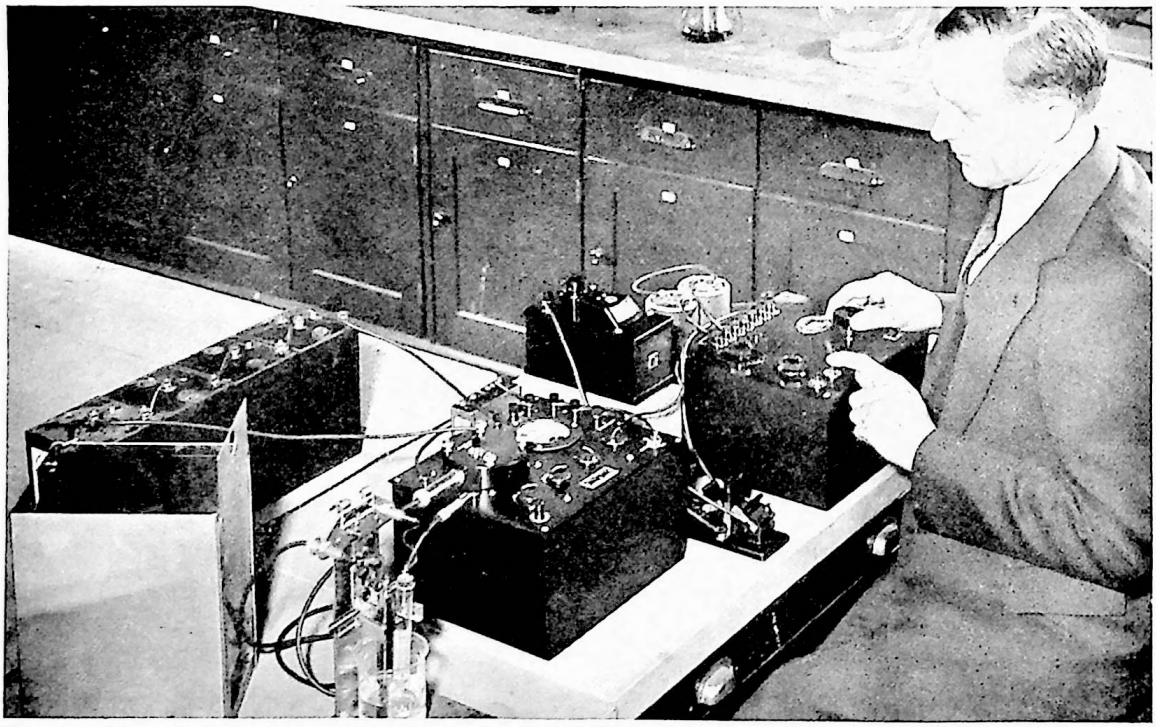
HEAT-TREATING FURNACES
4907 STENTON AVENUE, PHILADELPHIA 44, PA., U.S.A.

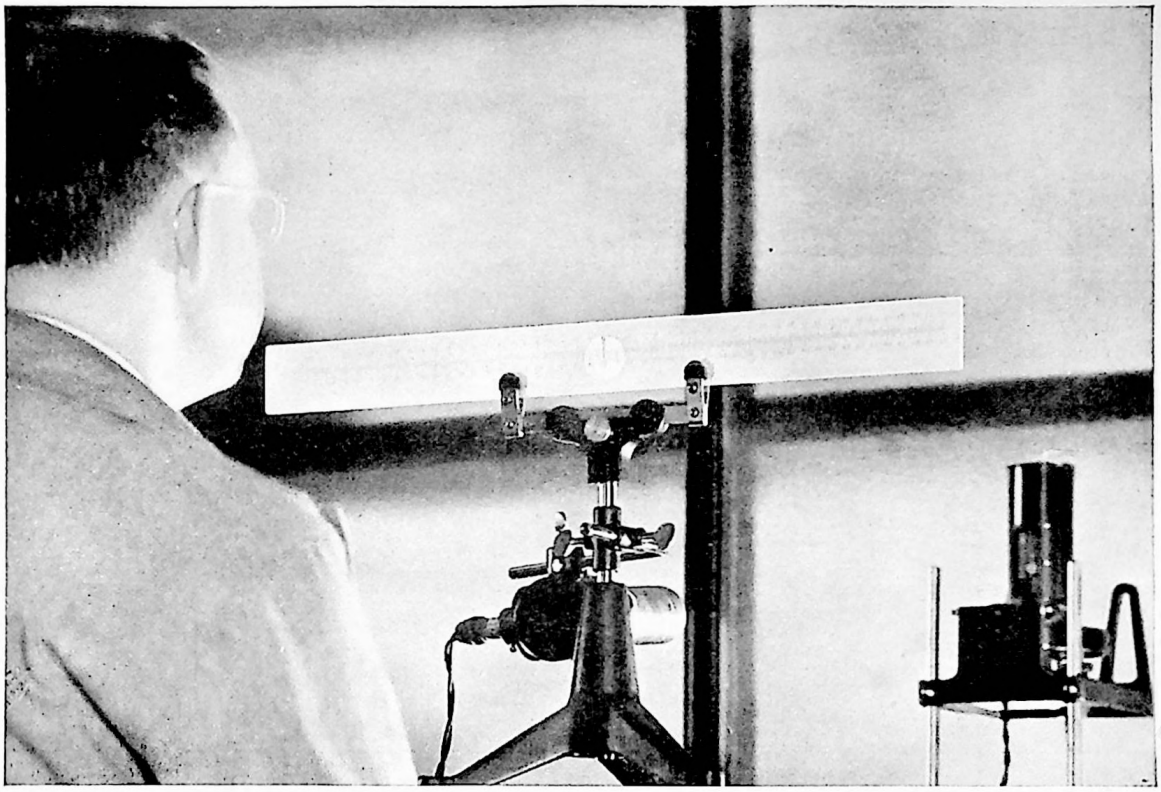
50-346



This convenient arrangement for calibration of thermocouples employs two high-sensitivity reflecting galvanometers, each with a 2100 Lamp and Scale. Thermocouple emf is checked at the right with a Type K-2 Potentiometer while simultaneously, at the left, the resistance of a certified resistance thermometer is measured with a Mueller Bridge. These galvanometers are ideal for use in research, educational or other laboratories and test rooms where great precision is required.



By using a Thermionic Amplifier and a short period galvanometer, any potentiometer of suitable range can be adapted to the measurement of potentials in high-resistance circuits. For many glass electrode applications where extremely high sensitivity is unnecessary, an ordinary pointer-type galvanometer, such as the 2310 (used above) is adequate. Still higher sensitivity can be obtained with a 2420 Enclosed Lamp-and-Scale Galvanometer or with a 2500 Type R Reflecting Galvanometer.



Among standard L&N galvanometers and dynamometers, you can almost always find the instrument you need, as a balance-point detector or for calibrated deflection measurements.

Above: 2500 Type R Reflecting Galvanometer (page 10) mounted on 2147 Wall or Table Bracket (page 25), and 2100 Lamp-and-Scale Reading Device (page 26).

A COMPREHENSIVE LINE OF GALVANOMETERS FOR RESEARCH, TEACHING AND TESTING

With the progressive broadening of scientific research, and the extension of scientific methods to routine testing—the work of chemists, physicists and electrical engineers has resulted in a demand for laboratory instruments of many different types and models. It is the original and continuing purpose of Leeds & Northrup to meet these needs of science. As a result, our once comparatively limited line of standards, galvanometers, bridges, potentiometers, etc.—at one time adequate for scientific research—has been progressively expanded until it now comprises a comprehensive selection of laboratory-type and automatic instruments for research, teaching and testing.*

The galvanometers, dynamometers and accessory equipment listed on the following pages offer a broad choice of models for general and specific use. Each instrument described is adapted to the latest needs of the research scientist, the student, or the man who makes routine tests in laboratory, plant or field. Practically the entire range of applications for a galvanometer or dynamometer is covered by the standard instruments we list. Among them you can almost always find the one you need for use as a balance-point detector in potentiometer or bridge measurements, or for calibrated deflection measurements. Usually the system is an easily interchangeable unit, so that one galvanometer with extra systems can be made to serve for a wide range of measurements. For special applications, non-standard characteristics can be supplied, usually in a standard construction.

*Automatic instruments are briefly described on pages 35 and 36.

In all cases sensitivities are at least as high as stated and other characteristics are within the best practical limits. Whatever the model, the same basic fundamentals are rigidly adhered to. First, the scientific principles are sound. Second, those principles are embodied in constructions of genuine merit—built of suitable materials—assembled by skilled craftsmen. Third, every instrument must combine in correct proportions the required accuracy, sensitivity, reliability and operating convenience.

Reflected in the design of these instruments are the extensive and ever-widening contacts we have had with both science and industry for almost fifty years. Such contacts have enabled us not only to adapt our laboratory instruments to the specific requirements of science, but—in more recent years—to apply scientific principles to an extensive line of rugged instruments suitable for the automatic measurement and even control of many variable quantities measurable in terms of resistance and potential change (see pages 35 and 36). This has allowed us to equip, staff and qualify more thoroughly than ever to carry forward the fundamentals of instrument making in step with the growing demands of science.

In this catalog, we list our standard galvanometers and dynamometers and the accessories necessary for each. Included are d-c galvanometers, both moving-coil and moving-magnet types; a-c galvanometers; astatic dynamometers; and accessories and parts such as mounting devices, reading devices, shunts, damping coils, extra systems, etc. In addition, equipments specifically designed for adapting certain types of standard galvanometers to unusual conditions are described on page 22. The Thermionic Amplifier, combined with a short period d-c galvanometer, permits the use of the d-c galvanometer as a null detector under conditions of high resistance. The Commercial Frequency Amplifier used with an ordinary pointer-type a-c galvanometer provides balance-point determination in an a-c circuit. In describing each item listed, an effort has been made to include all information which instrument users require to choose the apparatus they need for laboratory, plant or field. However, if further questions arise, too specific to be covered here, we'll be glad to give your problem individual attention. We invite you to consult us by mail, through our nearest representative (see page 37), or by personal visit to our plant.

GALVANOMETER CHARACTERISTICS DEFINED

SENSITIVITY

There are various ways of expressing galvanometer sensitivity, and for convenience we have adopted the four definitions given below, each involving a statement of the electrical conditions necessary to produce a standard deflection. This standard deflection in galvanometers having attached scales is assumed to be one scale division. In galvanometers not equipped with scales, the standard deflection is assumed to be one millimeter at a scale distance of one meter.

1. *Current Sensitivity* is the current required to give the standard deflection. All other expressions of galvanometer sensitivity are derived from the current sensitivity.

2. *Megohm Sensitivity* expresses the resistance in megohms which must be placed in series with the galvanometer in order that an impressed emf of one volt shall produce the standard deflection. Neglecting the resistance of the galvanometer coil itself, the number representing the megohm sensitivity is the reciprocal of the number representing the current sensitivity.

3. *Voltage Sensitivity** is the voltage that must be impressed on the circuit made up of the galvanometer coil and the external critical damping resistance in order to produce the standard deflection. The voltage sensitivity equals the product of the current sensitivity and the total circuit resistance when critically damped.

4. *Ballistic Sensitivity* is the quantity of electricity that must be discharged through the galvanometer in order to produce the standard deflection. In this catalog, undamped ballistic sensitivities are stated. When critically damped, the sensitivity of a ballistic galvanometer is about one-third of its undamped sensitivity.

EXTERNAL CRITICAL DAMPING RESISTANCE

This is the resistance which must be placed across the galvanometer to produce the critically damped condition.

PERIOD

The period usually stated for a galvanometer is the full undamped period, which is the time in seconds elapsing between two successive passages in the same direction through the position of rest. It is customary to take the period of a critically damped galvanometer as equal to its undamped period, for while the critically damped period is theoretically infinite, practically, a critically damped deflection is within about 1.5 per cent of its final position in the undamped periodic time. While the full undamped period is stated for ballistic galvanometers, the quarter-period (or the time for the initial deflection away from zero) is of principal interest in ballistic measurements. When critically damped, the time for the quarter-period is obtained by dividing the full undamped period by $2 \times \pi$ (6.3).

*The U. S. Bureau of Standards recommends including the external critical damping resistance in the galvanometer circuit when calculating or determining the voltage sensitivity of a d-c moving-coil galvanometer. Some foreign makers specify the voltage sensitivity at the terminals of the galvanometer without the critical damping resistance in series. The latter sensitivity may be several times the former. This fact should be borne in mind when selecting a d-c moving-coil galvanometer.

SELECTING THE PROPER GALVANOMETER

In choosing a d-c galvanometer, the characteristics of major significance are sensitivity, critical damping resistance and period. In an a-c galvanometer, sensitivity and period are important, but damping resistance, as such, is of less significance because proper damping depends also upon capacitance and inductance. It is often desirable to use some external capacitance to offset the inductance in the circuit, including that of the moving coil.

Because the exact characteristics desired, especially sensitivity and period, are apt to be in conflict, practical choice of the galvanometer best suited to a particular service is often a matter of compromise. As an aid in determining their relative importance, the principal characteristics are briefly discussed here. If you wish a more complete discussion of galvanometer characteristics and an explanation of fundamental principles underlying the construction and use of these instruments, we will gladly send you, on request, a copy of our 48-page, pocket-size Note Book ED(1), *Notes On Moving-Coil Galvanometers.*

SENSITIVITY

A sensitivity which will permit measurement within the required precision can usually be determined by simple calculation. It is not desirable to employ a galvanometer having a sensitivity far greater than the work demands, as this results in working with an instrument which is more difficult to use. Another objection arises from the corresponding increase in period which makes time required for successive adjustments or readings relatively longer. Also, considerable time is likely to be wasted by attempting too close adjustment. In addition, a galvanometer having an unnecessarily high sensitivity is likely to have a less stable zero, particularly since in this case the high sensitivity implies greater departure from zero in making observations. If the galvanometer of higher sensitivity has a larger zero shift, it may be actually less efficient than a galvanometer of lower sensitivity with a stable zero. This is particularly significant of course when the galvanometer is used for direct deflection measurements. Furthermore, increased sensitivity, in general, involves increased cost of galvanometer construction so that choice of the galvanometer which provides ample but not excessive sensitivity leads to best economy.

CRITICAL DAMPING RESISTANCE

The critical damping resistance is an extremely important characteristic, as it is very difficult to work with a galvanometer that is improperly damped. If much underdamped, the system oscillates about its position of rest after a deflection. If much overdamped, it travels to its position of rest so slowly that it is difficult to tell when it has come to rest. A critically damped galvanometer has the minimum damping which will avoid overshooting. Experience has shown that it is most convenient to work with a galvanometer which is just slightly underdamped and that it usually pays to sacrifice sensitivity to obtain such a condition.

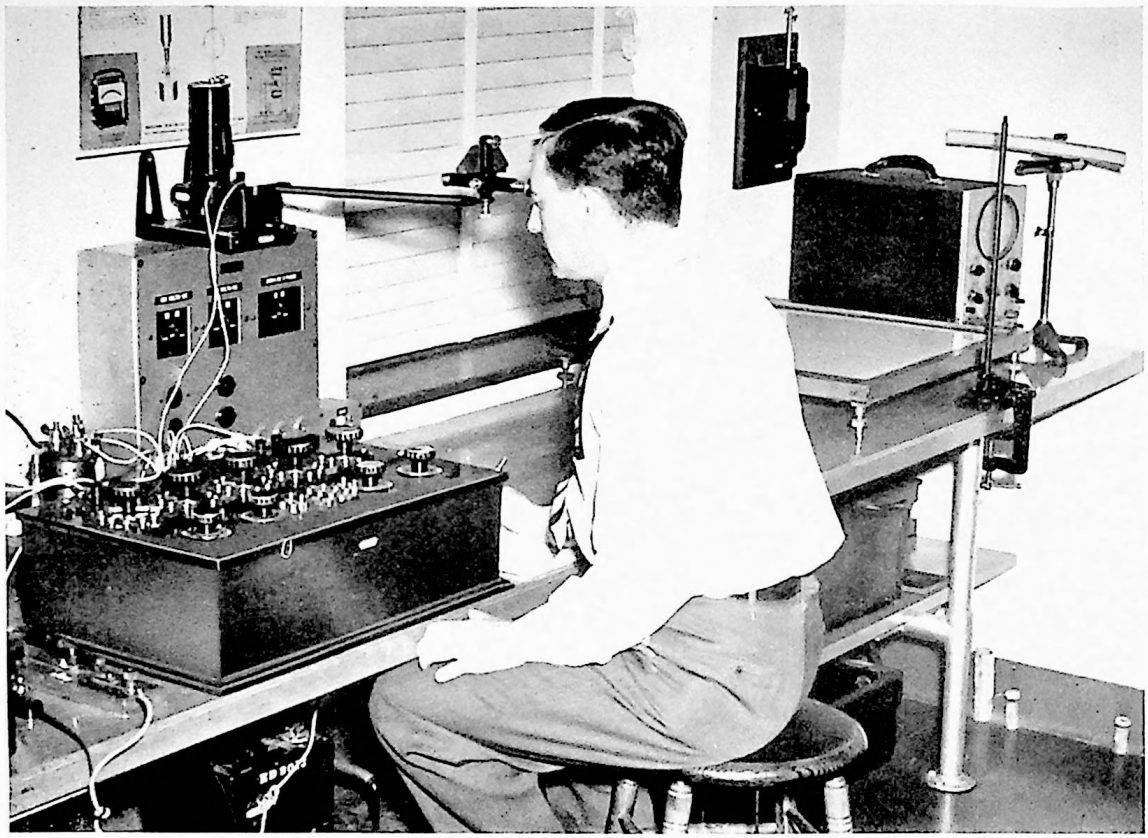
Theoretically, the time required for a critically damped galvanometer to come to rest after deflection is infinite. Practically, the deflection is within about 1.5 per cent of its final position in the undamped periodic time. Very often proper damping may be produced by a shunt or a combination of a shunt and series resistance. In specifying a galvanometer, the external critical damping resistance should be stated or, if this cannot be done readily, a complete description of the circuit, external to the galvanometer, should be given.

PERIOD

When the proper sensitivity and external critical damping resistance have been decided upon, it usually devolves upon the designer of the galvanometer to secure as short a period as is possible, since the shorter the period the faster may successive adjustments or readings be made. The principal exception to this statement arises in the application of galvanometers to ballistic measurements. Here a short period is undesirable (see Ballistic Measurements on page 6). In special cases where the period must not exceed a certain limit, it is better to specify the period and the external critical damping resistance, leaving it to the designer to obtain the greatest sensitivity possible.

SPECIAL INSTRUMENTS MEET LESS USUAL NEEDS

The standard instruments we list are those which have been found suitable for most applications. When there is need for a slightly modified standard instrument, or for one which is specially designed, we are glad to give the design and construction of such instruments the same care that standard apparatus receives. Because we carry in stock a large number of parts and assemblies which can often be utilized, special instruments frequently can be supplied at a cost not greatly in excess of that for listed apparatus. Give us full particulars and let us quote on an instrument to meet your specific need.



Designed for applications requiring great precision, high sensitivity galvanometers like the one pictured above (with a 2148 Telescope, Arm, Curved Scale and Wall Mounting) are made of fine materials and with great care. Because a choice of galvanometers can be made from such a complete line—which includes types for general use, for high current sensitivity and for high voltage sensitivity—each user can have an instrument which is ideally suited to his particular need.

BALLISTIC MEASUREMENTS

As mentioned previously, a short period is undesirable in a galvanometer which is to be used for ballistic measurements. Not only does a short period make it difficult to read the maximum deflection or throw, but the throw itself may be appreciably in error if the time of discharge through the galvanometer is not short in comparison with the period of the galvanometer.

It is believed by some that to be used ballistically a galvanometer should be undamped. While it is true that an undamped ballistic galvanometer is more sensitive than one that is critically damped, the latter is much more convenient. Ballistic galvanometers are now available with sufficiently high sensitivity to make it unnecessary to dispense with the damping.

FLUX MEASUREMENTS

For measurements where a fluxmeter is required, a ballistic galvanometer may be adapted to this use by highly overdamping. When measuring flux with such an instrument and an auxiliary exploring coil, the position of the galvanometer coil follows, almost immediately, any change in flux through the exploring coil.

USE OF MOVING-COIL GALVANOMETERS

In employing a galvanometer of the moving-coil type, there are certain suggestions, which, if observed, will contribute to more accurate and rapid work. Of course, specific instructions cannot be given here but any information needed, in addition to directions accompanying each instrument, will be supplied on request.

The first requirement, of course, is to have the circuit and the galvanometer adapted to each other. While in many cases this is a matter of selecting a galvanometer suitable for the circuit (see page 5), in some instances the circuit may be adapted to the galvanometer (see Note Book ED(1)), or a change made in both so that best results may be obtained.

SETTING UP

Any galvanometer should be used where it is as free as possible from disturbing influences, particularly vibration and dust. Galvanometers with taut suspensions—portable instruments, for example—require little special attention in setting up. With a galvanometer of higher sensitivity, attention must be given to leveling so that the coil hangs symmetrically in the air gap between the core and pole faces, and will swing freely past its zero position in either direction when the galvanometer is not connected to a circuit. However, high sensitivity in a galvanometer does not necessarily imply proportionally greater difficulties in setting it up as such instruments are often supplied with various refinements for ready adjustment that cannot be provided on less expensive ones.

ZERO SHIFT—MAGNETIC IMPURITIES

In a galvanometer of high sensitivity, the coil returning from a wide deflection may stop at some position other than the zero from which it was deflected. This zero shift, amounting to three or four millimeters in a sensitive instrument, results from hysteresis in the suspension, or from change in the direction of magnetization of magnetic foreign material in or on the coil.

The zero shift can be minimized by causing several deflections greater than any that may occur during measurements, to that side of zero to which the coil is to be deflected. The zero position will then be stable if the coil is not deflected to the opposite side of zero, which will not happen when the galvanometer is critically damped.

This precaution is not necessary when the galvanometer is used as a null instrument, for the deflections should then be too small to disturb the zero position.

When a deflection is included in a measurement, the zero from which it should be measured is the one to which the coil returns after the deflection rather than the one from which it was deflected, if they are not the same. The coil should be clamped only during transportation, as it sometimes requires as much as half a day for a suspension to regain its original characteristics after the coil has been lowered into position.

THERMAL EMF

A deflection may occur when a circuit in which the galvanometer is connected is closed with no apparent source of emf in it. This indicates a parasitic thermal emf, which may develop in the galvanometer circuit or in the external circuit, owing to difference in temperature of junctions of unlike metals.

In L&N galvanometers of high voltage sensitivity, thermal emf is rendered negligible by making the complete circuit and the binding posts of copper. Thermal emf in a galvanometer lacking this refinement can be reduced by enclosing the instrument in a pasteboard case or tube packed with loose cotton. Compensation can be made by taking as zero the position to which the deflection extends when the circuit is closed with no other source of emf in it. An alternate is to shunt into the circuit a counter emf to balance the thermal emf.

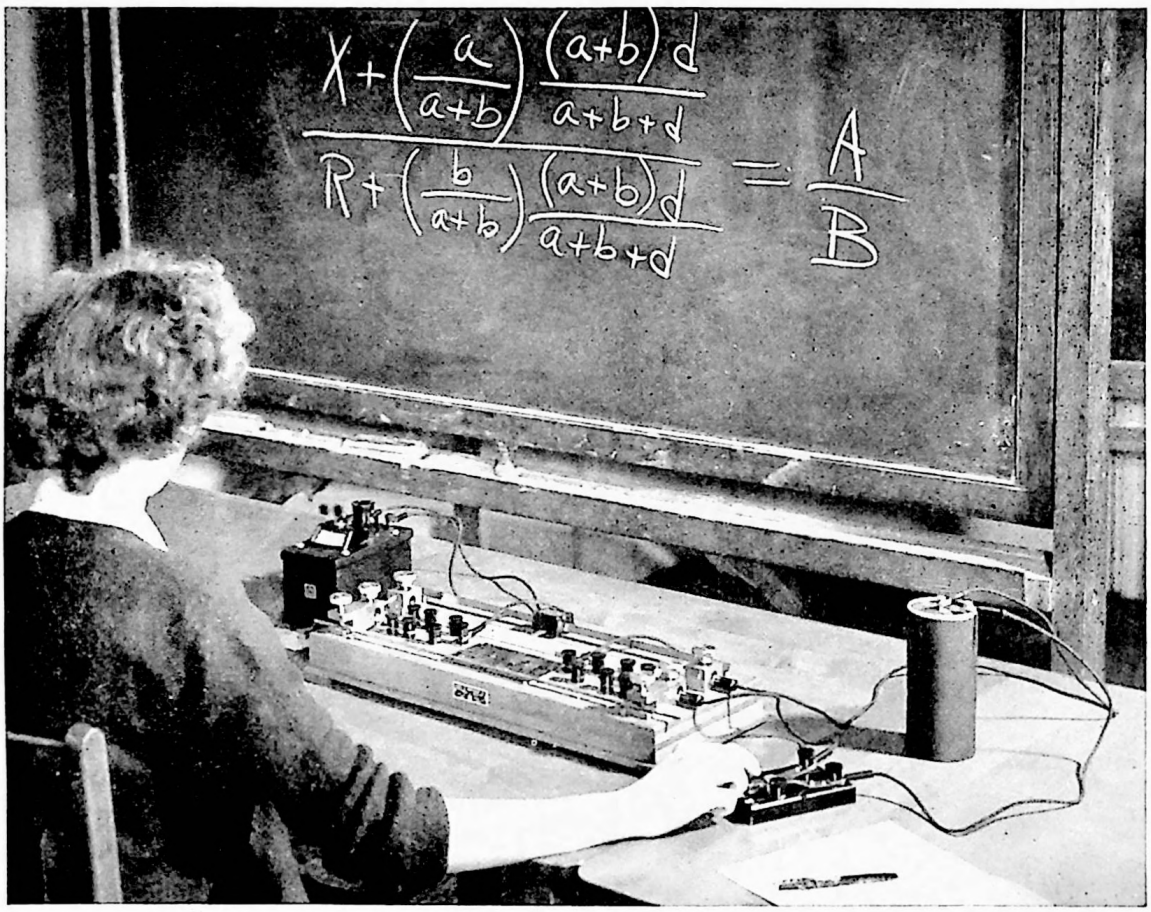
TEMPERATURE COEFFICIENT

A change in temperature of the galvanometer affects the rigidity of the suspension, the strength of the magnetic field, and the resistance of the system. The combined effect is an overall temperature coefficient, which in most uses of a galvanometer is of little importance, so that usually no attempt is made to hold it within rigid limits. It will vary somewhat with the materials used. In L&N galvanometers the temperature coefficient of current sensitivity is, in general, within the limits of 0.1 and 0.2 per cent per degree C. The sign of the coefficient is positive, that is, the sensitivity increases as temperature increases.

UNIFORMITY OF SCALE

For precise deflection measurements the galvanometer scale must be calibrated to avoid error from lack of linear relation between current and deflection. With a properly curved scale there is no error from the relation between the angle of deflection and its tangent, but there is another error if the magnetic field of the galvanometer is not strictly radial and uniform. It is convenient to include all corrections in a curve of error showing the amount to increase or diminish any scale reading. For small angles the cosine error due to a rectangular field is practically offset by the tangent error of a straight scale.

Serial # 773439 — Cat # 2420-5
Sensitivity 5.0 mm/mm Period 1 sec Rec 9.8 Ω



The precision with which this Students' Kelvin Bridge may be balanced depends upon the sensitivity of the galvanometer. For educational work, where accuracy of measurement is not vital but where simplicity and convenience are desired, a 2310-b Pointer Galvanometer, with its easy-to-read 45-degree scale, is generally recommended.

D-C GALVANOMETERS

D-C Moving-Coil Galvanometers are listed in a variety of reflecting and pointer types, each a time-tested construction which offers a choice of standard sensitivities, periods and critical damping resistances. Characteristics published in this catalog are nominal. Any of our galvanometers has sensitivity at least as high as stated, usually higher; other characteristics within 20 per cent.

For galvanometers with detached scales, sensitivity is expressed in terms of 1 mm deflection on a scale 1 meter from the galvanometer mirror. For those with integral scales, it is in terms of 1 scale division.

Where voltage sensitivity is expressed, it is for voltage impressed on a circuit in which the resistance external to the galvanometer is that required for critical damping. For voltage impressed at the galvanometer terminals, sensitivity would be higher.

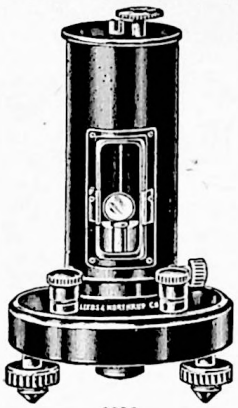
Resistance stated is actually that of the system including coil and suspensions.

So that either a telescope and scale, or a lamp and scale, can be used for reading deflections, a galvanometer for use with detached scale is equipped with a plane mirror and a lens of 1-meter focus. The lens is removable, and lenses of other focal lengths can be used.

Galvanometers especially designed for ballistic use are: 2285-d and e Type HS, and 2239-d and e Type P.

The Coblentz Moving-Magnet Galvanometer (page 15) is available for applications where voltage sensitivity must be better than that of the most sensitive moving-coil galvanometer.

Note: Prices listed may of course be changed without notice. Formal quotations, made on request, are always good for 30 days. Dimensions and weights listed are approximate.



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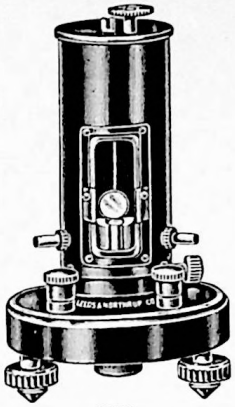

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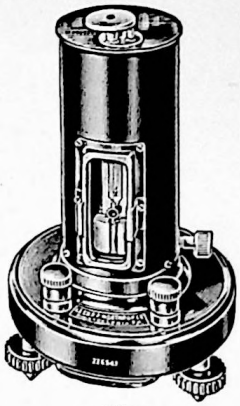

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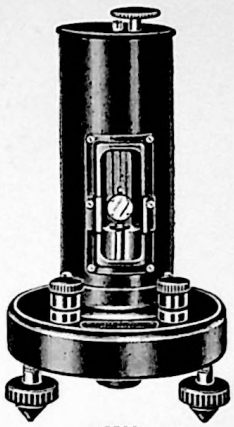

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D-C GALVANOMETERS, MOVING-COIL, REFLECTING

2285 **TYPE HS REFLECTING GALVANOMETER**.....**See table below**

The 2285 series of Reflecting Galvanometers offers a choice of highly sensitive instruments for the most precise uses. It includes voltage-sensitive, current-sensitive and ballistic types. The excellent characteristics of these instruments are due to careful design and proper choice of materials of construction. The coil turns in a radial magnetic field and is made up of wire and fittings tested for freedom from magnetic impurities.

Sensitivity, per mm at 1 meter	Period, seconds	Resistance, ohms: External Critical Damping	Resistance, ohms: System	List No.	Price
0.2 microvolt	5	40	16	2285-b	$100.00
0.1 microvolt	7.5	25	17	2285-a	100.00
0.008 microampere	1.5	2,500	515	2285-h	100.00
0.0003 microampere	7	10,000	525	2285-g	100.00
0.00004 microampere	20	70,000	800	2285-f	100.00*
0.003 microcoulomb	25	600	12	2285-e	115.00*
0.0003 microcoulomb	27	50,000	700	2285-d	115.00
As specified	—	—	—	2285-x	115.00

Mirror.....3/8-inch plane in 2285-a, b, f, g and h; 1/2-inch plane in 2285-d and e.
Lens.....Detachable, 1-meter focus
Case.....Dust-tight aluminum with black alumilited finish. Mounted on bakelite base with petticoat leveling screws. 10" high x 5-1/2" diameter.
Weight.....Net, 4 lb. Packed for shipment, 11 lb.

2290 **TYPE HS REFLECTING GALVANOMETER**..... **$150.00**

The 2290 Galvanometer is similar to the 2285 but is designed chiefly for extra high current sensitivities. This extreme current sensitivity is attained by adjusting the configuration of the magnetic field so that the reaction of magnetic impurities in the coil tends to oppose the restoring torque of the suspension. This is accomplished by means of adjustable pole pieces. The current sensitivity is thus increased beyond any previously obtainable in d'Arsonval galvanometers, but at the expense of a somewhat increased period.

Sensitivity.....0.00001 microampere per mm at 1 meter
Period.....40 seconds
Resistance.....External critical damping, 100,000 ohms; system, 800 ohms.
Mirror.....3/8-inch plane
Lens.....Detachable, 1-meter focus
Case.....Dust-tight aluminum with black alumilited finish. Mounted on bakelite base with petticoat leveling screws. 10" high x 5½" diameter.
Weight.....Net, 4 lb. Packed for shipment, 11 lb.

*Price includes external resistor for critical damping.
Note: For mounting and reading devices recommended for use with the above galvanometers, see chart on page 24.

Note: Sensitivities at least as high as stated; other characteristics within 20 per cent. Microvolt sensitivities are for critical damping resistance in series. System resistance includes coil and suspensions.

2284 **TYPE HS REFLECTING GALVANOMETER**.....**See table below**

The 2284 series of Reflecting Galvanometers (illustrated on page 9) is especially designed for high voltage sensitivity and short period. Particular care has been given in their design to reducing to a minimum the weight and moment of inertia of the moving system. In order to minimize stray internal thermal emf's, the circuit, including suspensions, is entirely of copper. The external critical damping resistance is kept as high as is consistent with the desired sensitivity.

Sensitivity, per mm at 1 meter	Period, seconds	Resistance, ohms		List No.	Price
		External Critical Damping	System		
0.5 microvolt	1.5	40	21	2284-a	$115.00
0.1 microvolt	5	20	16	2284-c	115.00
0.1 microvolt	5	50	25	2284-d	115.00
0.05 microvolt	7	10	16	2284-b	115.00
0.005 microampere	1.5	1200	300	2284-e	120.00
As specified	—	—	—	2284-x	—

Mirror.....1/4-inch plane
Lens.....Detachable, 1-meter focus
Case.....Dust-tight aluminum with black alumilited finish. Mounted on bakelite base with petticoat leveling screws. 10" high x 5-1/2" diameter.
Weight.....Net, 4 lb. Packed for shipment, 11 lb.

2500 **TYPE R REFLECTING GALVANOMETER**.....**See table below**

This series of Reflecting Galvanometers (illustrated on page 9) offers instruments of high sensitivity of the same general design as the 2285 and 2284. However, it is not attempted to attain in it sensitivities that cannot be obtained without great difficulty in this type of instrument. For convenience in replacing, suspensions are made removable at some sacrifice in sensitivity. The fine zero setting device, incorporated in the high sensitivity instruments, has been omitted. The 2500-a and c are equipped with all copper circuits to minimize internal thermal emf's.

Sensitivity, per mm at 1 meter	Period, seconds	Resistance, ohms		List No.	Price
		External Critical Damping	System		
0.5 microvolt	5	50	12	2500-a	$60.00
0.005 microampere	5	300	40	2500-c	60.00
0.003 microampere	3	2,200	500	2500-e	60.00
0.0005 microampere	6	10,000	500	2500-b	60.00
0.0001 microampere	14	22,000	500	2500-f	60.00
0.0005 microampere	6	7,000	500	2500-g	60.00

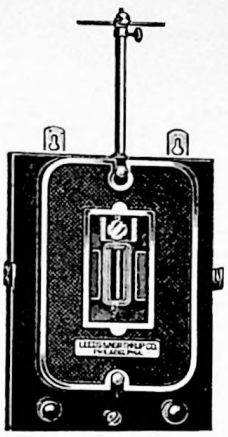
Mirror.....1/2-inch plane
Lens.....Detachable, 1-meter focus
Case.....Dust-tight aluminum with black alumilited finish. Mounted on bakelite base with petticoat leveling screws. 10" high x 5-1/2" diameter.
Weight.....Net, 4 lb. Packed for shipment, 11 lb.

2239 **TYPE P GALVANOMETER**.....**See table, page 11**

The Type P series of galvanometers has excellent working qualities, which will command the respect of students and the confidence of experienced investigators. So widely used that they are practically standard in many laboratories, these instruments have a combination of strength, sensitivity and accessibility. The external form, through more than thirty years of improvement of detail, has maintained the simplicity of structure that affords the visibility and accessibility of internal parts so important for student use. Although sensitivity is not as great as in the Type HS or R, they are admirably adapted to a wide variety of uses. Suspensions are of gold, and it is a comparatively simple matter to change coils and suspensions. The characteristics of the 2239-d and e make them suitable for use as fluxmeters.

(Continued on next page)

Note: For mounting and reading devices recommended for use with the above galvanometers, see chart on page 24.
Note: Sensitivities at least as high as stated; other characteristics within 20 per cent. Microvolt sensitivities are for critical damping resistance in series. System resistance includes coil and suspensions.



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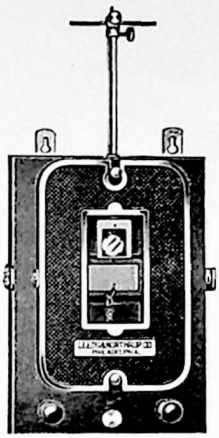

2239-d
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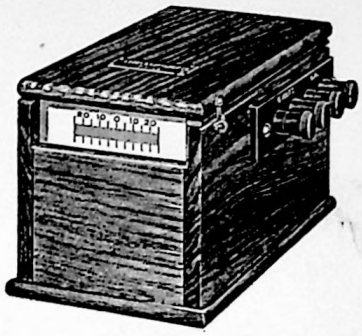

2420
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2239 TYPE P GALVANOMETER (Continued)

Sensitivity, per mm at 1 meter	Period, seconds	Resistance, ohms: External Critical Damping	Resistance, ohms: System	List No.	Price
1.5 microvolts	12	165	35	2239-c	$25.00
0.014 microampere	8	10,000 to 100,000	115	2239-a	25.00
0.001 microampere	14	10,000 to 25,000	1000	2239-b	25.00
0.0002 microampere	18	46,000	8000	2239-f	45.00
0.011 microcoulomb	24	230	60	2239-e	35.00*
0.002 microcoulomb	26	10,000	2000	2239-d	35.00

Mirror.....5/8-inch plane
Lens.....Detachable, 1-meter focus
Frame.....Arranged for wall mounting. Molded bakelite backboard and front plate, cast iron frame, glass window. 6-1/4" x 14" x 2-1/4".
Weight.....Net, 11 lb. Packed for shipment, 21 lb.

2420 GALVANOMETER WITH ENCLOSED LAMP AND SCALE.....See table below

The 2420 series are simple, sturdy galvanometers of sufficient sensitivity for a large majority of bridge and potentiometer measurements. They are as convenient to use as are the pointer type, and at the same time are more robust than many pointer instruments. Notwithstanding this, sensitivity is often as great as twenty times that of the ordinary pointer galvanometer.

Because of its great convenience in laboratory and shop work, the lamp-and-scale type of reading device is used in this instrument. Together with a galvanometer assembly, a lamp and scale are so installed in the case that all parts are easily accessible. The illuminating device throws a brilliant spot of light, about ¾ of an inch in diameter, on the scale. The spot is cut by a fine but distinct hairline, easily visible even in a fully lighted room. The lamp operates at 6 volts and requires a current of about 0.5 ampere.

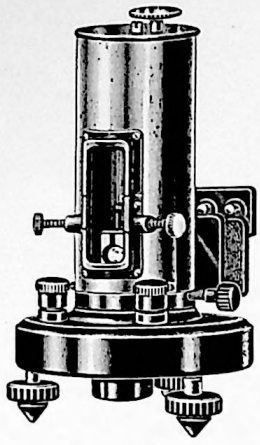
The robust systems are interchangeable. A duplicate system or a system of different characteristics may be quickly and easily installed.

Sensitivity, per scale division	Period, seconds	Resistance, ohms: External Critical Damping	Resistance, ohms: System	List No.	Price
25.0 microvolts	3	80	26	2420-b	$40.00
0.04 microampere	3	10,000	300	2420-a	40.00
0.04 microampere	3	2,000	300	2420-d	40.00
0.025 microampere	3	15,000	1000	2420-c	40.00

Scale.....Vertical. 25 one-millimeter divisions on either side of a central zero.
Case.....Walnut. 4-1/2" x 5" x 8-1/2".
Weight.....Net, 4 lb. Packed for shipment, 10 lb.

*Price includes external resistor for critical damping.
Note: For mounting and reading devices recommended for use with the above galvanometers, see chart on page 24.

Note: Sensitivities at least as high as stated; other characteristics within 20 per cent. Microvolt sensitivities are for critical damping resistance in series. System resistance includes coil and suspensions.



2255
(about 1/4 actual size)

2255 MARINE GALVANOMETER **$250.00**

Designed specifically for use on shipboard, this instrument incorporates the elements essential for satisfactory performance in such service. These include convenient means for accurate balancing of the system to prevent changes in deflection due to rolling or pitching, and a sufficient degree of rigidity and robustness in the system to avoid changes in balance due to tension of the suspension or vibration of the ship.

To avoid disturbing effects of air currents and to guard against damage to the system, as well as for convenience in balancing, all adjustments are made from outside the case. So that tension cannot alter the balance of the moving system, the inner ends of the suspension are fastened to the ends of an ivory shaft in the vertical axis of the moving coil. By this arrangement, the shaft takes all the strain of the suspension. A very powerful field produced by an electromagnet is used to provide sufficient sensitivity. The electromagnet operates from a 6-volt circuit and requires a current of 0.5 ampere.

Sensitivity	0.02 microampere (50 megohms) per mm at 1 meter
Period	2 seconds
Resistance	External critical damping, 100,000 ohms; system, 270 ohms.
Mirror	3/8-inch plane
Lens	Detachable, 1-meter focus
Case	Dust-tight aluminum with black alumilited finish. Mounted on bakelite base with petticoat leveling screws. 10″ high x 5½″ diameter.
Weight	Net, 4 lb. Packed for shipment, 11 lb.

Note: For mounting and reading devices recommended for use with the above galvanometer, see chart on page 24.

Students of physics and electrical engineering, and others interested in a detailed theoretical discussion of the principles underlying the construction and use of moving-coil galvanometers, may wish to request a copy of Note Book ED(1), *Notes On Moving-Coil Galvanometers.*

The primary purpose of this book is to guide galvanometer users in the proper choice of available instruments and to aid them in stating their requirements to the galvanometer manufacturer when a suitable instrument is not available.

Some generally useful information is given in the forepart of the publication including: Selection of the Proper Galvanometer, Precautions in Using a Moving-Coil Galvanometer, Comments on Design and Suspension Constants. This is followed by a theoretical discussion of the moving-coil galvanometer: Fundamental Conditions, Working Constants, Condition of Motion of a Galvanometer System, Galvanometer Sensitivity, Critical Damping, Logarithmic Decrement, Galvanometer Period, Changing the Working Constants, Ballistic Galvanometer, and Fluxmeter. A mathematical appendix and bibliography are also included.

Your copy of this 48-page, handy-size note book will be sent on request.

2310
(about 1/4 actual size)

2320
(about 1/4 actual size)

D-C GALVANOMETERS, MOVING-COIL, POINTER

2310 **POINTER GALVANOMETER, 45-Degree Scale**.....**See table below**

The 2310 series of Pointer Galvanometers is intermediate in sensitivity between the 2320 and the 2420 galvanometers. It often has about four times the sensitivity of the smaller pointer galvanometers.

The 45-degree scale is an important feature of this instrument. For some applications the line of vision of the operator lies somewhere between a horizontal and vertical position. Our experience has shown that in such cases a 45-degree angle is very satisfactory and often adds to the operating convenience of the instrument.

The systems are interchangeable. The coil is suspended between taut suspensions, so that no leveling is required, and there are no jewels and pivots to cause friction. A clamping device protects the system in transit.

Sensitivity, per scale division	Period, seconds	Resistance, ohms		List No.	Price
		External Critical Damping	System		
2 microamperes	2.5	20	12	2310-a	$25.00
1 microampere	3	110	25	2310-b	25.00
1 microampere	4.5	30	16	2310-e	25.00
0.25 microampere	3	1,800	250	2310-c	25.00
0.125 microampere	3.5	10,000	1000	2310-d	25.00

Scale..... 45-degree. 15 one-millimeter divisions either side of a central zero. Etched on metal.
Case..... Hardwood. Overall 3-3/8" x 5-3/8" x 6-3/4".
Weight..... Net, 4 lb. Packed for shipment, 10 lb.

2320 **POINTER GALVANOMETER, Horizontal Scale**.....**See table below**

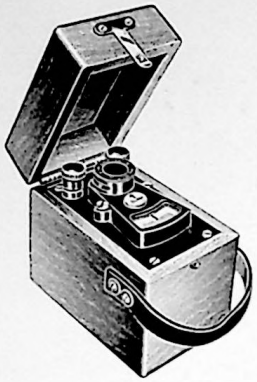
This series of sturdy, simple galvanometers, which will withstand severe shocks without damage, has a wide range of applications for which sensitivity is ample. The sensitivities obtainable are sufficient, in most cases, for Wheatstone bridge work with a limit of error of 0.1 per cent or potentiometer measurements to 0.05 millivolt. These qualities make an ideal instrument for testing and portable use. The systems are easily interchanged. A coil-clamping device is provided for safety during transportation.

Sensitivity, per scale division	Period, seconds	Resistance, ohms		List No.	Price
		External Critical Damping	System		
4 microamperes	3	50	20	2320-b	$15.00*
1 microampere	3	950	250	2320-c	15.00*
0.5 microampere	3	2400	1000	2320-d	15.00*

Scale..... Horizontal. 12 one-millimeter divisions either side of a central zero. Etched on metal.
Case..... Bakelite. Overall 2-3/4" x 4" x 4-5/8".
Weight..... Net, 2 lb. Packed for shipment, 5 lb.

*Less 10 per cent for lots of 6 to 11; 20 per cent for lots of 12 or more. A group of galvanometers subject to these discounts may include: 2320's only; 2322's only; 2320's and 2322's; or 2330's only.

Note: Sensitivities at least as high as stated; other characteristics within 20 per cent. System resistance includes coil and suspensions.



2322
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2330
(about 1/3 actual size)

2322 PORTABLE GALVANOMETER, Horizontal Scale ..... See table below

This series is similar to the 2320 Pointer Galvanometer, listed on page 13, except that it is designed especially for field use and assembled in a portable case.

Sensitivity, per scale division	Period, seconds	Resistance, ohms		List No.	Price
		External Critical Damping	System		
4 microamperes	3	50	20	2322-b	$24.00*
1 microampere	3	950	250	2322-c	24.00*
0.5 microampere	3	2400	1000	2322-d	24.00*

Scale ..... Horizontal. 12 one-millimeter divisions either side of a central zero. Etched on metal.
Case ..... Hardwood with hinged lid and carrying strap. Overall 3-3/8" x 5" x 5-1/4".
Weight ..... Net, 3 lb. Packed for shipment, 4 lb.

2330 POINTER GALVANOMETER, Vertical Scale ..... See table below

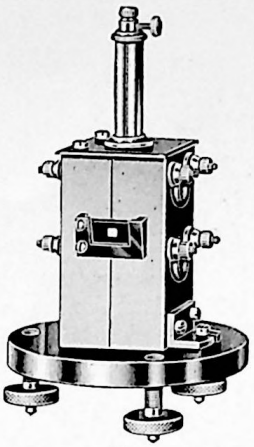
Except that the scale is vertical instead of horizontal, this series of galvanometers is similar to the 2320, listed on page 13. The vertical scale is often more convenient, particularly in cases where it is desired to make routine measurements with great rapidity. By mounting the galvanometer so that the scale is directly in the operator's line of vision, greater speed in reading can be obtained. For convenience in routine measurements when a precise balance is not necessary, but where maximum visibility of the indicator is extremely important, a small target has been added to the pointer. An "easy-to-read" scale further simplifies the reading. Because of these features, this type of galvanometer has met with great favor in winding rooms, for use in connection with limit bridges for rapid resistance measurements. Zero adjustment may be made by means of a slotted screw on the top of the unit.

Sensitivity, per scale division	Period, seconds	Resistance, ohms		List No.	Price
		External Critical Damping	System		
4 microamperes	3	50	20	2330-b	$16.00*
1 microampere	3	950	250	2330-c	16.00*
0.5 microampere	3	2400	1000	2330-d	16.00*

Scale ..... Vertical. 10 one-millimeter divisions either side of a central zero. Etched on metal.
Case ..... Bakelite. Overall 2-3/4" x 4" x 4-5/8".
Weight ..... Net, 1-1/2 lb. Packed for shipment, 2 lb.

*Less 10 per cent for lots of 6 to 11; 20 per cent for lots of 12 or more. A group of galvanometers subject to these discounts may include: 2320's only; 2322's only; 2320's and 2322's; or 2330's only.

Note: Sensitivities at least as high as stated; other characteristics within 20 per cent. System resistance includes coil and suspensions.



2270
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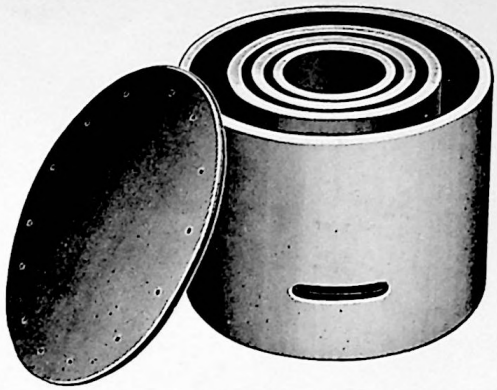


Coblentz Galvanometer Shield
(about 1/8 actual size)

D-C GALVANOMETER, MOVING-MAGNET, REFLECTING

2270 **COBLENTZ GALVANOMETER** **$500.00**

Designed by Dr. W. W. Coblentz of the Bureau of Standards*, this galvanometer is intended primarily for use with thermopiles for measuring minute quantities of radiant energy. It is an astatic moving magnet instrument, similar to the Kelvin type of galvanometer, but the field coils are encased in iron. A magnetic shield is provided.

While the sensitivity of this instrument is in excess of that of the best d'Arsonval instruments under similar conditions, the difficulties in setting up and using are also greater. Accordingly, it is not recommended as a substitute for a d'Arsonval galvanometer but for that class of work which lies beyond the bounds of possibility with the d'Arsonval type.

This instrument is equipped with four fixed coils, which can be connected in three different arrangements—series, series-parallel or parallel, thereby giving three sets of characteristics. The complete circuit, including the binding posts, is made of copper to avoid parasitic thermal emf's.

Sensitivity..... In series: 0.0002 microampere, 0.008 microvolt per mm at 1 meter.
In series-parallel: 0.0004 microampere, 0.004 microvolt per mm at 1 meter.
In parallel: 0.0008 microampere, 0.002 microvolt per mm at 1 meter.

Period..... 8 seconds approximately

Resistance..... In series, 40 ohms.
In series-parallel, 10 ohms.
In parallel, 2.5 ohms.

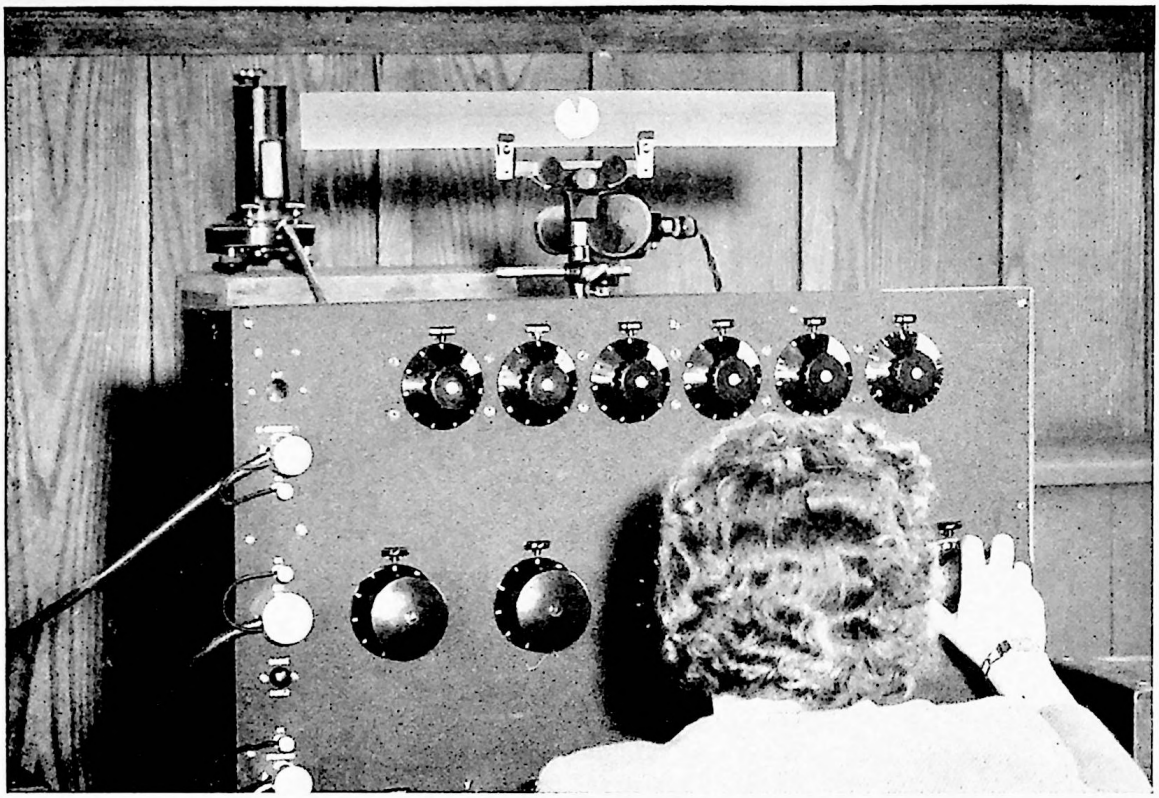
Mirror..... Plane

Lens..... Detachable, 1-meter focus

Case..... 8⅛" high x 4¾" diameter

Weight..... Net, 200 lb. Packed for shipment, 212 lb with shields.

*Bureau of Standards Scientific Paper #282.
Note: For mounting and reading devices recommended for use with the above galvanometer, see chart on page 24.
Note: Sensitivity at least as high as stated; other characteristics within 20 per cent. Voltage sensitivities are at galvanometer terminals, and will be proportionately reduced as total circuit resistance is increased. No damping resistance is stated as, practically, the damping is unaffected by changes in external circuit resistance.



Operator measures the dielectric characteristics of a sample with an L&N Modified Schering Bridge and a 2350-a Vibration Galvanometer. Both 2350-a and 2351-a are widely used with conductance and capacitance bridges and for measuring ratio and phase angle of potential transformers. For similar measurements of current transformers, there is the 2350-b or 2351-b.

A-C GALVANOMETERS

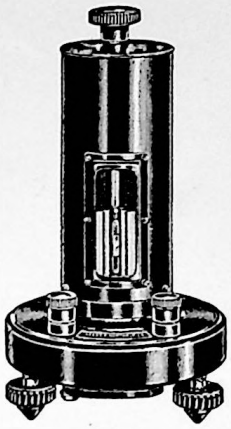
For use on 60-cycle circuits, A-C Moving-Coil Galvanometers are offered in reflecting and pointer types, each a thoroughly reliable construction especially adapted for a-c work. You will find a choice of sensitivities and periods. Because proper damping of these galvanometers depends upon capacitance and inductance, as well as upon resistance, no critical damping resistance is stated. Each galvanometer we provide has sensitivity at least as high as stated, usually higher; other characteristics, within 20 per cent.

For galvanometers with detached scales, sensitivity is expressed in terms of 1 mm deflection on a scale 1 meter from the galvanometer mirror. For those with integral scales, it is in terms of 1 mm scale division.

Sensitivities stated apply when current in the moving coil is in phase with that in the field coil. In a non-inductive circuit, such as an ordinary resistance bridge, this condition is obtained by supplying the bridge with current obtained by taking a drop across a non-inductive resistance in series with the field coil. In the 2370 Galvanometer, a non-inductive resistance is built into the instrument, and internal connections are so arranged that the in-phase condition is obtained automatically by plugging into a 115-volt, 60-cycle source.

Resistance stated is actually that of the system, including coil and suspensions.

Note: Prices listed may of course be changed without notice. Formal quotations, made on request, are always good for 30 days. Dimensions and weights listed are approximate.



2350
(about 1/4 actual size)

A-C GALVANOMETERS, REFLECTING

2350 **VIBRATION GALVANOMETER**.....**See table below**

Widely used as a detector in impedance bridges, and in measuring the ratio and phase angle of current and potential transformers. This series has a high intrinsic sensitivity with wide resonance range. The instrument is designed for a normal frequency of 60 cycles but can be tuned to resonance at frequencies between 55 and 65 cycles. Corresponding galvanometers for a normal frequency of 25 cycles can be provided at the same price or, on special order, for other frequencies between 5 and 200 cycles.

Sensitivity, per mm at 1 meter		Resonance Range, per cent		Resistance, ohms	List No.	Price
60 Cycles	3rd Harmonic	Current	Emf			
500.0 microvolts / 0.025 microampere	111 microamperes	0.3	1.5	800.0	2350-a	$150.00
2.0 microvolts / 5.0 microamperes	5000 microvolts	0.3	0.7	0.35	2350-b	150.00

Mirror.....Narrow-strip concave with 1-meter radius of curvature
Case.....Dust-tight aluminum with black alumilited finish. Mounted on bakelite base with petticoat leveling screws. 10" high x 5-1/2" diameter.
Weight.....Net, 4 lb. Packed for shipment, 11 lb.

2351 **VIBRATION GALVANOMETER**.....**See table below**

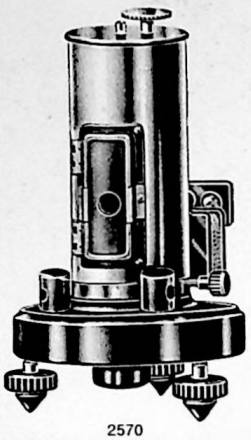
The 2351 series of Vibration Galvanometers is identical to the 2350, listed above, except that it is equipped with a remote tuning device which allows the galvanometers to be tuned at a distance.

Sensitivity, per mm at 1 meter		Resonance Range, per cent		Resistance, ohms	List No.	Price
60 Cycles	3rd Harmonic	Current	Emf			
500.0 microvolts / 0.025 microampere	111 microamperes	0.3	1.5	800.0	2351-a	$175.00
2.0 microvolts / 5.0 microamperes	5000 microvolts	0.3	0.7	0.35	2351-b	175.00

Mirror.....Narrow-strip concave with 1-meter radius of curvature
Case.....Dust-tight aluminum with black alumilited finish. Mounted on bakelite base with petticoat leveling screws. 10" high x 5-1/2" diameter.
Weight.....Net, 4 lb. Packed for shipment, 11 lb.

Note: For mounting and reading devices recommended for use with the above galvanometers, see chart on page 24.
Note: Sensitivities at least as high as stated; other characteristics within 20 per cent.

Note: Vibration galvanometers for normal frequency of 25 cycles supplied at same prices as 60-cycle instruments; for other frequencies between 5 and 200 cycles, prices on request.



2570
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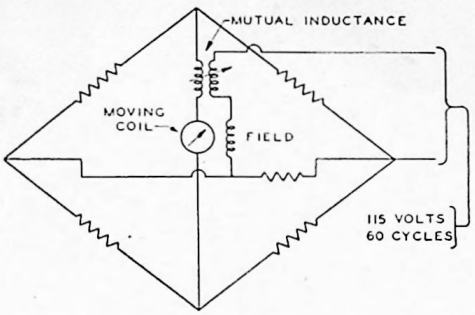

Circuit for use of 2570 Galvanometer

2570 HIGH SENSITIVITY A-C REFLECTING GALVANOMETER..... $350.00

This galvanometer has the same general construction as the 2285 Moving-Coil Type, listed on page 9, but instead of a permanent magnet, a laminated core electromagnet is used. When used under proper conditions this construction gives about the same sensitivity as the best d'Arsonval galvanometers. It is intended for use as a null instrument.

To obtain full sensitivity, the current in the moving coil must be in phase with the flux in the field. Current is supplied to an ordinary resistance bridge by connecting it across a non-inductive resistance in series with the field coil. Where the bridge circuit contains inductance or capacitance, the problem is more involved. An adjustable mutual inductance is required in order that the open and closed circuit zeros coincide.

To obtain proper damping it is necessary that the circuit external to the galvanometer have not only an approximately correct resistance value, but also approximately correct values of inductance and capacitance. Accordingly, in ordering, the complete circuit constants should be stated. The field operates at 115 volts, 60 cycles and requires a current of 0.1 ampere.

Sensitivity.....0.0035 microampere per mm at 1 meter
Period.....10 seconds
Resistance.....Of coil, 18 ohms
Power Factor.....Of field coil, 10 per cent
Energy Consumption...Of field circuit, 1 watt
Mirror.....⅜-inch plane
Lens.....Detachable, 1-meter focus
Case.....Dust-tight aluminum with black alumilited finish. Mounted on bakelite base with petticoat leveling screws. 10″ high x 5½″ diameter.
Weight.....Net, 4 lb. Packed for shipment, 11 lb.

Note: For mounting and reading devices recommended for use with the above galvanometer, see chart on page 24.

A-C GALVANOMETERS, POINTER

2370 A-C POINTER GALVANOMETER.....See table, page 19

The moving system of this series is practically identical with that of the 2320 Moving-Coil Type, listed on page 13. It is suspended in the field of a laminated iron-core electromagnet designed for operation on 115-volt, 60-cycle circuit. The galvanometer can be used also at lower frequency at reduced voltage.

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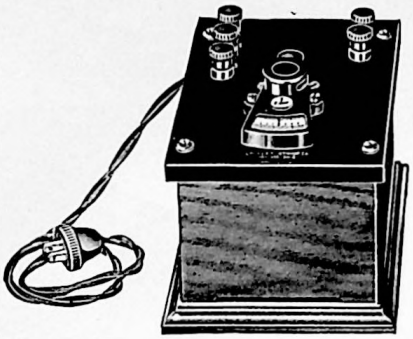

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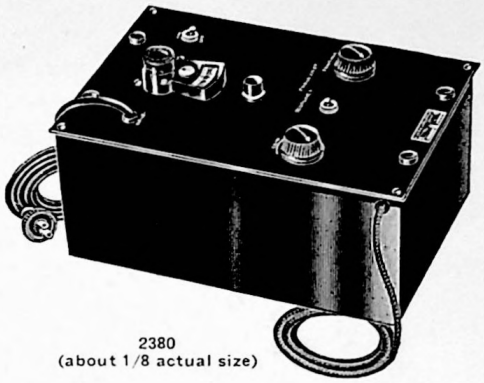


2380
(about 1/8 actual size)

Sensitivity is ample to permit use in numerous alternating-current bridges, potentiometers and special setups. Intended for null measurements, these galvanometers are regularly used in test sets for measuring the ratio and phase angle of instrument transformers, and in alternating-current bridges for measuring the conductivity of electrolytes.

The scheme of connections, for current in the moving coil in phase with the flux in the field, is the same as in the 2570 High Sensitivity A-C Galvanometer, listed on page 18. Binding posts on the top plate connected to non-inductive resistances in series with the field coil provide for current in the bridge circuit, at approximately 3 or 6 volts in the 2370-a, and 6 or 9 volts in the 2370-c and d. The mechanical zero is set by the cap on the top of the moving system. A magnetic zero adjuster is controlled by a small knob in back of the mechanical zero adjuster. The field circuit, including the electromagnet and two resistors, requires about 0.5 ampere at 115 volts, 60 cycles.

Sensitivity, per scale division	Period, seconds	Resistance, ohms	List No.	Price
5 microamperes	2.6	20	2370-a	$60.00
1 microampere	2.6	250	2370-c	60.00
0.5 microampere	2.6	1000	2370-d	60.00

Power Factor.....Of field coil, 25 per cent
Energy Consumption.....Of field circuit, 14 watts
Case.....Polished mahogany. 6-1/4" x 7-1/2" x 8".
Weight.....Net, 5 lb. Packed for shipment, 13 lb.

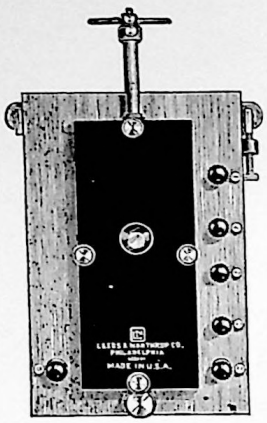
2380 **A-C DETECTOR**..... **$375.00**

The A-C Detector provides a convenient adaptation of the pointer-type a-c galvanometer with a self-contained amplifier, power supply and phase shifter. Designed for use as a null indicator in balancing 60-cycle networks such as in transformer testing, dielectric loss testing, etc., this instrument has a working sensitivity about ten times greater than the ordinary a-c pointer-type galvanometer. For all practical purposes, the detector is insensitive to stray magnetic fields, as 0.1 gauss produces only a 0.2 division deflection of the galvanometer when gain control is at maximum.

A continuous gain control is provided so sensitivity may be adjusted to meet users' requirements. Two phase-shifting controls are provided. One shifts the phase through 90 degrees in one step and is switch-operated. The other is a continuously adjustable control permitting variation of phase over a range of approximately 100 degrees. Zero adjustment is made by means of a large knob on the galvanometer, and once made is stable regardless of external circuit conditions. The operating power (about 40 watts) is supplied from a 115-volt, 60-cycle line. No batteries are necessary.

Sensitivity.....Approximately 25 microvolts or 0.05 microampere per division
Period.....3 seconds
Input Impedance..500 ohms
Case.....Metal, 13" x 8¾" x 6¼"
Weight.....Net, 14 lb. Packed for shipment, 26 lb.

Note: Sensitivities at least as high as stated; other characteristics within 20 per cent. Sensitivities stated assume that current in moving coil is in phase with current in field coil. System resistance includes coil and suspensions.



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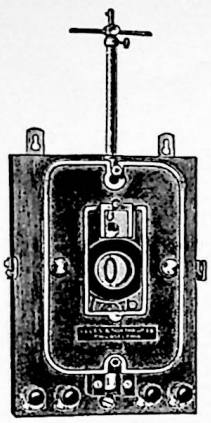

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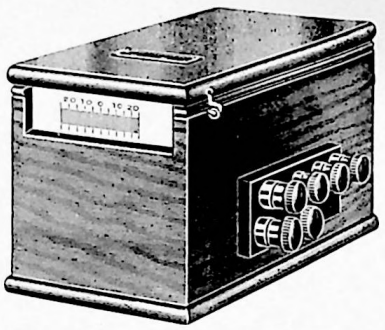


2460
(about 1/4 actual size)

ASTATIC DYNAMOMETERS

For measurements of voltage, current and power, and for power factor by the phase-defect method, we offer three astatic dynamometers . . . instruments which are characterized by unusually high sensitivity to power.*

2440 HIGH SENSITIVITY ASTATIC DYNAMOMETER..... $275.00

This dynamometer follows the Rowland design in having a moving system of two coils that renders it astatic, but differs in having two sets of fixed coils, for greater torque, giving higher sensitivity. The moving system is damped by a vane in oil. Because of high resistance of foil for electrostatic shielding in the case, induced currents are too small to cause error in measurements. A binding post provides for connecting the shield to the proper point in the circuit. The fixed and moving coils have separate pairs of posts. A capacitor shunted by a resistor is incorporated in the instrument, each unit being of such value that the combination compensates for self inductance in the moving coils at 60 cycles. The combination has a binding post so that the dynamometer can be used with or without compensation.

With the fixed system as the potential coil, protected by a proper amount of resistance in series, this instrument has been used extensively as a watt dynamometer in dielectric loss measurements. When the protective resistance is sufficient to permit connecting the potential circuit to 115 volts, the watt sensitivity is as shown below. With the fixed and moving coils in series the instrument is suitable for use as an ammeter or voltmeter.

Watt Sensitivity*	5 microwatts per millimeter at 1 meter
Current Sensitivity*	0.05 microampere per millimeter at 1 meter
Period	10 seconds
Total Resistance	Moving coils, 200 ohms; fixed coils, 125 ohms.
Total Inductance	Moving coils, 15 millihenrys; fixed coils, 110 millihenrys.
Continuous Current Rating	Moving coils, 0.05 ampere; fixed coils, 0.1 ampere.
Mirror	½-inch plane
Lens	Detachable, 1-meter focus
Case	Bakelite with backboard and leveling screws
Weight	Net, 6 lb. Packed for shipment 16 lb.

*Current sensitivities are with fixed coil circuit separately excited and carrying full current. Watt sensitivity assumes sufficient external resistance for 115 volts, that is, total resistance 1,150 ohms.

Note: Sensitivity at least as high as stated; other characteristics within 20 per cent.

Prices listed may of course be changed without notice. Formal quotations, made on request, are always good for 30 days. Dimensions and weights listed are approximate.

For mounting and reading devices recommended for use with the above dynamometers, see chart on page 24.

On special order, we can provide dynamometers built to specifications other than those listed in this catalog.

2450 **ASTATIC DYNAMOMETER** **$115.00**

This instrument follows the same general design as the 2440, listed on page 20, but there is only one set of fixed coils. The moving system has two coils so that the system is astatic, but the absence of the second set of fixed coils results in lower sensitivity than is obtained with the 2440.

The 2450 Dynamometer and the Type P Galvanometer have frames of the same size and take the same type of leveling device. This arrangement is intended to make the 2450 Dynamometer convenient for use in a large number of educational laboratories, which are equipped with Type P Galvanometers. As in the 2440 Dynamometer, the moving system is damped by a vane in oil. Separate binding posts are brought out for the moving coils and for the fixed coils, so that the instrument may be used as a wattmeter, a voltmeter or an ammeter.

Watt Sensitivity*	50 microwatts per millimeter at 1 meter
Current Sensitivity*	0.5 microampere per millimeter at 1 meter
Period	8 seconds
Total Resistance	Moving coils, 35 ohms; fixed coils, 25 ohms.
Total Inductance	Moving coils, 0.5 millihenry; fixed coils, 12 millihenrys.
Continuous Current Rating	Moving coils, 0.1 ampere; fixed coils, 0.1 ampere.
Mirror	½-inch plane
Lens	Detachable, 1-meter focus
Frame	Arranged for wall mounting, wood backboard, cast iron frame, metal front, glass window. 6¼" x 14" x 2¼".
Weight	Net, 2 lb. Packed for shipment, 10 lb.

2460 **ASTATIC DYNAMOMETER WITH ENCLOSED LAMP AND SCALE** **$150.00**

This is a robust Astatic Electro-Dynamometer, which will stand more rough handling than an ordinary voltmeter, and at the same time has sufficient sensitivity for a great many measurements requiring the use of a dynamometer. The instrument is complete with an improved lamp-and-scale reading device enclosed, as in the 2420 Moving-Coil Galvanometer on page 11.

This instrument is intended to be portable, and for portable use, oil damping is unsatisfactory. Accordingly, a simple but effective air damper is provided. To produce an astatic dynamometer system of small size and robust character and to provide for air damping, the Irwin dynamometer type of construction is utilized.** The sturdiness of this instrument and the ease with which it can be set up and used should appeal to many users of dynamometer instruments.

One of the important features of this instrument is that of a null-detector in a special bridge setup for measuring the power factor of full reel lengths of high voltage cable. The lamp requires about 0.5 ampere at 6 volts.

Watt Sensitivity*	300 microwatts per mm division
Current Sensitivity*	3 microamperes per mm division
Period	3.6 seconds
Total Resistance	Moving coils, 200 ohms; fixed coils, 20 ohms.
Total Inductance	Moving coils, 3.3 millihenrys; fixed coils, 3.3 millihenrys.
Continuous Current Rating	Moving coils, 0.03 ampere; fixed coils, 0.1 ampere.
Case	Walnut, 5½" x 5" x 8½"
Weight	Net, 5 lb. Packed for shipment, 14 lb.

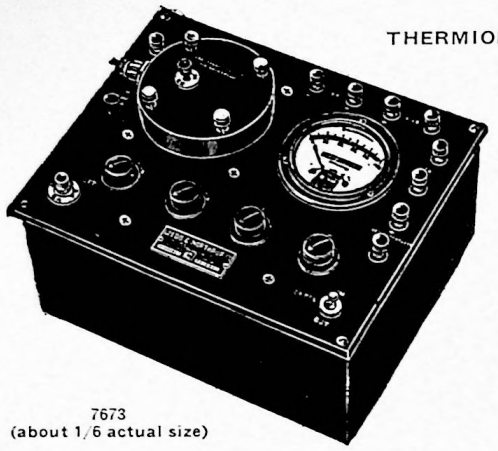
Note: For mounting and reading devices recommended for use with the above dynamometers, see chart on page 24.

Note: Sensitivities at least as high as stated; other characteristics within 20 per cent.

*Current sensitivities are with fixed coil circuit separately excited and carrying full current. Watt sensitivity assumes sufficient external resistance for 115 volts, that is, total resistance 1,150 ohms.

**F. A. Laws, *Electrical Measurements*, 2nd Edition, 1938, McGraw-Hill Co.

THERMIONIC AMPLIFIER



7673
(about 1/6 actual size)

7673 THERMIONIC AMPLIFIER.....$155.00

The Thermionic Amplifier makes possible the use of a d-c galvanometer as the null detector for any potentiometer used for measurements of potential difference or emf in high-resistance circuits.* The amplifier connects between the galvanometer terminals of the potentiometer and a suitable external galvanometer. With this amplifier the 2310-d Pointer-Type Galvanometer (period 3 seconds) is capable of detecting a potentiometer unbalance of 0.005 volt in circuits whose resistance is as high as 10^{+11} ohms in the measured source of potential. Under similar circumstances a 2420-c Galvanometer (period 3 seconds) detects an unbalance of 0.001 volt. The sensitivity is substantially independent of the resistance in the measured circuit. While the voltage sensitivity is theoretically limited only by the current sensitivity of the galvanometer, practically it is limited to 0.0001 volt by inherent instabilities in the amplifier and its associated batteries. If either the 2500-b or 2500-e Galvanometer is used, the sensitivity should be reduced by the use of suitable galvanometer shunts to a value such that the random disturbances are not troublesome.

The amplifier is assembled in a metal case with a top plate of suitable material. The electron tube is mounted within a practically air-tight chamber with a drying agent to assure proper insulation resistance. Developed primarily for this application, the electron tube possesses the required properties of extremely low control current, high insulation resistance, stability and long life. Write for Catalog E-00A. The 7674 Shielded Control-Current Check-Resistor, for use when checking the control bias, is available at $15.00.

*"The Measurement of Direct Potentials Originating in Circuits of High Resistance," R. H. Cherry, Transactions of the Electrochemical Society, Vol. 72, 1937.

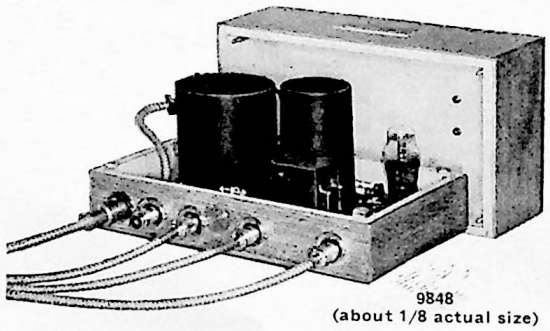
COMMERCIAL FREQUENCY AMPLIFIER

9848 COMMERCIAL FREQUENCY AMPLIFIER....$260.00

A sensitivity and stability of balance-point determination comparable to that of the best d-c galvanometer can be obtained by combining the Commercial Frequency Amplifier with an ordinary pointer-type a-c galvanometer. The amplifier consists of two stages of resistance-coupled vacuum tube amplification with gain control having a specially shielded input transformer and is usable over the 25- to 60-cycle range. Although often used with the 2370-c Pointer-Type Galvanometer it also can be combined with the 2350-a Vibration Galvanometer for use with the Schering Bridge or wherever greater sensitivity is desired.

Input terminals marked "LOW" lead to the step-up transformer; terminals marked "HIGH", directly to the electronic tube. Impedance at 60 cycles at "LOW" input terminals is about 800 ohms and about 320,000 ohms at input terminals "HIGH". Combined sensitivity at 60 cycles with the 2370-c is 2 microvolts or 0.0025 microampere; with the 2350-a, 0.5 microvolt or 0.0006 microampere, using input terminals marked "LOW" in both cases.

The amplifier uses standard electronic tubes, electrostatically and magnetically shielded, and is supplied

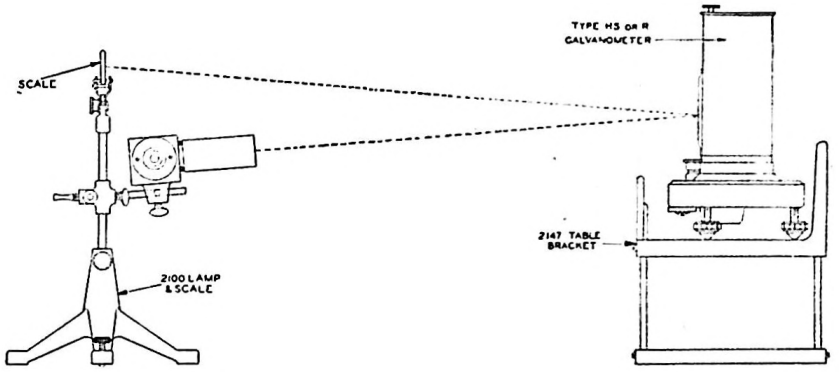


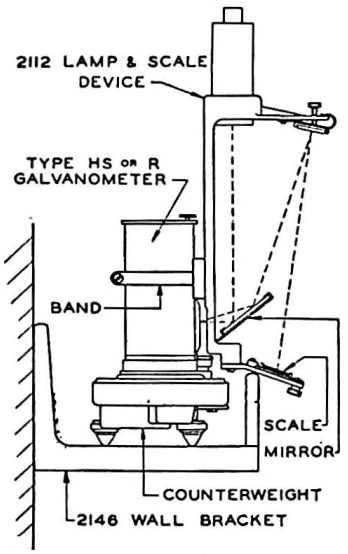
9848
(about 1/8 actual size)

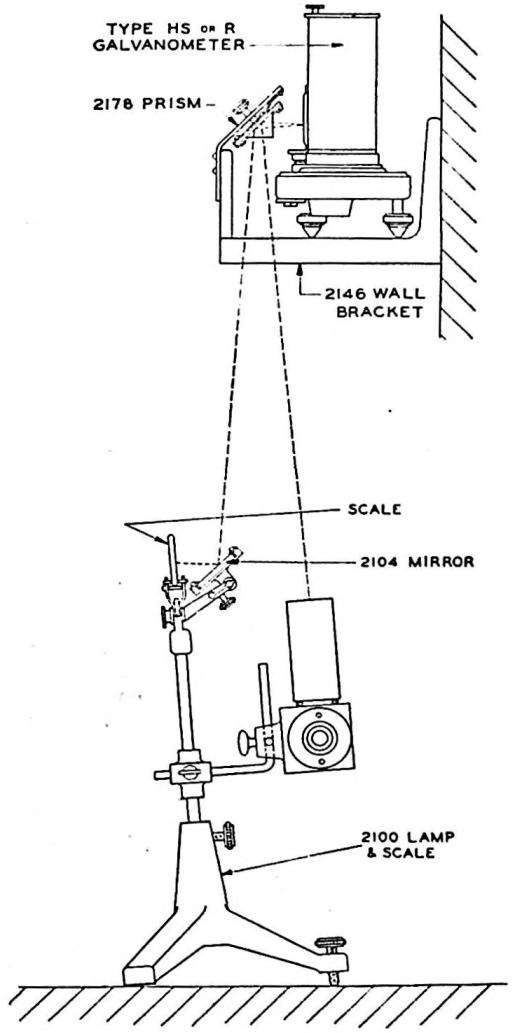
with a complete set of shielded leads. Shielding allows operation in stray fields as high as 0.1 gauss rms value without galvanometer deflection caused by pick-up being greater than deflection produced by 2 microvolts at input terminals "LOW".

Mounted in an oak case, 12-7/8" long x 8" wide x 7½" high, with cover and carrying handle, the instrument, with leads, weighs about 27 lb. A 6-volt storage battery and a 90-volt B-battery, not included in the price, are required for operation.

LAMP-AND-SCALE READING DEVICE ARRANGEMENTS







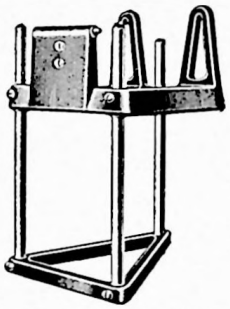
Lamp-and-scale reading devices are shown here schematically. They may be arranged in any of the ways shown with any of the reflecting galvanometers or dynamometers except the enclosed lamp-and-scale type. The two vertical arrangements are particularly advantageous where horizontal space is limited. Although the 2112 device gives only one-half the sensitivity of the 2100, it has the advantage of not being thrown out of adjustment by an accidental jolt. When using the 2112, the room need not be darkened at all. The 2100 may be used in daylight if the scale does not face a window.

GALVANOMETER MOUNTING AND READING DEVICE COMBINATIONS

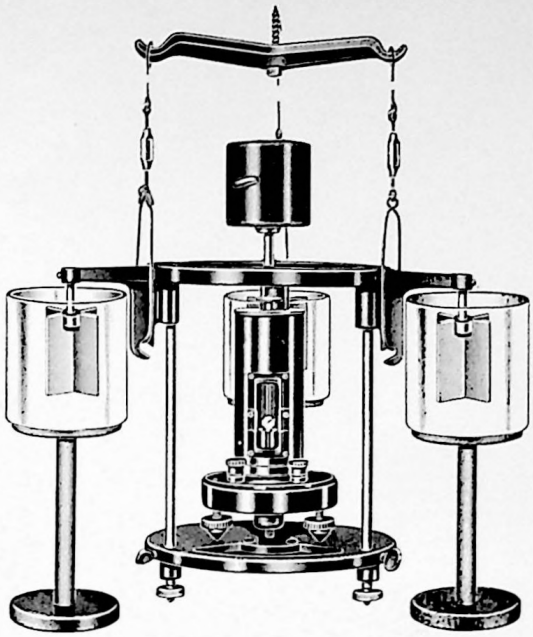
Galvanometer List No.	Use any combination between horizontal lines	
	Mounting	Reading Device
2285 Type HS Reflecting 2290 Type HS Reflecting 2284 Type HS Reflecting 2500 Type R Reflecting	(a) For Table Mounting with 2147 Bracket (b) For Wall Mounting with Horizontal Projection with 2146 Bracket	(a) 2100 Lamp and Scale (b) 2112 Lamp and Scale (c) Telescope and Scale consisting of: 2197 Telescope PI-156 Arm 2170-A Curved Scale (d) 2196 Telescope and Scale
	(c) Wall Mounting with Vertical Projection with 2146 Bracket	(a) 2100 Lamp and Scale with 2104 Mirror and 2178 Prism
	(d) Julius Suspension with Horizontal Projection (e) Julius Suspension with Vertical Projection	(a) 2100 Lamp and Scale (b) 2100 Lamp and Scale with 2104 Mirror and 2178-S Prism
2239 Type P 2450 Astatic Dynamometer	(a) For Table Mounting with 2126 Tripod (b) For Wall Mounting with 2127 Bracket	(a) 2100 Lamp and Scale (b) 2111 Lamp and Scale (c) Telescope and Scale with 2170 Curved Scale or 2171 Straight Scale
2270 Coblentz	Customer Design	(a) 2196 Telescope and Scale
2570 A-C High Sensitivity 2255 Marine	(a) For Table Mounting with 2147 Bracket (b) For Wall Mounting with Horizontal Projection with 2146 Bracket	(a) 2100 Lamp and Scale (b) 2112 Lamp and Scale (c) Telescope and Scale consisting of: 2197 Telescope PI-156 Arm 2170-A Curved Scale (d) 2196 Telescope and Scale
	(c) Wall Mounting with Vertical Projection with 2146 Bracket	(a) 2100 Lamp and Scale with 2104 Mirror and 2178 Prism
2350 A-C Vibration 2351 A-C Vibration	(a) For Table Mounting with 2147 Bracket (b) For Wall Mounting with Horizontal Projection with 2146 Bracket	(a) 2100 Lamp and Scale (b) 2112 Lamp and Scale
	(c) Wall Mounting with Vertical Projection with 2146 Bracket	(a) 2100 Lamp and Scale with 2104 Mirror and 2178 Prism
2440 HS Astatic Dynamometer	Integral Wall Mounting	(a) 2100 Lamp and Scale (b) 2196 Telescope and Scale

2126 Table Tripod
about 1/7 actual size)

2127 Wall Mounting
(about 1/7 actual size)



2147 Wall or Table Bracket
(about 1/6 actual size)



2162 Julius Suspension and 2161 Wood Supports
(about 1/7 actual size)

GALVANOMETER AND DYNAMOMETER ACCESSORIES

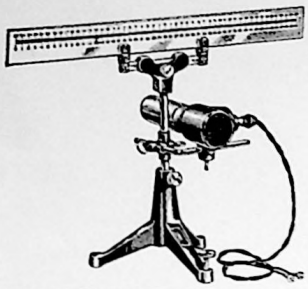
GALVANOMETER MOUNTINGS

Devices are here listed for mounting a galvanometer on a table or on a wall. Mountings for 2239 and 2450 Galvanometers are provided with leveling screws. All of the devices are suitable for use with a prism, lamp and scale.

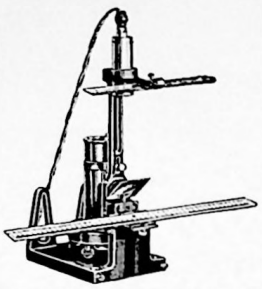
The Julius Suspension is designed for Type HS and Type R galvanometers. The wood supports for the oil vessels are not supplied as a part of the equipment, but are listed as a separate item. The Julius Suspension, when properly adjusted, brings the center of oscillation of the whole mass to the center of suspension of the galvanometer system. Horizontal component of vibration is damped by vanes in oil, and the oscillation is so small that the moving system is not appreciably disturbed.

2126	TABLE TRIPOD, WITH LEVELING SCREWS. *For 2239 Galvanometer and 2450 Dynamometer*	$ 7.00
2127	WALL MOUNTING, WITH LEVELING SCREWS. *For 2239 Galvanometer and 2450 Dynamometer*	7.00
2146	WALL BRACKET. *For 2284, 2285, 2290, 2350, 2500 and 2570 Galvanometers*	7.00
2147	WALL OR TABLE BRACKET. *Same as 2146, but with legs for table mounting*	10.00
2162	JULIUS SUSPENSION. *For 2284, 2285, 2290, 2350 and 2500 Galvanometers.* For mounting to overcome effect of vibration.	60.00
Std. 3323-AN	SPIRAL SPRINGS. *For insertion in suspending cables of 2162 Julius Suspension to minimize any vertical vibration which may exist.*	Each $0.15; (6) $0.54; (12) $0.84
2161	WOOD SUPPORTS, set of three. *For holding oil vessels of 2162*	7.50
2162-A1	JULIUS SUSPENSION ASSEMBLY. *Includes 2162 Julius Suspension, 2161 Wood Supports and three Std. 3323-A N Spiral Springs.*	67.50

Note: Prices listed may of course be changed without notice. Formal quotations, made on request, are always good for 30 days



2100 Lamp and Scale
(about 1/13 actual size)



2112 Lamp and Scale with Type R Galvanometer and 2146 Wall Bracket (about 1/12 actual size)

LAMP-AND-SCALE READING DEVICES

The Lamp-and-Scale Reading Devices listed below are for reading deflections of a galvanometer with a plane mirror and a convex lens, or with a concave mirror. The scales may be arranged in various ways as shown on page 23.

The reading is indicated by a bright spot of light, split by an index line, which is reflected to the scale from the mirror on the moving coil of the galvanometer.

In lecture room demonstration involving the use of a galvanometer, the behavior of the galvanometer can be exhibited to a large group by means of the Lecture Room Lamp-and-Scale Assembly listed below. The manner in which it is used is indicated on page 27. When the scale is mounted at an appropriate height, the deflections of a galvanometer below it can be observed from almost any position in the room. The illuminating device projects a light image which can be seen clearly in diffused daylight.

The Scale is approximately ten feet long and six inches wide. It is supported on a frame for fastening it to the wall, holding it at an angle of 45 degrees to the wall. It has a white matte opaque surface, with broad scale divisions. The graduations are heavy lines in black on one side of a central zero and red on the other side. The frame supports the scale at such a distance from the wall that it can be mounted above a roller curtain, or screen for lantern slides, so that neither device will interfere with the use of the other.

The Illuminating Device has a 50 candlepower automobile lamp in a housing at one end of the lighting tube, with a lens in a focusing adjustment at the other end. The device is fitted with a bracket for mounting it on a wall. The distance of the lighting tube from the galvanometer is governed chiefly by that between the galvanometer and the scale, the limit of which, for a bright image, is about ten feet.

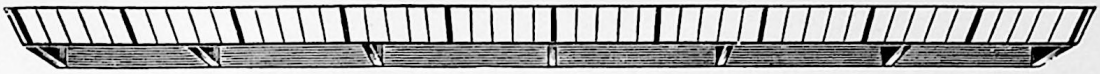
For brilliant illumination the lamp is lighted with current at 6 to 8 volts, which is obtained from 115 or 230-volt alternating current by use of the Transformer included in the assembly. When alternating current is not available, the lamp can be lighted from a six-volt storage battery.

The reflecting Prism is a right angle prism mounted on a bracket for attaching it to the front of the galvanometer case. It is held in place by a thumb screw, supplied with it, which is substituted for one of the screws in the case. The position of the prism in front of the mirror is adjustable in different directions.

A 2239 Galvanometer is shown on page 27 with the Lecture Room Lamp and Scale simply to illustrate the manner in which the prism is attached. Practically, this reading device can be used with any wall type mirror galvanometer such as the 2500, 2285 and 2284 as well as the 2239. None of these galvanometers is included as part of the assembly as listed below.

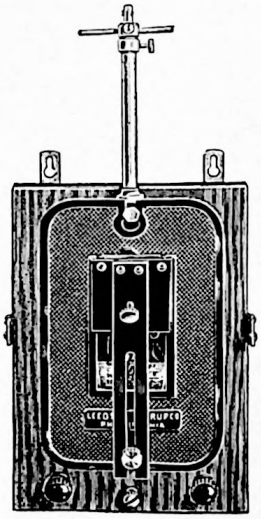
2050-A1	**LECTURE ROOM LAMP-AND-SCALE ASSEMBLY** *For 115-volt, 60-cycle circuit.* Includes 2050 Opaque Scale (about 10½ feet long), 2051 Illuminating Device, 2178-A Prism and 10608 Transformer.	$112.00
2050-A2	**LECTURE ROOM LAMP-AND-SCALE ASSEMBLY** *For 115-volt, 25-cycle circuit.* Includes 2050 Opaque Scale (about 10½ feet long), 2051 Illuminating Device, 2178-A Prism and 10607 Transformer.	114.00
2100	**LAMP AND SCALE** 6-volt lamp. Half-meter scale, etched on heavy plate glass with 500 mm divisions, marked 0-50 and 25-0-25.	30.00
2110	**LAMP AND SCALE** 6-volt lamp. One-meter paper scale on metal strip, 1000 mm divisions, marked 0-100. Equipped with mirror and light shield.	110.00
2111	**LAMP AND SCALE** *For mounting on front of 2239 Galvanometer.* Provides a galvanometer sensitivity for half-meter scale distance.	45.00
2112	**LAMP AND SCALE** *For mounting on front of 2284, 2285, 2290 and 2500 Galvanometers.* Includes 2111-P1 Band and Counterweight. Provides a galvanometer sensitivity for half-meter scale distance.	50.00

LAMPS AND SCALES AND THEIR PARTS FOR THE LECTURE ROOM

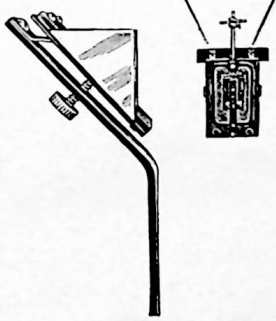


2050 Opaque Scale

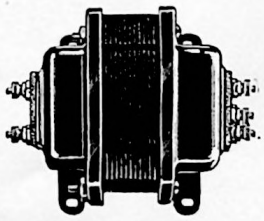
The parts of the Lecture Room Lamp-and-Scale Assembly, which are shown separately on this page, are described on pages 28 and 29. Their relation to each other when assembled for use is indicated in the surrounding diagram. The large Scale, shown above, is fastened to a wall in an elevated position, and a galvanometer is mounted about ten feet below the middle of the scale. A galvanometer on a wall mounting is preferable, but one set on a table or shelf can be used. The Illuminating Device is fastened to the wall directly above the galvanometer. The Transformer for lighting the lamp can be fastened wherever it is convenient. The Prism is set in front of the galvanometer to reflect rays from the lighting tube upon the galvanometer mirror, and from the mirror to the scale.



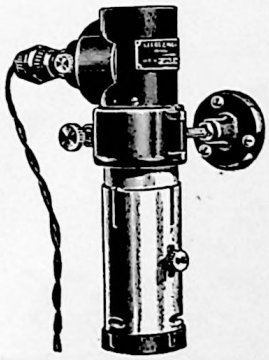
2239 Galvanometer Showing Prism in Place



2178-A Prism



10608 Transformer



2051 Illuminating Device

PARTS FOR LAMP-AND-SCALE READING DEVICES

2050	**OPAQUE SCALE** *For 2050-A1 and 2050-A2 Lecture Room Lamp-and-Scale Assemblies.* Length, about 10½ feet.	$46.00
2051	**ILLUMINATING DEVICE** *For 2050-A1 and 2050-A2 Lecture Room Lamp-and-Scale Assemblies.* Has 6-volt, 50-cp lamp.	46.50
2178-A	**PRISM** *For galvanometer used with 2050-A1 or 2050-A2 Lecture Room Lamp-and-Scale Assembly*	12.50
2099	**ILLUMINATING DEVICE AND BRACKETS** *For 2100 Lamp and Scale*	15.00
Std. 309	**ETCHED PLATE GLASS SCALE** *For 2100 Lamp and Scale.* Two sets of graduations: 0-50 and 25-0-25.	5.00
Std. 309-1	**ETCHED PLATE GLASS SCALE, Graduations 0-50**	5.00
2104	**MIRROR** *For use with galvanometer mounted above 2100 Lamp and Scale*	10.00
2178	**PRISM** *For use with galvanometer mounted above 2100 Lamp and Scale.* Includes bracket for mounting in front of galvanometer.	10.00
2178-S	**PRISM** *For use with 2284, 2285 and 2500 Galvanometers when mounted on 2162 Julius Suspension*	15.00
2111-P1	**BAND AND COUNTERWEIGHT** *For adapting 2111 Lamp and Scale for use on 2500, 2284, 2285 and 2290 Galvanometers*	5.00
Std. 587-A	**LENS** *For using lamp and scale with galvanometer having plane mirror.* 1-meter focus. Fits lens holders on all L&N Galvanometers.	0.50
Std. 587-B	**LENS** *Same as Std. 587-A, except ⅓-meter focus*	0.50
Std. 589-A	**LENS** *Same as Std. 587-A, except ½-meter focus*	0.50
Std. 587-C	**LENS** *Same as Std. 587-A, except 2-meter focus*	1.50

LAMPS

Std. 307	**LAMP, STRAIGHT-FILAMENT TYPE** *For 2420 Galvanometers having the following serial numbers: 218951 and below; 219001; 219052 to 219056 inclusive; 219060 to 219068 inclusive; 219612 and 219613. Also for 2470 Galvanometers having serial numbers 218280 and below.* Note: Any galvanometer, having above serial numbers, which has been converted from old straight filament lamp to present automobile tail-light type, will require Std. 3038 Lamp.	Each, $1.00; (12) $10.00
Std. 3038	**LAMP** *For 2460 Dynamometer and all 2420 and 2470 Galvanometers other than those having serial numbers listed above under Std. 307.* Mazda No. 64, 6-volt, 3-cp.	Each, $0.50; box of 10, $2.00
Std. 2544	**LAMP** *For 2100, 2110, 2111 and 2112 Lamps and Scales.* Mazda No. 1130, 6-volt, 21-cp.	Each, $0.50; box of 10, $2.00
Std. 2544-B	**LAMP** *For 2051 Illuminating Device.* Mazda No. 1184, 6-volt, 50-cp.	Each, $0.50; box of 10, $2.00

TRANSFORMERS AND CURRENT LIMITING RESISTORS

10608	**TRANSFORMER**..... *For operating 2051 Illuminating Device.* Operates on 115 volts, 60 cycles. Output, 6 volts.	$7.00
10607	**TRANSFORMER**..... *For operating 2051 Illuminating Device on 25-cycle circuit.* Otherwise same as 10608.	9.00
10609	**TRANSFORMER**..... *For operating lamp in 2100, 2110, 2111 or 2112 Lamp and Scale, in 2420 or 2470 Galvanometer or in 2460 Dynamometer.* Operates on 115 volts, 60 cycles. Output, 5 volts.	4.00
Std. 1178-26	**TRANSFORMER**..... *Operates on 230 volts. 60 cycles. Output, 5 volts.*	4.00
10610	**TRANSFORMER**..... *For operating lamp in 2100, 2110, 2111 or 2112 Lamp and Scale, in 2420 or 2470 Galvanometer or in 2460 Dynamometer on 25-cycle circuit.* Otherwise same as 10609.	7.50
10766	**RESISTANCE UNIT**..... *For operating lamp in 2100, 2110, 2111 or 2112 Lamp and Scale on 115 volts d-c*	4.50
10767	**RESISTANCE UNIT**..... *For operating lamp in 2420 or 2470 Galvanometer or in 2460 Dynamometer on 115 volts d-c*	6.50

TELESCOPE-AND-SCALE READING DEVICES

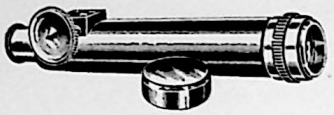
Telescopes and scales are used for reading deflections of galvanometers with plane mirrors. The 2149 Telescope-and-Scale Reading Device is convenient for use with galvanometers like the Types HS and R. It includes a telescope and scale and a galvanometer mounting bracket, which is designed to hang from the wall or to stand on a table. The scale is curved to avoid tangent error when used with a galvanometer having a radial field. The assembly without the legs is listed as 2148.

For Type P galvanometers, we provide the 2170 and 2171 Telescope-and-Scale Reading Devices. The telescope arm of these devices attaches directly to the galvanometer. The 2170 includes a curved scale, and the 2171 a straight scale. The curved scale is for the 2239-d and 2239-e Galvanometers. For other 2239 Galvanometers, and also for the 2450 Dynamometer, the straight scale is recommended, as these instruments do not have radial fields and the tangent error with a straight scale tends to offset the cosine error due to lack of radial field.

A telescope-and-scale device on a tripod base is used to read deflections of a galvanometer with a plane mirror at various distances from the scale. Apparent galvanometer sensitivity and ease of reading vary according to this distance. These devices are supplied in two grades, one for student use and one for precise investigational work. Both have straight scales and altitude and azimuth adjustments.

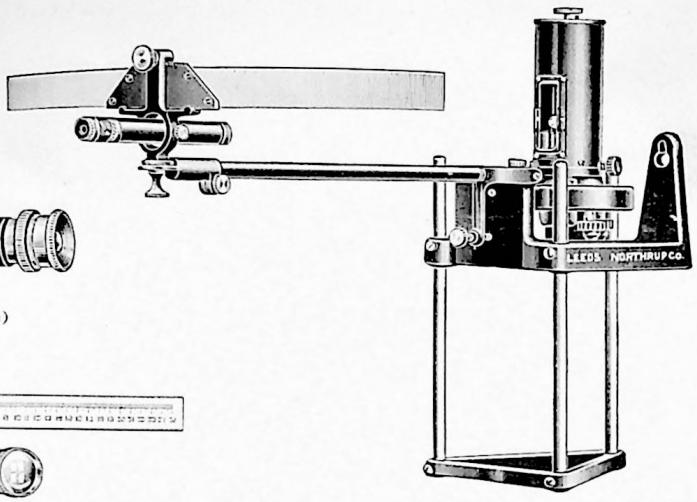
ATTACHABLE TELESCOPES AND SCALES

2148	**WALL BRACKET WITH TELESCOPE, ARM AND CURVED SCALE**..... *For 2290, 2284, 2285, 2500, 2255, 2570, 2350 and 2351 Galvanometers.* Includes 2146 Wall Bracket, 2197 Telescope, PI-156 Arm and 2170-A Scale. Magnification 4 diameters. Scale has 500 mm divisions, marked 25-0-25.	$34.00
2149	**WALL OR TABLE BRACKET WITH TELESCOPE, ARM AND CURVED SCALE** *For 2290, 2284, 2285, 2500, 2255, 2570, 2350 and 2351 Galvanometers.* Same as 2148 but with legs for table mounting.	37.00
2170	**TELESCOPE, ARM AND CURVED SCALE**..... *Especially suitable for 2239 Ballistic Galvanometer.* Includes 2197 Telescope with 2174 Arm and 2170-A Curved Scale. Magnification 4 diameters. Scale has 500 mm divisions, marked 25-0-25. Arm attaches to galvanometer frame.	23.00
2171	**TELESCOPE, ARM AND STRAIGHT SCALE**..... *For 2239 Galvanometer and 2450 Dynamometer.* Includes 2197 Telescope with 2174 Arm and 2171-A Straight Scale. Magnification 4 diameters. Scale has 500 mm divisions, marked 25-0-25. Arm attaches to galvanometer frame.	19.00

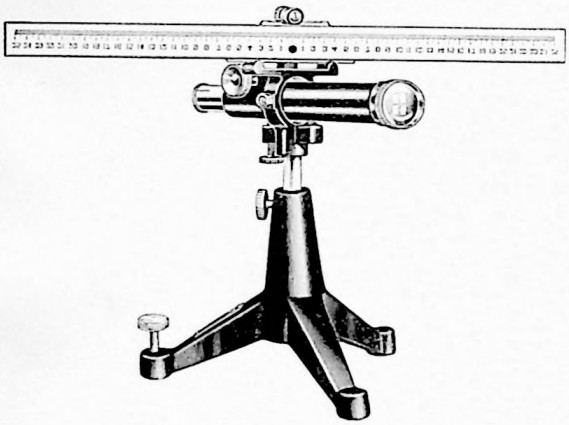


2198 Telescope
about 1/4 actual size)

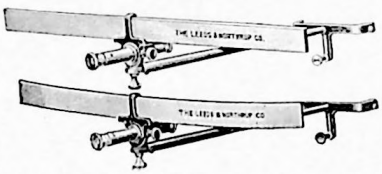
2197 Telescope
(about 1/3 actual size)



2149 Wall or Table Bracket with Telescope, Arm and Curved Scale (about 1/6 actual size)



2195 and 2196 Telescope and Scale
(about 1/6 actual size)



Upper: 2171 Telescope, Arm and Straight Scale. Lower: 2170 Telescope, Arm and Curved Scale (about 1/12 actual size)

SEPARATE TELESCOPES AND SCALES

2196 **TELESCOPE AND SCALE** **$80.00**
Magnification 12 diameters. On tripod base with leveling screws, and altitude and azimuth adjustments. Scale, on metal strip, has 500 mm divisions, marked 25-0-25.

2195 **TELESCOPE AND SCALE** **39.00**
Magnification 4 diameters; otherwise similar to 2196.

PARTS FOR TELESCOPE-AND-SCALE READING DEVICES

2170-A **CURVED SCALE, MOUNTED** ..... **$ 9.00**
For 2170 Telescope and Scale. Has 500 mm divisions, marked 25-0-25.

2171-A **STRAIGHT SCALE, MOUNTED** **5.00**
For 2171 Telescope and Scale. Has 500 mm divisions, marked 25-0-25.

2174 **ARM** **5.00**
For 2170 or 2171 Telescope and Scale. Fits 2239 Galvanometer and 2450 Dynamometer.

PI-156 **ARM** **9.00**
For 2146, 2147, 2148 or 2149 Bracket

2198 **UNMOUNTED TELESCOPE** **40.00**
For 2196 Telescope and Scale. Magnification 12 diameters.

2197 **UNMOUNTED TELESCOPE** **9.00**
For 2148, 2149, 2170 or 2195 Reading Device. Magnification 4 diameters.

CARDBOARD SCALES FOR GALVANOMETER READING DEVICES

UNMOUNTED

Divisions, mm	Graduated	List No.	Price
500	0-50 (inverted)	Std. 884	$0.25
500	0-50 (upright)	Std. 885	0.25
500	25-0-25 (inverted)	Std. 875	0.25
500	25-0-25 (upright)	Std. 888	0.25
500	Unnumbered	Std. 881	0.25
1000	0-100 (inverted)	Std. 882	0.50
1000	50-0-50 (inverted)	Std. 883	0.50

MOUNTED ON METAL STRIP

For Replacement In	Divisions, mm	Graduated	List No.	Price
Straight Scales, Without Rack Plate				
2171, 2171-A	500	0-50	2180-2	$1.50
2171, 2171-A	500	25-0-25	2180-4	1.50
2171, 2171-A	500	Unnumbered	2180-6	1.50
Straight Scales, With Rack Plate				
2110	1000	0-100 (inverted)	2180-8	4.00
2110	1000	50-0-50 (inverted)	2180-10	4.00
2111, 2112	500	0-50 (upright)*	2180-12	3.50
2195, 2196	500	0-50 (inverted)*	2180-12	3.50
2111, 2112	500	25-0-25 (upright)*	2180-14	3.50
2195, 2196	500	25-0-25 (inverted)*	2180-14	3.50
2111, 2112, 2195, 2196	500	Unnumbered	2180-16	3.50
Curved Scales, With Rack Plate				
2170, 2170-A, 2148, 2149	500	0-50	2180-18	3.50
2170, 2170-A, 2148, 2149	500	25-0-25	2180-20	3.50
2170, 2170-A, 2148, 2149	500	Unnumbered	2180-22	3.50

*When ordering, specify whether upright or inverted after list number.

AYRTON SHUNTS

An Ayrton shunt is used with a galvanometer to obtain reduced current sensitivities. The marking at each shunt switch position indicates the ratio of resistance between shunt switch and fixed terminal, to total shunt resistance.

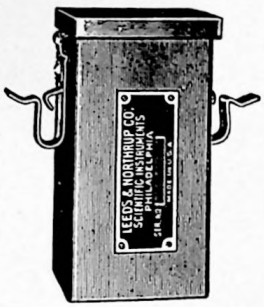
Where the measured circuit resistance is very high compared with the Ayrton shunt resistance (as in insulation resistance measurements and in ballistic galvanometer measurements of capacitance) the effective current sensitivity is reduced proportionately to the calibrated values on the shunt. For these cases the Ayrton shunt resistance should be high in order that high sensitivity be available on unit setting, but of a value to damp the galvanometer satisfactorily.

For external circuit resistances comparable to the Ayrton shunt resistance the calibrated values no longer produce proportional galvanometer deflections. The effective sensitivity of the shunt and galvanometer combined with the measured circuit, must be calculated or determined experimentally. Likewise, the damping effect of the shunt and external circuit combined must be considered.

Shunts 2115, and 2165 to 2167 inclusive, have substantial exposed studs and switch with calibrated ratios of 1.0, 0.1, 0.01, 0.001, 0.0001, zero (short circuiting external circuit) and INF (open circuiting external circuit). Shunt 2164 has an additional ratio of 0.000 01.

Intended primarily for student use, 2116 Shunt has enclosed type switch and studs with calibrated ratios of 1.0, 0.1, 0.01, 0.001, zero and INF. Total resistance about 10,000 ohms, critically damps 2239-a Type P Ballistic Galvanometer, and is satisfactory for use with Type P Galvanometers ordinarily used for insulation resistance measurements.

2165 Ayrton Shunt



4198-A Mounted Resistor

2116 Students' Ayrton Shunt

2164	**AYRTON SHUNT** *100,000 ohms.* Multipliers 1, 0.1, 0.01, 0.001, 0.0001, 0.000 01, 0 and infinity. Limit of error of ratios ±0.1 per cent. Molded bakelite case.	$45.00
2165	**AYRTON SHUNT** *40,000 ohms.* Multipliers 1, 0.1, 0.01, 0.001, 0.0001, 0 and infinity. Limit of error of ratios ±0.1 per cent. Molded bakelite case.	35.00
2115	**AYRTON SHUNT** *25,000 ohms; otherwise same as 2165.*	30.00
2166	**AYRTON SHUNT** *10,000 ohms; otherwise same as 2165.*	27.50
2167	**AYRTON SHUNT** *3,000 ohms; otherwise same as 2165.*	25.00
2116	**STUDENTS' AYRTON SHUNT** *10,000 ohms.* Multipliers 1, 0.1, 0.01, 0.001, 0 and infinity. Limit of error of ratios ±0.1 per cent. Molded bakelite case.	18.00

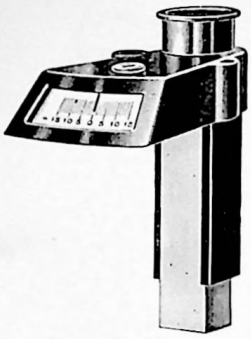
DAMPING COILS

4198-A	**MOUNTED RESISTOR** *For damping galvanometer or for protecting galvanometer, standard cell or other instrument against excessive current.* Resistance 10,000 ohms. Limit of error ±2 per cent.	$5.50
4198-X	**MOUNTED RESISTOR** *Resistance as specified between 1,000 and 10,000 ohms; otherwise same as 4198-A.*	6.00
4199-A	**MOUNTED RESISTOR** *Resistance 100 ohms; otherwise same as 4198-A.*	3.50
4199-B	**MOUNTED RESISTOR** *Resistance 300 ohms; otherwise same as 4198-A.*	3.50
4199-X	**MOUNTED RESISTOR** *Resistance as specified below 1,000 ohms; otherwise same as 4198-A.*	4.00
Std. 3164-3	**RESISTOR** *For damping 2500-b Galvanometer in low-resistance glass-electrode measurements.* Resistance about 10,000 ohms.	3.00

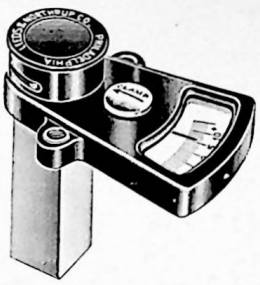
GALVANOMETER REPAIR KITS

2139	**REPAIR KIT** *For 2239 Galvanometer.* Wooden box containing six upper and three lower suspensions, three suspension terminals, two pairs of tweezers and a jeweler's screw driver. Add letter to list number to specify characteristics of galvanometer.	$7.00
2509	**REPAIR KIT** *For 2500 Galvanometer; otherwise same as 2139.*	7.00

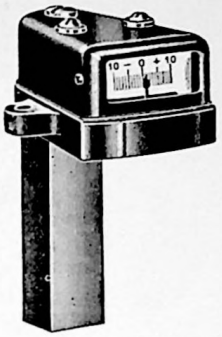
Note: When galvanometer characteristics require copper suspensions, four upper suspensions and three lower suspensions are supplied.



PI-50 System



PI-24 System



PI-36 System

PI-102 System

GALVANOMETER AND DYNAMOMETER PARTS

Galvanometer systems, removable coils and suspensions, suspension material, and mirrors are listed on this and the following page.

Many users keep on hand extra systems, not simply as replacements, but for obtaining a choice of galvanometer characteristics without buying a complete galvanometer for each. The various systems for any one type of galvanometer are interchangeable.

SYSTEMS

For Galvanometer No.	Consists of:	System* No.	Price
2285	System	2286	$75.00
2310	System	PI-50	15.00
2320 or 2322	System	PI-24	10.00
2330	System	PI-36	11.00
2370	System	PI-29	12.00
2380	System	PI-29-1-A	45.00

For Galvanometer No.	Consists of:	System* No.	Price
2420	System	PI-102	$16.00
2440	Moving System	2448	75.00
2450	Moving System	2458	35.00
.....	PI-50 System, Magnet and Set of Parts for Panel Mounting**	2314	20.00
.....	PI-24 System, Magnet and Set of Parts for Panel Mounting**	2324	11.20

NEW SYSTEMS SUPPLIED ON A FURNISH-CREDIT BASIS:

When a PI-24, PI-36 or PI-29 Galvanometer System is returned to us for repair, we can render faster and more satisfactory service by sending our customer a new system immediately, instead of awaiting repairs on the damaged one. In billing, we credit the old system toward the cost of the new.

PI-24 System is replaced for $4.50. (New system, $10.00; credit for old system $5.50). If replaced system is an old style PI-24, without clamp, or PI-10, with brass case and without clamp, the charge is $7.50. (New system $10.00; credit for old system $2.50).

PI-36 System is replaced for $4.50. (New system $11.00; credit for old system $6.50).

PI-29 System is replaced for $4.50. (New system $12.00; credit for old system $7.50). If replaced system is the old style without clamp, or with brass case and without clamp, the charge is $9.50. (New system $12.00; credit for old system $2.50).

COILS WITH MIRRORS

For Use With Galvanometer	List No. of Coil with Mirror*	Price
2239-a, b or c	2238	$8.00
2239-d or e	2238	10.00
2239-f	2238	14.00
2500	2508	8.00
2285-d or e	2288†	15.00

Note: Prices listed may of course be changed without notice. Formal quotations, made on request, are always good for 30 days.

*Add letter to list number to specify characteristics of galvanometer.

**Specify panel material and thickness.

†Suspensions for these two types of galvanometers are removable. Suspensions for all other Type HS Galvanometers are soldered on and replacement of coils or suspensions should be done at our plant.

SUSPENSIONS

For Galvanometer	Size,* Inch	Material**	Length Centi-meters	Torsion	List No.	Price		
						Each	Box of 3	Box of 6
2239-a Upper	0.003	Gold Strip 14K	13.5	1.54	Std. 656	$0.50		$2.00
Lower	0.0015	Gold Strip 14K		Negligible	Std. 660	0.75	$1.50	
2239-b Upper	0.0015	Gold Strip 14K	13.5	0.09	Std. 659	0.50		2.00
Lower	0.0015	Gold Strip 14K		Negligible	Std. 660	0.75	1.50	
2239-c Upper	0.002	Gold Strip 24K	13.5	0.16	Std. 662	0.50		2.00
Lower	0.002	Gold Strip 24K		Negligible	Std. 661	0.75	1.50	
2239-d Upper	0.0015	Gold Wire 14K	13.5	0.59	Std. 659-A	0.50		2.00
Lower	0.0015	Gold Strip 14K		Negligible	Std. 660	0.75	1.50	
2239-e Upper	0.002	Gold Strip 14K	13.5	0.36	Std. 662-B	0.50		2.00
Lower	0.0015	Gold Strip 14K		Negligible	Std. 660	0.75	1.50	
2239-f Upper	0.0015	Gold Strip 14K	13.5	0.09	Std. 659	0.50		2.00
Lower	0.0015	Gold Strip 14K		Negligible	Std. 660	0.75	1.50	
2284-a Upper	0.0015	Copper Strip	6.5	0.075	Special	0.75		
Lower	0.001	Copper Strip		Negligible	Std. 664-BC	1.00		
2284-b Upper	0.0007	Copper Strip	6.5	0.009	Std. 663-AC	0.75		
Lower	0.0007	Copper Strip		Negligible	Std. 664-AC	1.50		
2284-c Upper	0.0007	Copper Strip	6.5	0.009	Std. 663-AC	0.75		
Lower	0.0007	Copper Strip		Negligible	Std. 664-AC	1.50		
2284-d Upper	0.0007	Copper Strip	6.5	0.009	Std. 663-AC	0.75		
Lower	0.0007	Copper Strip		Negligible	Std. 664-AC	1.50		
2285-a Upper	0.0007	Copper Strip	6.5	0.009	Std. 663-AC	0.75		
Lower	0.0007	Copper Strip		Negligible	Std. 664-AC	1.50		
2285-b Upper	0.001	Copper Strip	6.5	0.030	Std. 663-DC	0.75		
Lower	0.0007	Copper Strip		Negligible	Std. 664-AC	1.50		
2285-d Upper	0.001	Copper Strip	5.5	0.036	Std. 663-BC	0.75		
Lower	0.001	Copper Strip		Negligible	Std 664-BC	1.00		
2285-e Upper	0.001	Copper Strip	5.5	0.036	Std. 663-BC	0.75		
Lower	0.001	Copper Strip		Negligible	Std. 664-BC	1.00		
2285-f Upper	0.0007	Gold Strip 24K	6.5	0.009	Std. 663-A	1.00		5.00
Lower	0.0007	Gold Strip 24K		Negligible	Std. 664-A	1.50	4.00	
2285-g Upper	0.0015	Copper Strip	6.5	0.075	Special	0.75		
Lower	0.001	Copper Strip		Negligible	Std. 664-BC	1.00		
2285-h Upper	0.0025	Gold Strip 14K	6.5	1.28	Special	1.00		5.00
Lower	0.002	Gold Strip 24K		Negligible	Std. 661	0.75	1.50	
2290 Upper	0.0007	Gold Strip 24K	6.5	0.009	Std. 663-A	1.00		5.00
Lower	0.0007	Gold Strip 24K		Negligible	Std. 664-A	1.50	4.00	
2440 Upper	0.002	Gold Strip 24K	7.5	0.29	2446	0.50		2.00
Lower	0.0007	Gold Strip 24K		Negligible	2447	0.75	1.50	
2450 Upper	0.002	Gold Strip 14K	11.5	0.42	2456	0.50		2.00
Lower	0.0015	Gold Strip 14K		Negligible	2457	0.75	1.50	
2500-a Upper	0.0015	Copper Strip	5.5	0.089	Std. 663-EC	0.75		
Lower	0.001	Copper Strip		Negligible	Std. 664-BC	1.00		
2500-b Upper	0.0015	Gold Strip 24K	5.5	0.089	Std. 663-E	0.50		2.00
Lower	0.001	Gold Strip 24K		Negligible	Std. 664-B	0.75	1.50	
2500-c Upper	0.0015	Copper Strip	5.5	0.089	Std. 663-EC	0.75		
Lower	0.002	Copper Strip		Negligible	Std. 661-C	1.00		
2500-e Upper	0.002	Gold Strip 14K	5.5	0.89	D-45-A	0.50		2.00
Lower	0.001	Gold Strip 24K		Negligible	Std. 664-B	0.75	1.50	
2500-f Upper	0.0007	Gold Strip 24K	5.5	0.011	Std. 663-F	0.50		2.00
Lower	0.0007	Gold Strip 24K		Negligible	Std. 664-A	1.50	4.00	
2500-g Upper	0.0015	Gold Strip 24K	5.5	0.089	Std. 653-E	0.50		2.00
Lower	0.001	Gold Strip 24K		Negligible	Std. 664-B	0.75	1.50	

*Size is the diameter of wire before rolling. Length is the effective length (not including tips). Torsion is dyne-centimeters per radian twist for the particular suspension.

**Gold suspensions supplied in boxes of one, three or six. Copper suspensions supplied in sealed glass tubes, one suspension per tube.

SUSPENSION MATERIAL

List No.	Material	Size, Inch	Torsion, 10 Cm	Res., 10-Cm Strip
Std. 1105	14K Au	0.0015	0.12	13.0
Std. 1106	14K Au	0.0020-S	0.39	7.0
Std. 1107	14K Au	0.002	0.49	6.5
Std. 1108	14K Au	0.0025	1.40	5.0
Std. 1109	14K Au	0.003	2.05	3.5
Std. 1110	14K Au	0.004	7.30	1.8
Std. 1111	24K Au	0.0007	0.006	9.0

List No.	Material	Size, Inch	Torsion, 10 Cm	Res., 10-Cm Strip
Std. 1112	24K Au	0.001	0.021	4.0
Std. 1113	24K Au	0.0015	0.049	2.5
Std. 1114	24K Au	0.002	0.22	1.0
Std. 1115	Cu	0.0007	0.006	8.0
Std. 1116	Cu	0.001	0.02	3.5
Std. 1117	Cu	0.0015	0.049	2.2

Note: Spools of suspension material with constants listed above are: for sizes 0.0015 inch and up, $1.00 per 2-foot spool; for sizes 0.001 inch and below, $2.00 per 2-foot spool. If wire is wanted, add W to the list number.

MIRRORS

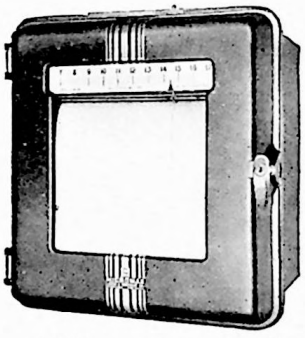
Concave Mirrors (1-meter radius)		
Diameter, Inch	List No.	Price
1/4	Std. 1142-2	$1.50
3/8	Std. 1142-3	1.50
1/2	Std. 1142-4	1.50
5/8	Std. 1142-5	1.50

Plane Mirrors		
Diameter, Inch	List No.	Price
1/4	Std. 1143-2	$1.50
3/8	Std. 1143-3	1.50
1/2	Std. 1143-4	1.50
5/8	Std. 1143-5	1.50

AUTOMATIC INSTRUMENTS WIDELY USED IN THE LABORATORY

Wherever laboratory technicians require a reliable, continuous guide to a quantity measurable in terms of resistance or potential change, you're likely to see L&N electrical balance-type measuring instruments providing the needed data. These instruments can be supplied to indicate, record . . . or to control a given variable automatically. Used extensively in industry, they provide such high accuracy that they also have scores of exacting applications in the research laboratory, the experimental station, the technical school, and the college. Featured below and on the next page are the various Micromax instrument models available. Also described and pictured below is the Speedomax Recorder, used whenever unusually fast or detailed recording is required. For an index to the various quantities measured by these instruments, turn to the table on page 36.

TO DRAW A DETAILED RECORD AUTOMATICALLY . . .



Height . . . . . 20"

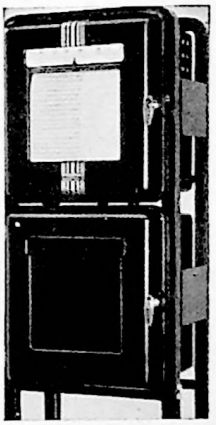
Model S Micromax records on a wide strip-chart (over-all width 10 1/16"; calibrated width 9 7/8"), which travels downward over a flat metal plate and rerolls. Every *curve-drawing* Model S has a pen which draws an unbroken red-ink record when the instrument is single-point . . . either a continuous line or a dot-and-dash when the instrument is two-point. Every *curve-printing* Micromax has a print-wheel with a motor-driven switch that connects one after the other of its 2, 3, 4, 5, 6, 8, 10, 12 or 16 detectors. Model S indicates on a clearly-calibrated scale and can be supplied to operate any type of control, from a simple two-position up to and including Micromax Electric or Micromax Pneumatic Control. It's available as an automatically standardized potentiometer for use with thermocouple or Rayotube or pH electrode . . . as a Wheatstone or Kelvin bridge with Thermohm, and as an a-c recorder for electrolytic conductivity, frequency, etc. Many experimenters, of course, arrange their own measuring circuits. More detailed information about the Model S for temperature measurements with thermocouples, is given in Catalog N-33A(1); with Rayotubes, in Catalog N-33B; with Thermohms, in Catalog N-33C. In addition, publications discussing the Model S for measuring other quantities are listed on page 37.

TO INDICATE WITH UNUSUAL CLEARNESS . . .

Model R Micromax Recorder has a big black pointer which moves around an extra-bold circular scale of 28" calibrated circumference. At the same time a pen records continuously on a 24-hour round chart, with straight radial lines. The instrument can be supplied to record one point continuously or two points alternately . . . can be equipped to operate signals, alarms, or a variety of automatic controls, including Micromax Electric Control. Model R is available for most of the Model S uses previously listed. Further details of the Model R for use with thermocouples are given in Catalog N-33A(2); with Rayotubes, in Catalog N-33B; with Thermohms, in Catalog N-33C. For applications to other measurable quantities refer to the list of specific publications on page 37.

Height . . . . . 16-3/8"

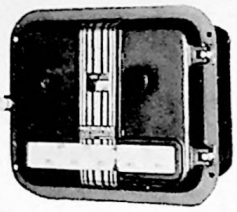
TO RECORD TEMPERATURES WITH UNUSUAL SPEED . . .



Height mounted on Stationary Rack . . 42-1/4"

the pen of a Speedomax instrument sweeps all the way across its wide strip-chart in approximately 1½ seconds. A black pointer moves across a bold scale so a technician can easily "take a reading" from a distance of ten feet or more. Designed to measure temperature of moving objects through the use of a quick-acting Rayotube which sights on a surface to be measured. (It can be supplied for use with a thermocouple.) In addition it can be used to measure radio field strength, and for other applications which require exceptional speed. The instrument employs vacuum tubes to amplify the voltage being measured, and balance is achieved by means of a reversing motor. For additional information, request Catalog N-33B.

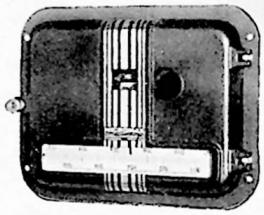
TO CONTROL AND TO INDICATE TEMPERATURE—NO RECORD . . .



Height.....12-13/16"

Model C Micromax holds the measured condition within narrow limits. Indicating scale has two pointers . . . a black one to show actual temperature, a red one to show control-point setting. Adapted to two-position and to Micromax Electric Control, Model C can be supplied as a potentiometer for use with thermocouple or Rayotube . . . as a Wheatstone or Kelvin bridge for use with Thermohm. When supplied as a potentiometer, it checks its circuit automatically at frequent intervals against a standard cell. Further details about Model C for temperature measurements with a thermocouple, Rayotube or Thermohm are given in Catalog N-33A(3), N-33B or N-33C respectively.

TO CONTROL—NO RECORD, NO INDEX . . .



Height.....12-13/16"

Model NC Micromax is similar in outward appearance to the Model C, but with only one pointer to show the control setting. It can operate signals, alarms . . . or almost any two-position control where neither index nor record is needed. Can be supplied with either mercury switch or, for greater sensitivity, open-type control contacts. Available as a self-standardizing potentiometer for use with a thermocouple, or as a Wheatstone bridge for use with a Thermohm. Write for Catalog N-33A(4).

For many laboratory applications where basic readings are desired, the L&N instruments described on this and the preceding page can be supplied calibrated in ohms and millivolts. Where the user wishes to read the measured quantity directly, these instruments can be supplied with indicating scales (and charts) calibrated for the various quantities as noted below.

L&N ELECTRICAL MEASURING INSTRUMENTS AND AUTOMATIC CONTROLS	QUANTITIES MEASURED OR CONTROLLED																												
	POSITION & LEVEL	PRESSURE	SPEED	FLOW		TEMPERATURE			ELECTRICITY — AC			ELECTRICITY — DC			RADIANT ENERGY	GAS ANALYSIS					HUMIDITY	SMOKE	ELECTROLYTIC COND	pH
				Total	Rate				Volt Age	Frequency	Power	Volt Age	Current	Power											
Primary Elements	Float or Mercury Gage	Pressure Transmitter	Tachometer	Orifice or Venturi Tube	Orifice or Venturi Tube	Thermocouple	Rayotube	Thermohm	Lamp	Impedance Bridge	Thermal Converter	Volt Box	Shunt	Volt Box and Shunt	Photoelectric Cell	CO_2 Cell	SO_2 Cell	Oxygen Purity Cell	Hydrogen Purity Cell	Hydrogen and Nitrogen Cell	Transmitter Wet & Dry Bulb	Sampling Manifold	Electrolytic Conductivity Cell	Glass Electrode
L&N PANEL MANUAL INDICATOR						▫		▫		▫		▫	▫										▫	
MODEL NC MICROMAX NON INDICATING CONTROLLER						▭		▭																
MODEL C MICROMAX INDICATING CONTROLLER						▭	▭	▭																
MODEL R MICROMAX INDICATOR / INDICATING RECORDER / INDICATING RECORDING CONTROLLER		○	○		○	○○○	○○	○○○	○○	○	○○	○○	○○	○○		○	○	○	○	○		○	○	○○
MODEL S MICROMAX INDICATOR / INDICATING RECORDER (SINGLE POINT, MULTIPLE POINT) / INDICATING RECORDING CONTROLLER		▫	▫		▫	▫▫▫	▫▫	▫▫▫	▫▫	▫	▫▫	▫▫	▫▫	▫▫		▫▫	▫▫	▫	▫	▫	▫	▫	▫▫	▫▫
MICROMAX ELECTRIC CONTROL — POSITION ADJUSTING TYPE / DURATION ADJUSTING TYPE						■ ■	■ ■	■ ■								■	■				■ ■		◪	■
MICROMAX PNEUMATIC CONTROL						▫	▫	▫								▫	▫	▫	▫	▫			▫	▫
SPEEDOMAX ELECTRONIC RECORDER						▫ ■	▫ ■																	

LITERATURE DESCRIBING STANDARD L&N EQUIPMENT

CATALOGED BY TYPE OF EQUIPMENT

Operating Supplies for L&N Equipments ..... Cat. ENT-W

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Load-Frequency Control for Interconnected Power Systems ..... Tech. Pub. ... N-56—161(1)
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Simplified Signalling Controller for Automatic Testing of Condensate Purity ..... Cat ... N-95—163(1)

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