Weston ENGINEERING NOTES

VOLUME 13 | DECEMBER 1959 | NUMBER 2

CALIBRATING AND STANDARDIZING PROCEDURES

The following address was given on September 17, by Dr. Robert C. Langford, Chief Engineer of Weston Instruments, Division of Daystrom, Inc., to a group of leading authorities in the instrumentation field. The address was in connection with a seminar held discussing the state of calibration equipment and instrumentation procedures.

PREVIOUS speakers in the other discussions have covered with you the principles of measuring instruments and, further, the selection of instruments. At this point, then, I would like to assume that you are now the proud possessor of several instruments and are interested in making certain that the principles of operation are fully substantiated. Basically, the job of calibrating and standardizing is to make certain that the inherent accuracy and stability built into the instruments is fully maintained and any departure from the initial conditions carefully noted. This may occur when repairing an instrument or doing regular preventive maintenance. At this point it is not without interest to note that the actual terms "calibrating" and "standardizing" do have an interesting but important difference between them. In the general sense of the word calibrating an instrument implies the idea of starting with a mechanism and a blank scale and determining where to put the cardinal points and lines. Standardizing, on the other hand, implies the idea of checking the calibration of an already established instrument. To my knowledge these definitions have not yet been finalized in any specific form by ASA etc., but they are in use by a reasonably large number of major companies today.

When you stand and look at this problem, perhaps, the first important question that must be answered is how accurate is accurate, and it is for this reason that the story starts a rather long way back. In the United States, the National Bureau of Standards; in Germany, the Bundesanstalt; and in the United Kingdom, the National Physical Laboratory are each charged by law with the fundamental determination of the ampere, volt, ohm and other electrical parameters. It is the job of these national institutions to make absolute determinations that are independent of physical entities. It is also their task to provide themselves with working standards which they check periodically back to fundamental absolute determinations. To help complete the chain they supply a service for the comparison of industries working standards against their own. It will be appreciated that with the use of Ohm's law, it is only necessary to obtain any two standard quantities of the ampere, volt or ohm to obtain all three. Further, using the theory of dimensions, if units obtained of say permeability are included, all other phenomena in the electromagnetic spectrum may be determined. The NBS has chosen in the electrical field to standardize on the use of standard resistors and Weston standard cells as their two necessary working primary standards for ohms and volts respectively. This practice, of course, has been followed throughout industry and we are no exception to the rule in having our own primary standards of standard resistors and Weston standard cells. For many years Weston Instruments, Division of Daystrom, Inc.,

In This Issue

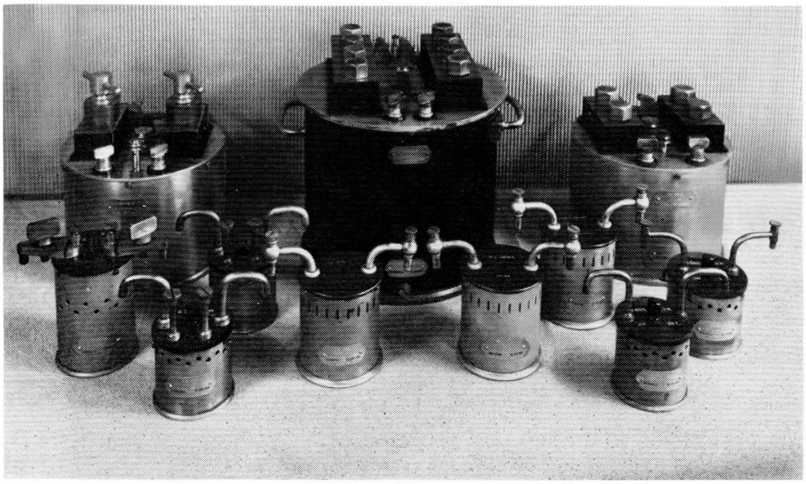
Calibrating and Standardizing Procedures

Weston Model 610 D-C Summation Meter

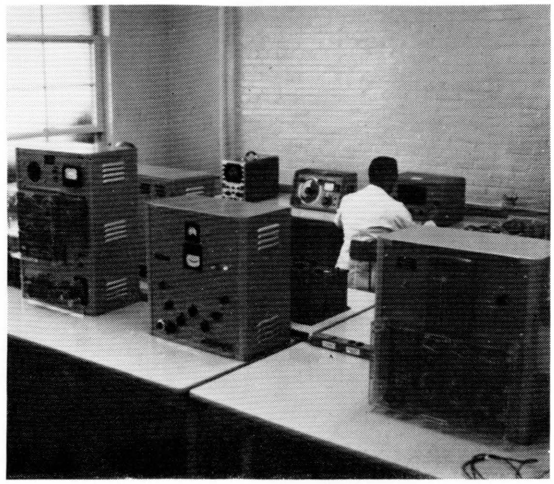
John Parker, Editor

W. A. Graham, Technical Editor

DAYSTROM, INCORPORATED
Daystrom-Weston Sales Division
614 Frelinghuysen Avenue,
Newark 12, N. J., U. S. A.



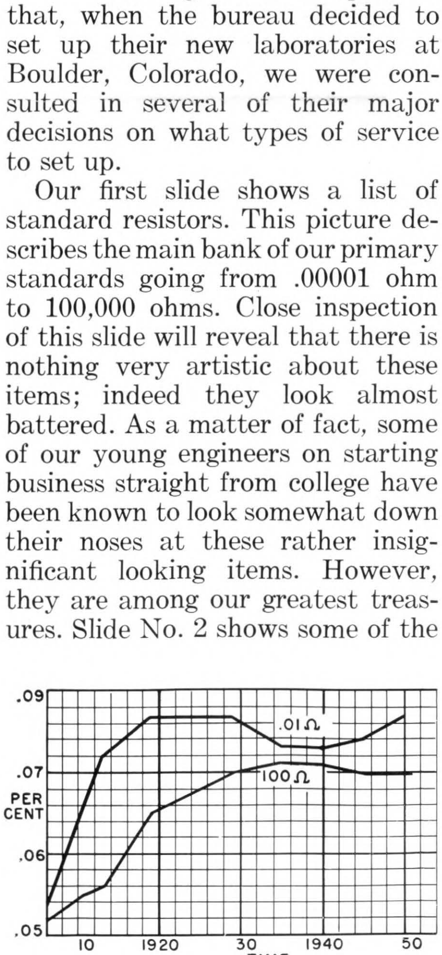
Slide 1—Main bank of primary standard resistors.



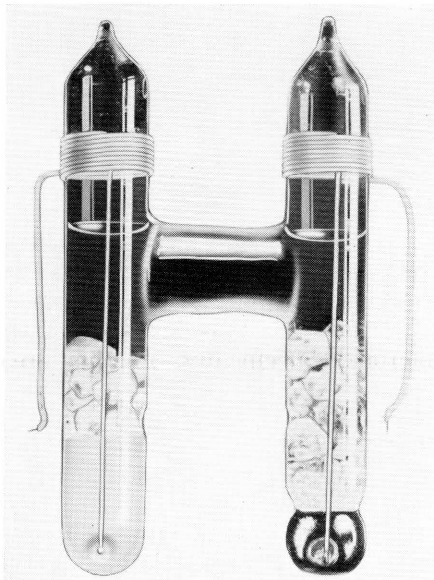
Slide 4—Standardizing Laboratory.

has been in the closest contact with the national institutions such as the Bureau of Standards in all forms of standardizing activity, two of our previous speakers Messrs. Lamb and Miller having been elected fellows of the AIEE for their contributions to such activities. Indeed it was something of a compliment that, when the bureau decided to set up their new laboratories at Boulder, Colorado, we were consulted in several of their major decisions on what types of service to set up.

Our first slide shows a list of standard resistors. This picture describes the main bank of our primary standards going from .00001 ohm to 100,000 ohms. Close inspection of this slide will reveal that there is nothing very artistic about these items; indeed they look almost battered. As a matter of fact, some of our young engineers on starting business straight from college have been known to look somewhat down their noses at these rather insignificant looking items. However, they are among our greatest treasures. Slide No. 2 shows some of the

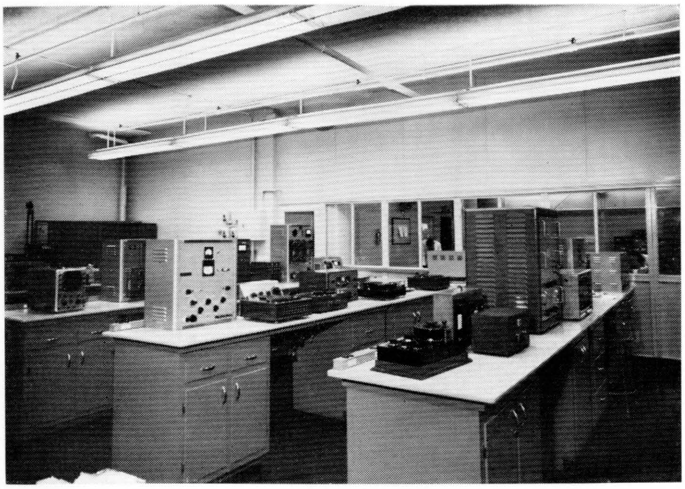


Slide 2—History of changes in standard resistors.



Slide 3—Saturated form Weston Standard Cell.

variations in a .01 ohm and 100-ohm unit that was purchased from Wolff in 1893 and the other made by Weston in 1907. The Wolff unit was shipped into this country carrying the seal of the Reichsanstalt (the forerunner of the Bundesanstalt), probably the top technical bureau of the world at that time. The other unit manufactured by Dr. Weston, the founder of our Company, embodied his own version of certain novel features. Today, half a century later we have a rich summary of data on these old units. Any changes which were likely to have occurred in these items, have long since occurred and by constant checks against the working primary standards of the bureau it has been found possible to note carefully these changes as listed. These resistors are the basic working standards of our Company; however, each of these is supplemented by an auxiliary standard of a similar type and similar records are kept on these so that if some accident should happen to our basic standard, the auxiliary standard would take over as our primary standard. Weston no longer makes for commercial sale standard resistors as such, but the history of Weston made standards is still prevalent in the organization. The second partner in the list of primary standards is that of the Weston standard cell. It was introduced in 1892 and 1893 in two forms, the unsaturated and the saturated form. In the saturated form, slide No. 3, it had become a reproducible, stable and practical primary standard of voltage. In one leg is mercury and mercurous sulphate paste, in the other leg an amalgam of cadmium and mercury. In the legs of the "H" is a cadmium sulphate solution. In the saturated form of the cell the cadmium sulphate solution is in a permanently saturated state with an excess of cadmium sulphate crystals. With this type of cell a temperature coefficient of voltage is experienced of approximately −50 micro volts per degree C. This can be expressed by means of the Wolff formula in very exact terms. However, in order to be used as a practical standard it is common to maintain this all in a standard cell bath at a constant temperature which does not vary by more than plus and minus one hundredth of a degree. With these cells under such an



Slide 5—Standardizing Laboratory.

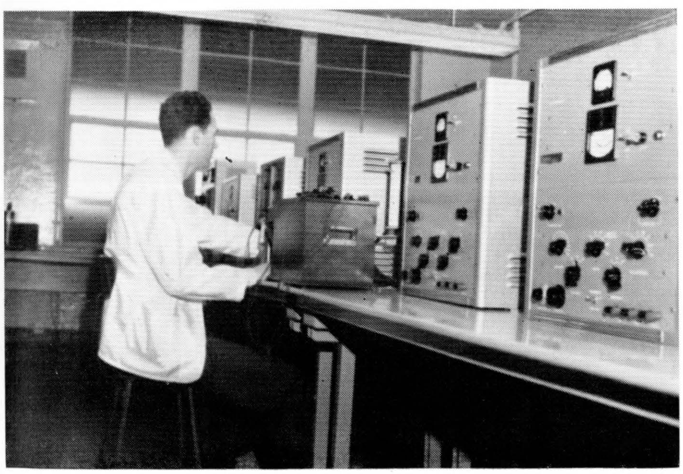
ITEM	RATED ACCURACY	NOMINAL VALUES	NOTES	CALIBRATION ACCURACY
RESISTORS	0.01%	0.0001 Ω TO 10,000 Ω	25°C	0.002% TO 0.005% (0.0001 Ω TO 0.01%)
CURRENT SHUNTS	0.04%	0.00001 Ω TO 20 Ω	1000 AMP TO 0.075 AMP	0.01% TO 0.05%
STANDARD CELLS (UNSATURATED)		1.0183 V TO 1.0198 V		0.01%
RESISTANCE BRIDGES	0.01% TO 0.02%			0.01%
RESISTANCE BOXES	0.01% TO 0.05%			0.01%
KELVIN BRIDGE	0.01% TO 0.02%			0.01%
RATIO BOX	0.01%			0.01%
POTENTIOMETERS	0.01% TO 0.02%			0.01%
VOLT BOXES VOLTAGE DIVIDERS	0.01% TO 0.04%	750 V TO 3 V/1.5 V	20% TO 100% RATED V	0.01%
FIXED CAPACITORS ADJ. CAP. BOXES	0.1% TO 0.5%	100 μμF TO 1 μF	60 CPS TO 1000 CPS	0.03% TO 0.1%
FIXED INDUCTORS ADJ. IND. BOXES	0.1% TO 0.5%	100 μH TO 10 H	60 CPS TO 1000 CPS	0.03% TO 0.1%
CURRENT TRANSFORMERS	0.3% RATIO 10 MINUTES PHASE ANGLE	0.1 AMP TO 4000 AMP	60 CPS	0.1% RATIO 2 MINUTES PHASE ANGLE
POTENTIAL TRANSFORMERS	0.3% RATIO 10 MINUTES PHASE ANGLE	TO 25,000 V	60 CPS	0.1% RATIO 2 MINUTES PHASE ANGLE
DC AMMETERS	0.1% TO 0.5%	100 μAMP TO 100 AMP		0.05% TO 0.1%
DC VOLTMETERS	0.1% TO 0.5%	0.1 V TO 1000 V		0.05% TO 0.1%
AC AMMETERS AC AND DC AMMETERS	0.1% TO 0.5%	10 MA TO 100 AMP	DC TO 30,000 CPS AC-DC DIFFERENCE	0.05% TO 0.1%
AC VOLTMETERS AC-DC VOLTMETERS	0.1% TO 0.5%	0.1 V TO 1000 V	DC TO 30,000 CPS AC-DC DIFFERENCE	0.05% TO 0.1%
WATTMETERS	0.1% TO 0.5%	0.1 TO 100 AMP 30 TO 1000 V	REVERSED DC AC-DC DIFF TO 3000 CPS	0.05% TO 0.1%

Slide 7—Typical test requirements.

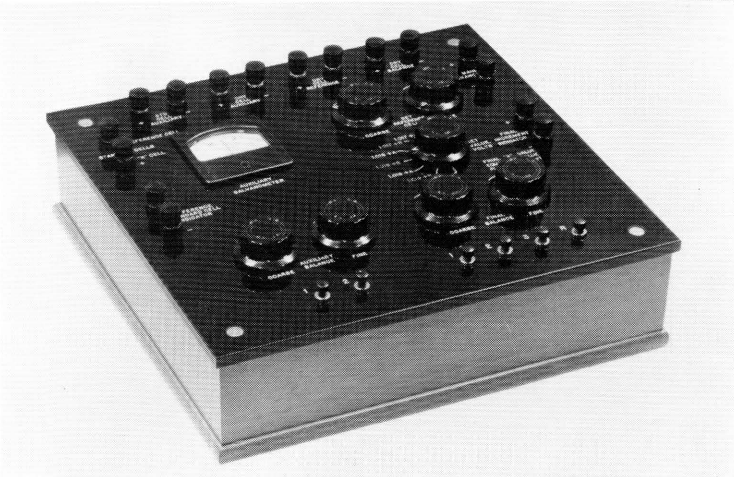
environment, it is readily possible to achieve a few micro volts order of accuracy. Standard cells continue to be made in the Weston organization, indeed it is a thriving portion of our business. This places us in the fortunate position of having two excellent sets of primary working standards of ohms and volts which enables us to achieve the ultimate in precision and accuracy in supplying standardizing laboratories throughout the country with the ultimate in indicating instruments. It will be seen that once these fundamental standards are obtained and kept in good condition, a whole series of other tests become possible. To do this it is important that the working quarters of a standardizing laboratory be good. A common practice, for example, is to maintain the temperature at 73° plus and minus 1½° with a relative humidity at 50 plus and minus 2%. This gives a satisfactory choice, bearing in mind the consideration of the basic cost of the air-conditioning equipment, cost of operation and the comfort of the staff. The next three slides show some of the pictures of our own standardizing laboratory which you will see and visit later during your tour of the factory. Specifically, in this area cleanliness and adequate humidity and temperature have been stressed. There also is slight pressurizing of the room to help keep out dust particles. Slide No. 7 lists most of the important tests that are required in our own laboratories for our own usage on test panels, etc. To calibrate such items as occur on this list we must use perforce our standards of resistance and voltage. Just as important, however, is the intermediate and final test equipment that must be used with these standards to secure the desired results.

Slide 8—Weston Model 66 Standard Cell Temperature Bath for saturated standard cells.

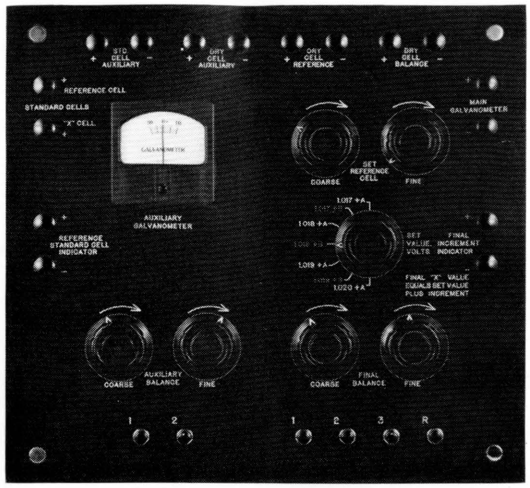
Consider first the intermediate type of equipment such as the standard cell temperature bath shown in slide No. 8. This unit is a control temperature bath designed to maintain three banks of saturated cells at a constant temperature of 35° C plus and minus .01° C. It is intermediate in the sense that it is not directly connected into the circuit. However, by its use it is sufficient to hold the temperature sufficiently constant to hold voltage variations of the cell to within ½ micro volt. The type of construction employed in the bath is that of a



Slide 6—Standardizing Laboratory.



Slide 9—Weston Standard Cell Comparator—Model 1000.

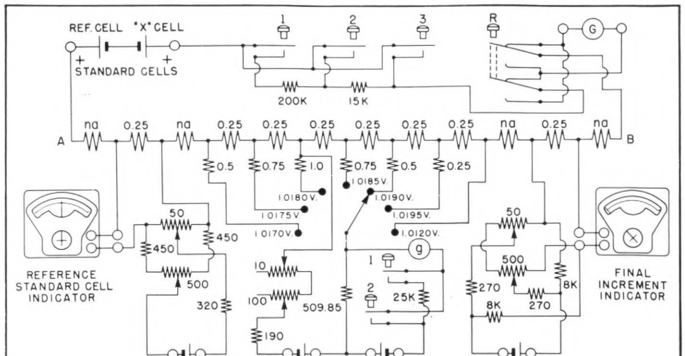


Slide 11—Panel view of Standard Cell Comparator.

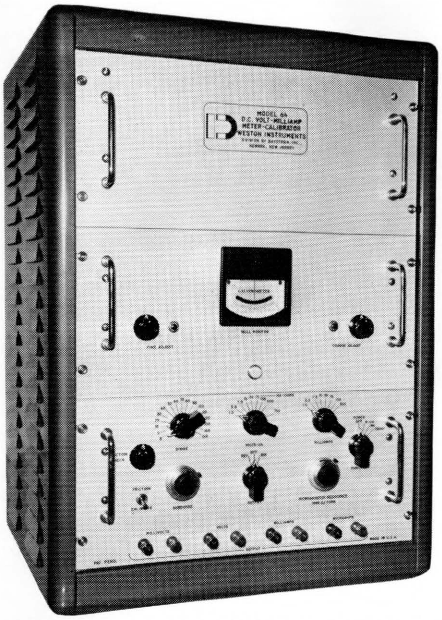
rapid oil circulatory type. This is extremely important since standard cells not only have a temperature coefficient over-all but much more importantly have a temperature coefficient between the two legs of the "H" tube, one being −1,050 and the other +1,000 micro volts per degree C. It will be readily appreciated that air baths commonly employed for this type of duty do not have enough thermal transfer capacity to give adequate assurance that the legs are at equal temperatures. An electronic control unit under the supervision of a master thermostat maintains the desired temperature. The rack carrying cases are of the type that can immediately be transferred to the bureau for incorporation in their equipment for certification. After the intermediate type of equipment comes the test equipment designed for a specific test. Such an item shown in slide No. 9 is the Standard Cell Comparator. As the name implies, this piece of equipment was developed for the specific task of checking Standard Cells. This model, shown with associated equipment in slide No. 10, needs as an input a reference voltage such as would be obtained from a saturated standard cell in a controlled temperature bath. When this is done, the unit becomes a precision instrument capable of measuring the voltage of all unsaturated or common forms of standard cell and giving the voltage directly on an indicating instrument. It will do this very rapidly and simply to an accuracy of better than 5 microvolts, giving indications of both emf and internal resistance of the cell. In this way it is possible for a standardizing laboratory to rapidly check the emf and condition of all standard cells in a given plant and determine that these are in good condition on a permanent basis. The circuitry is shown in slide No. 12. This latter type of standard cell comparator comes very probably under the heading of calibration equipment. Necessarily such equipment must be precise, accurate and stable. It would be ideal if the equipment were also simple and reliable to operate and could perform its function at low cost rapidly. Much existing equipment, unhappily, is of the type which needs a plurality of operators and very frequent manual restandardization and checking due to its inherent fragility and uncertainty.

It has become very necessary over the course of years at Weston to devise a specific type of calibration equipment that can be used for determining scale characteristics of instruments that are our main source of business. Further, when these instruments are fully completed, our inspection must make doubly certain that they con-

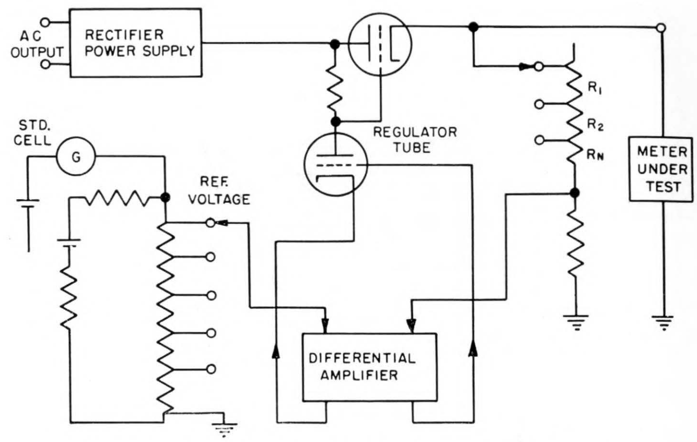
Slide 10—Weston Standard Cell Comparator with associated equipment.



Slide 12—Circuitry of Standard Cell Comparator.



Slide 13—Weston D-C Voltmeter Calibrator—Model 64.



Slide 15—Equalizing Circuitry of Weston D-C Calibrator.

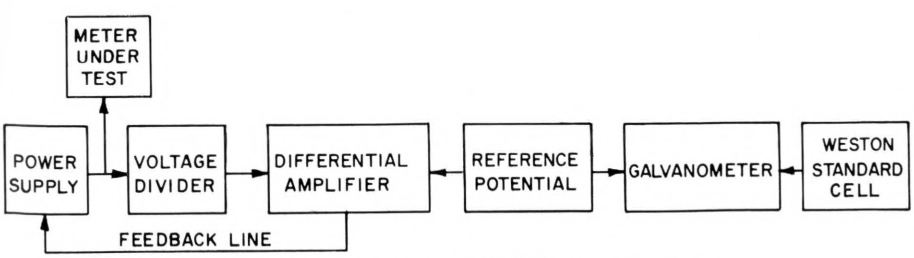
tinue to enjoy all the accuracy and stability inherent in their design. Since these instruments have to be sold on a competitive basis it has become important that our calibration test equipment must possess the attributes of accuracy, stability and simplicity as a first characteristic, but coupled with this must be the ideas of non ambiguity, constant standardization and constant accuracy at all points on the scale. It has been found possible to give one-man operation of these pieces of equipment which gives reduced calibrating time associated with continuity of accurate operation. The traditional concept of instrument calibration has been a two-man team—one controlling and measuring the energy supply to the instrument under test and the other man noting the indication of the instrument under test. When it is desired to check an instrument for accuracy, this can only be done when a constant indication is being held. This has led to the incorporation in the line calibrating equipment of an ultra stable power supply which has eliminated the need for the first man of the team supplying the energy. For general purpose usage four specific pieces of equipment are used.

a. D-C Calibrator—Millivolts, Volts, Microamps and Milliamps.

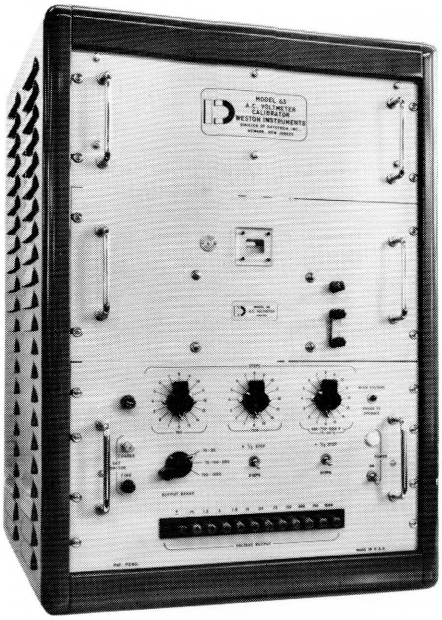
Resistors "R" are of nominal tolerance and serve to divide the output voltage of the rectifier into fifteen approximately equal parts. Precision resistors are not required in this divider. The resistances of the meters being tested will have a wide range of values, and may not even be known. Since the meters being calibrated are in shunt with a variable number of the resistors "R" as the output tap is changed, the specific output tap is sampled as to voltage output and this sample compared against the reference standard voltage. The sampling is accomplished by pairs of 0.02% resistors that are matched for ratio and temperature coefficient only. Their absolute values are not critical. Any difference in voltage between this sample and the reference standard becomes the input signal of a very stable and high-gain electronic servo-amplifier whose output adjusts the bias of a series regulator tube in a direction as to reduce the amplifier input signal to essentially zero.

The zero-drift and resolution of the amplifier contribute no more than 0.01% to the possible output error. The sampling resistors can contribute another 0.02%. The standard cell, which is of the unsaturated variety, can drift another 0.005% per year. It may therefore be seen that the rating of 0.05% applied to the output is conservative and valid over extended intervals between standardization checks. Adjustments are provided to standardize the Models 64 and 65 against various standard cell voltages as these cells age.

Slide 16—Weston Model 65 D-C Ammeter Calibrator.



Slide 14—Block Diagram of D-C Voltmeter Calibrator.



Slide 17—Weston Model 63 A-C Voltmeter Calibrator.

Function—Weston Model 64 Calibrator has been specifically designed to provide an easy and rapid method for precise calibration of direct current voltmeters—millivoltmeters—milliammeters—mircoammeters.

Features

Any range can be automatically divided into as many as 15,000 equally divided parts.

Any drift or deviation in output voltage is instantaneously and automatically corrected.

A reference standard (Weston Standard Cell) is provided so that calibrator can be standardized.

Semi-automatically divides each step equally regardless of the range or number of steps.

Can be used as a precise regulated d-c source.

Calibrator requires only *one* operator.

b. D-C Calibrator—Amperes.

Regulation of the Model 65 is very similar, but in this instance, precision shunts in the output circuit allow the millivolt drop across them to act as the sample to compare against the voltage reference standard. Any difference is again amplified and then used to regulate the power supply to exactly the output current required.

c. A-C Calibrator—Volts.

d. A-C Calibrator—Amperes.

Function—Weston Model 62 semi-automatic calibrator provides a quick easy-to-use and precisely accurate method of checking or calibrating a-c ammeters, from 1 to 50 amperes full scale inclusive.

Features

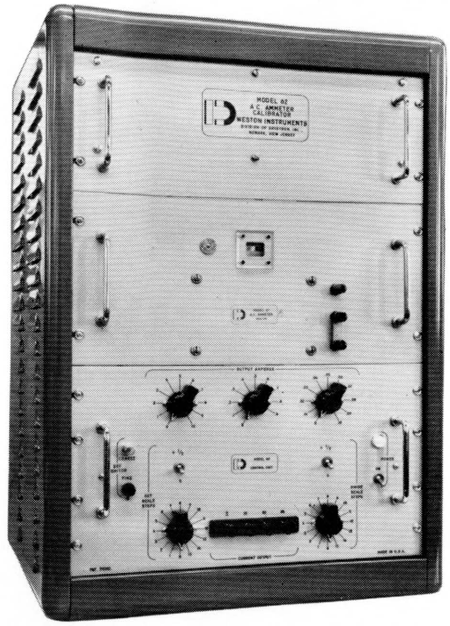
Scale can be subdivided into hundredths.

Calibrator will automatically divide any range into as many as 30 equally divided parts.

No longer necessary to compute the value of each check point and then set up several pieces of equipment to obtain the required current when calibrating a-c ammeters having odd ranges to match instrument transformer ranges.

Reading accuracy is assured through the use of mirror scales and knife-edge pointer on the precision monitoring instrument.

Calibrator can also be used as a



Slide 18—Weston Model 62 A-C Ammeter Calibrator.

precisely regulated constant current supply.

Any load variation on the calibrator will be automatically adjusted.

Input power can be supplied from any standard 115 volt 60 or 400 cycle a-c source (400 cycles on special order).

Calibrator requires only *one* operator.

Specifications

Accuracy—0.05% of indicated value.

Ranges—1 through 50 amperes.

Range extremes—0.033 ampere—55 amperes.

Output power—10 volt amperes maximum.

E. N.—No. 129 —*R. C. Langford.*

WESTON MODEL 610 D-C SUMMATION METER

General

THE Naval Research Laboratory at Washington, D. C., has developed an Air Analyzer System. One of the components of the system is a d-c switchboard instrument capable of an indication which is proportional to the millivolt output of five independent circuits. A Model 610 D-C Summation Meter, described herein, was developed at Weston to meet the requirements of the Air Analyzer System.

The D-C Summation Meter, as shown in Figure 1, contains a 1.0″ Cormag® mechanism with five independent windings on the movable coil. It was designed to provide a pointer deflection proportional to the millivolts applied to one or more of the circuits. Each of the five circuits on the movement is approximately 50 ohms, and the sensitivity is such that 1 milliampere flowing through any circuit will produce full-scale deflection. The prominent pear-shaped pointer of the movement, combined with highly legible black scale markings on a white background, provides maximum readability.

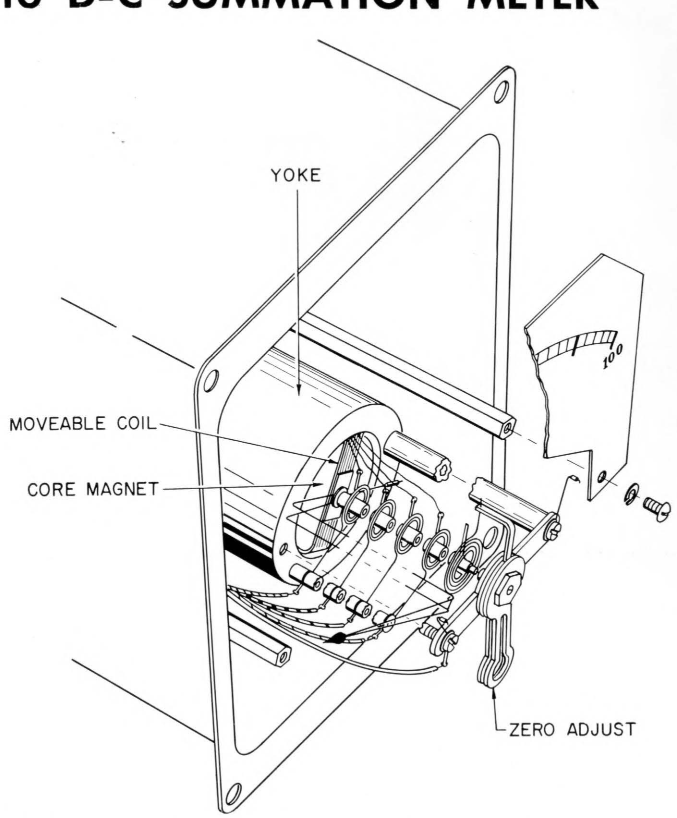


Figure 1—Exploded view of mechanism assembly. Weston Model 610 D-C Summation Meter.

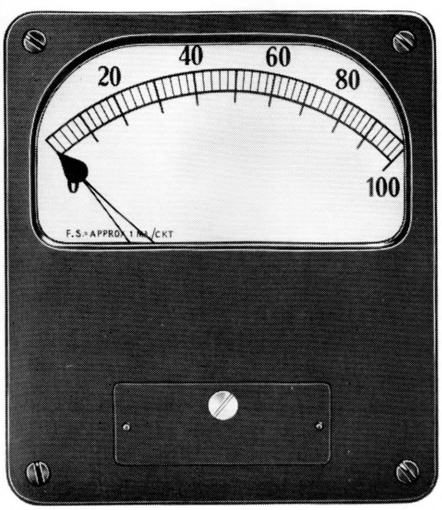
Instrument Housing

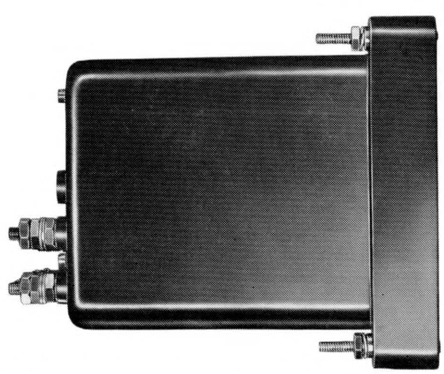
The instrument housing consists of a steel case, Bakelite base, and Bakelite cover. Four #8-32 threaded mounting studs of the flush type case are an integral part of the flange, and are suitable for mounting the instrument on panels up to ½″ thick. Five marked sets of #10-32 threaded back connection studs are included on the Bakelite base and an external zero corrector is provided which is accessible from the front of the instrument. Internal illumination can be provided by means of two internally mounted 6 volt Mazda #47 lamps connected in parallel.

Front, side, and rear views of the instrument are shown in Figures 2, 3, and 4.

Mechanism

The mechanism of the Summation Meter, as shown in Figure 5, is the inherently stable 1.0″ Cormag mech-





Figures 2, 3, 4—Front, side and rear views—Model 610 Summation Meter.

December 1959

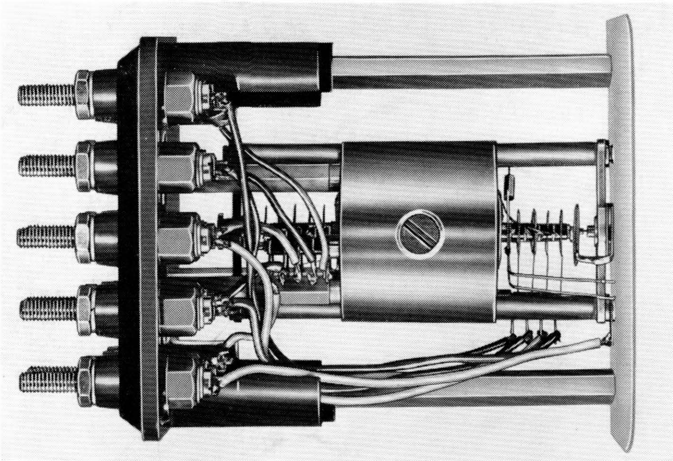


Figure 5—Mechanism Assembly of the D-C Summation Meter.

anism used with Weston portable and laboratory standard type instruments. This mechanism is a permanent-magnet pivoted movable coil design consisting of: an Alnico magnet, soft-iron pole pieces, and a return path or yoke of soft iron. Fewer parts are contained in the compact 1.0″ Cormag mechanism than in a comparable C-shaped magnet construction, resulting in a weight advantage of .7 lb.

The magnetic shielding property of the mechanism is significant. External magnetic flux is carried around the magnetic system of the mechanism by the yoke, thus preventing an external field from entering the air gap and affecting the reading of the instrument. A magnitude of shielding may be visualized if we consider the magnetic field produced by a current-carrying conductor. A 50-oersted field, which may be obtained 16 inches away from a 10,000-ampere conductor, would produce a transient error of less than .7% measured on the self-shielded Cormag mechanism, while the permanent error would be negligible.

The movable element of the mechanism includes a multiple circuited movable coil, two extended pivot bases, pointer, and ten control springs. The complex movable coil is frameless and contains five independent windings of aluminum wire. Each winding is insulated to serve as one of the instrument circuits. A frameless coil, although more difficult to fabricate, was necessary to provide the instrument with a satisfactory damping factor. Low external resistance of the millivolt circuits and the damping produced by all five circuits would result in an extremely overdamped instrument if the windings were wound on a frame. Aluminum wire was specified since a similar copper winding would increase the movable coil weight, thereby decreasing the torque-to-weight ratio of the movable element, and increasing the pivot friction of the instrument to an undesirable level. Windings of the coil are progressively wound and insulation is applied between windings. All spring terminals of the control springs are extended to allow the leads of the movable coil to be connected without interfering with convolutions of the springs. A zero corrector abutment of the top bridge is directly connected to the top spring. To obtain the correct amount of zero correction, this spring has a restoring torque 33% greater than that of the sum of the other springs and twelve times that of the torque of each of the other springs.

Bridge support studs of the mechanism are exceptionally long to provide adequate clearance between the movable coil and bridges. Clearance was required for mounting five springs and insulators on each pivot base.

On the yoke of the mechanism are two projections which are secured to the top and bottom surfaces of the yoke. Each projection is mounted with terminals and insulators which serve to conduct the current from the back connection studs through the springs to the windings of the movable coil. The projections are so positioned that the control springs when deflected will not interfere with the bridge support studs.

Electrical Characteristics

The Model 610 Summation Meter has a full scale deflection angle of 86 degrees and a scale length equal to 3.5 inches. For the Air Analyzer System, each of the circuits was externally adjusted to 50 millivolts. A damping factor of 100 exists with all circuits connected. The damping factor, being a function of the number of circuits energized, will decrease if less than five circuits are used. Response time of the instrument for 99.8% of full scale deflection is in the order of 1.5 seconds.

Calibration of the instrument is performed on one circuit and the other circuits will track within 1% of full scale of this calibration. Basic accuracy of the instrument is 2% of full scale.

The Summation Meter is capable of withstanding a dielectric test voltage of 5 volts between circuits and 2,600 volts, 60 cycles RMS between the mechanism and the case, mounting hardware and zero corrector.

E. N.—No. 130 —*C. B. Stegner.*