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A Variable Ratio-Arm Conductivity Bridge

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A shielded conductivity bridge employing direct balance to ground and variable ratio arms is described. The bridge as a whole is probably capable of an accuracy of about 0.01 percent over a range of one million ohms with greater flexibility than that of the customary fixed ratio-arm conductivity bridge. The range may be extended to ten million ohms with only slight loss in precision. By using the two extra ratios provided in the ground arms the resistance of all solvents except those of lowest dielectric constant may be measured to a few percent on the same bridge.

FOLLOWING the lead of Grinnell Jones, precision conductivity bridges previously described[1–3] have been based on the use of equal ratio arms. The bridge herewith described offers the convenience and flexibility of a variable ratio-arm bridge while retaining the precision and other advantages of the equal ratio-arm bridge.

The bridge employs a modified Wagner ground to eliminate the transformer between the bridge and amplifier.[3] A knob and pointer switch on the panel permits use of either the equal 10,000-ohm ratio arms or the replacement of one of them by a 1000-ohm or 100-ohm arm. This provides a choice of a multiplying factor of 1, 10, or 100 on the "standard" arms. Used with five decades giving a maximum of 11,111.1 ohms, the range of precision measurements is thus over a million ohms. This is as high as accurate measurements can be made conveniently, but two additional ratios in the "ground" arms are provided to permit measurements of solvent resistance. Binding posts in series with the decades are also provided so that by using higher values of inexpensive resistors the conductance of most solvents can be obtained closely enough for the purpose for which it is ordinarily used; namely, to see that it is negligible compared to the conductance of the lowest concentration of the solutions being measured.

As can be seen in Fig. 1, the amplifier, the controls, and the decades are mounted together on standard relay rack panels. The oscillator and its power supply are located ten feet away. The amplifier, the oscillator, and its power supply have been described previously.[3] The five decades are General Radio Type 510 removed from their shields and mounted on a steel $7'' \times 19''$ relay rack panel. The three lowest decades are mounted directly on the panel and as close to each other and to the end of the panel as possible. The other two are provided with longer shafts and mounted an inch and a quarter from the panel and as far apart as possible. Alternate resistors on the highest decade were disconnected and resoldered projecting outward. These changes

[1] Jones and Josephs, J. Am. Chem. Soc. **50**, 1049 (1928).
[2] T. Shedlovsky, J. Am. Chem. Soc. **52**, 1793 (1930).
[3] W. F. Luder, J. Am. Chem. Soc. **62**, 89 (1940).

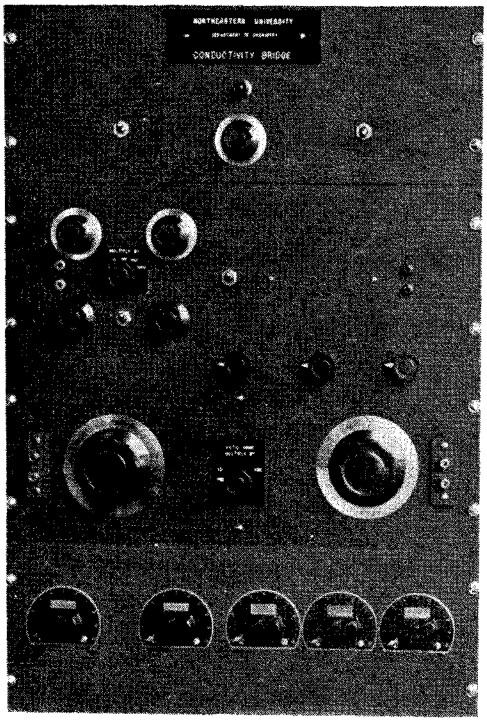

FIG. 1.

were made to reduce distributed capacity. A one-hundred thousand ohm box[3] may be constructed if desired. It is inexpensive and makes calibration of the bridge more convenient. The entire bridge, the lead wires to the cell, and the thermostat are shielded after Shedlovsky.[2] The shields for the cell leads were made by slipping flexible shield braid over large Pyrex tubing.

Figure 2 is the wiring diagram of the 14″×19″ control panel. The ground network is mounted in a separate 6″×6″×6″ iron shield on the upper left corner of the panel. A five-point switch provides five ratios of the ground arms: 1, 10, 100, 1000, and 10,000. R_1 and R_2 provide the fine adjustment of the ground resistance arms against the standard arms. C_1 and C_2 provide the capacitance adjustment, C_2 acting as a vernier for C_1. The banana jacks J_1 provide for extra capacitance needed when balancing against the 10 and 100 standard ratios. Usually it is unnecessary to adjust more than three of the five controls to make a reading. Many times only the two verniers C_2 and R_1 need be touched in going from one concentration to the next during a run.

The large knob at lower left in Fig. 1 is the small condenser C_3 across the cell. The cell is connected to the General Radio combination banana jacks and binding posts to the left of the knob. The knob at the lower right is the condenser across the measuring resistors C_4. The jacks on the right of this knob permit extra capacitance to be used when there is more than usual in the cell. The pointer knob between the two large knobs is the General Radio low capacity double pole, double throw switch S_3. This switch carries the 1000-ohm and 100-ohm ratio arms and is enclosed in a 6″×6″×6″ iron shield to which are attached sheet iron strips shielding the two condensers. The other three pointer knobs are from left to right S_4, S_5, and S_6. The two 10,000-ohm ratio arms are enclosed in shields behind the upper right corner of the panel.

When the Wagner ground is modified to permit the elimination of the transformer, as is done in this bridge, the cell and decades are balanced directly against the ground arms. In effect the ground arms are calibrated against the standard arms at each reading, but the standard arms are not directly in the bridge when the final reading is made. This means that the

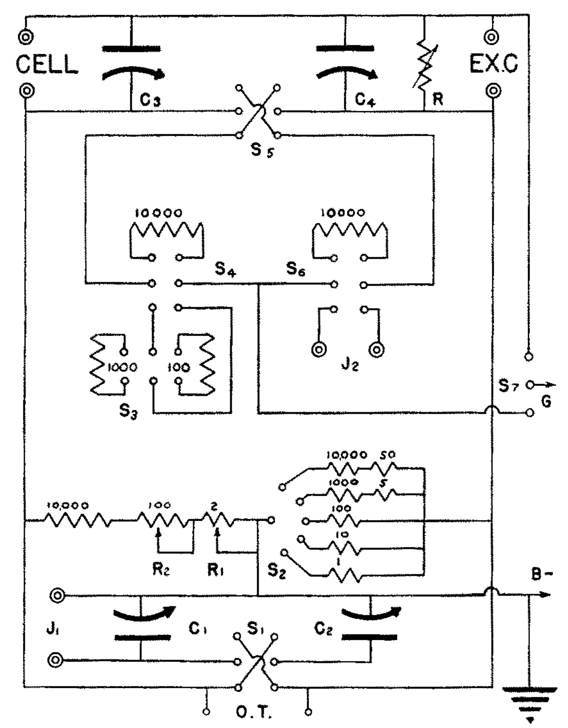

FIG. 2.

ground arms must be capable of as fine an adjustment as the decades and balancing condensers. This is readily achieved by the small rheostat and condenser R_1 and C_2 in the ground network. S_7 connects the grid of the amplifier first to the point between the cell and the decades. By adjusting the decades and S_2, the proper ratio of the ground arms is chosen and a rough balance reached. Then throwing S_7 to the point between the ratio arms, the ground network is balanced carefully against the corresponding standard arms. The final reading is made by throwing S_7 back to its original position and readjusting the decades and the balancing condensers. A check may be made by throwing the switch back to the other position to see if the phones are still dead. When the 10 and 100 ratios are being used, extra capacitance is required in the ground network. This is provided by a series of mica and paper condensers wired to General Radio double plugs. Using the amplifier and oscillator previously described,[3] balance to one part per million is easily obtained with the one-to-one ratio arms. The sensitivity is somewhat less on the 10 and 100 ratios. When the solvent conductance is being measured on the higher ratios, no attempt is made to balance capacitance in the ground arms. The amplifier volume control is turned down and the bridge is balanced to a minimum, adjusting only S_2 in the ground network and the decades. The capacitance of the cell must be balanced by plugging extra condensers into the jacks on the other side of the bridge.

The resistors in the standard ratio arms were measured and chosen from stock by the General Radio Company so as to be within 0.01 percent of their nominal values. If greater accuracy is desired, calibration by measuring the same resistance with two ratios may be made.

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A Cold Cathode X-Ray Diffraction Tube*

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The design and construction details for making a cold cathode x-ray diffraction tube are included. A metal bellows incorporated in the cathode assembly permits adjustment of the cathode-target distance. Vertical fins provide adequate cooling without forced draft and a simple target sealing assembly permits rapid interchange of targets.

INTRODUCTION

THE features incorporated in the design of this x-ray tube are mechanically simple and lend themselves well to improved performance. The tube consists essentially of a cathode assembly and a body assembly, separated by a Pyrex glass tube insulator. The general design is similar to that described by Hägg[1] and employed by J. T. Norton[2] and others. In the tube described here, facility is provided for adjusting the cathode-target distance. In addition, the cathode cooling arrangement and the target sealing method are revised. The tube is shown in operating position in Fig. 1. With the present arrangement, three cameras may be operated simultaneously. A small lead sheet is slipped over a port when not in use.

An estimate of the maximum time required by a machinist of ordinary skill to construct such a tube would be about 60 hours. The cost of materials is estimated at $17.00 which includes the cast iron bracket supporting the tube (Fig. 1). This estimate does not include the vacuum pump, leak valves, or accessory electrical equipment.

Some of the dimensions of the apparatus are shown in Fig. 2. Those not included in the illustration or following description may be scaled from the drawing. It might be pointed out that a close fit is desired where the cathode rod slides

* Publication No. 10 of the Solar Energy Conversion Research Project.
[1] G. Hägg, Rev. Sci. Inst. **5**, 117 (1934).
[2] X-Ray Metallography Laboratory, Mass. Inst. Tech.