

Western New York Branch.

University of Syracuse Medical School, May 14, 1927.

3603

An Adaptation of the Electron Tube to the String Galvanometer.

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In coupling the string galvanometer to the output of an electron tube, various devices have been used to avoid placing the string directly in the output circuit.^{1, 2} This has been done to avoid damage to the string because of the high plate voltages used. However, the voltage amplification factor (μ) which is one of the most important constants in amplification equations, is a function of the geometry of the tube.

$$\mu = \frac{2\pi p}{a \log_e \frac{a}{2\pi r}}$$

approximately³ where p = distance from grid to plate, a = distance between adjacent wires of grid, r = radius of grid wires. Practically μ is found to vary but little within a wide range of plate voltage. Therefore, there is only slight loss of amplification involved in operating at low plate potentials, and there is considerable gain in safety of manipulation. Furthermore, in operating at low plate potentials and normal filament temperatures, one is working on that part of the characteristic of a tube where the plate to filament current is limited by space charge. This tends to reduce fluctuations in the tube circuit which are due to the so called "shot effect."⁴

When low plate potentials are used, the galvanometer may be placed directly in the output, and zero position of the string maintained by applying to the string terminals a potential equal and opposite to the P. D. set up by the passage of the plate current.

The circuit adopted is shown in Fig. 1. It consists of one stage of voltage amplification and one stage of power amplification. The resistances used are practically pure resistance and when the string is placed directly in the output circuit the amplifier is aperiodic. Con-

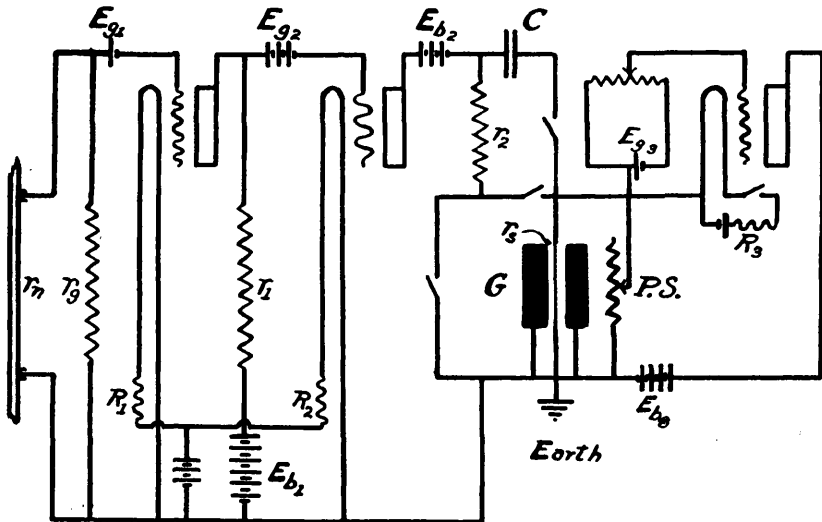


FIG. 1.

Conventional symbols throughout. r_n tissue resistance. r_g a non inductive resistance of from $10^4\omega$ to $2 \times 10^6\omega$ depending on stability of circuit and amplification desired. r_1 = plate to filament resistance of first tube $\times 5$. $r_2 + r_g$ = plate to filament resistance of second tube. R_1 , R_2 , and R_3 are ballast resistances. C is a 2 mfd. condenser. P. S. a protective shunt. μ of first tube = 27. μ of second tube = 3.1. E_{b_1} 90 volts. E_{b_2} 22.5 volts.

stant current amplification of from slightly less than unity to some two hundred times may be secured, depending on the tissue resistance and the value of r_g used. Compensation is effected by means of a third vacuum tube which acts as a variable high resistance.⁵

When recording slowly changing potential differences, a heavy string of 800ω resistance direct coupled to the amplifier is used. When rapid changes of potential lasting 10σ and less are recorded, a light, high resistance string is used coupled to the amplifier through a capacity of 2 mfd. This does away with the necessity for compensation of the plate current, and at the frequencies mentioned no appreciable distortion is introduced.

This is a preliminary report.

¹ Forbes and Thatcher, *Am. J. Physiol.*, 1920, lii, 409.

² Chaffee, Bovie and Hampton, *J. Optical Soc. Am.*, 1923, vii, 1.

³ Van der Bijl, "The Thermionic Vacuum Tube," New York, 1920, pp. 229 *et seq.*

⁴ Hull and Williams, *Phys. Rev.*, Feb., 1925, pp. 166 *et seq.*

⁵ Steinhausen, *Pflüger's Archiv.*, 1920, clxxxv, 703.