DISCUSSION

Lewis M. Hull (by letter): Mr. Weinberger's paper shows his appreciation of the importance of a matter which will, in the future, surely figure largely in the intelligent design of all electron tube receiving apparatus. However, I wish to comment on his method of measuring the input impedance. It seems that the effect upon the current thru L (Figure 1), which is what is indicated indirectly by the galvanometer deflection, of connecting a pure resistance across the condenser C , is intended to replace entirely the effect of the input impedance of the tube that in a similar connection, or at least the resistance component of that impedance. Apparently it is assumed that the input impedance is a pure resistance; the statement that "the circuit LC was kept tuned to resonance" does not refute this, since the addition of a parallel resistance would detune the circuit. Attention is therefore called to two points in this connection. (In this discussion C_1 =capacity between grid and filament, isolated; C_2 , grid and plate; and C_3 , filament and plate.)

(1) This method does not indicate the total impedance of the tube, as may be deduced from the observed result: "with the external plate circuit resistance equal to zero the effective input resistance is infinite." The input impedance under these conditions is really C_1+C_2 . Taking average values for a "D" tube and socket ($C_1=12\ \mu\mu\text{f.}$; $C_2=18\ \mu\mu\text{f.}$), this makes the impedance at 6,000 meters, 106,000 ohms, which is less than two of the resistance values given in Table 1. This impedance, being wholly reactive, and representing a detuning of the capacity C by only 3 per cent., would, of course, give a deflection of the galvanometer closely equal to the limiting resonance value, attained when R is infinite.

(2) Likewise the galvanometer deflection obtained with the tube connected across C , translated in terms of the R in Figure 2, does not indicate the resistance component of the input impedance. It has been shown ("Dependence of the Input Impedance of a Three-electrode Vacuum Tube Upon the Load in the Plate Circuit," Scientific Paper of the Bureau of Standards, Number 351) that the input impedance of a tube having a pure resistance load in the plate circuit can be represented by a resistance in series with a capacity. Over a wide range of radio frequencies, both the resistance and capacitive components of the impedance are important. At the wave lengths employed by Mr. Weinberger, the input capacity is given by

$$C_g = C_1 + C_2 \left[1 + \frac{\mu R_p}{R_o + R_p} \right]$$

which becomes $C_1 + C_2$ when R_p is short-circuited. The fraction in the brackets is, of course, the over-all voltage amplification. Thus it would seem that the phenomena in the measuring circuit are more complicated than is implied by Mr. Weinberger's discussion. If a certain reading be obtained at resonance in the LC circuit, for a given value of the resistance R , it must be apparent that for a series combination of resistance and capacity giving exactly the same deflection, R does not necessarily represent either the effective resistance or the total impedance, particularly in view of the fact that the capacity-reactive component of this impedance is usually larger than the resistance component.

Julius Weinberger (communicated): Mr. Hull's discussion brings out a number of points which are quite correct. Dr. Miller has, no doubt, covered the theory of operation of a vacuum tube in the admirable paper cited by Mr. Hull, in a much more thoro manner than the foregoing note of mine. However, the data given in this note was taken about a year before Dr. Miller's paper appeared and was written up at that time, but owing to other questions involved, publication could not be permitted until recently.

It is possible that the method employed in these experiments will prove useful to investigators who are limited in the amount of apparatus at their disposal. Dr. Miller's method, using a capacity bridge at 1,000 cycles, is possibly more accurate in its determination of the various capacities which enter into this phenomenon; but even Dr. Miller states in his paper that the dielectric losses in the tube capacities exert an important effect on the input impedance, and this in itself would indicate that a radio frequency measurement is preferable (since it cannot be assumed that the dielectric losses at radio frequencies can be computed from audio frequency observations). Moreover, the determination of the capacity component of the input impedance is quite possible with the radio frequency method by computation from the observed amount of detuning on the variable condenser. When a tube is connected to the secondary circuit of a receiving set, the resistance component is all that is important since the capacity component (which may just as correctly be assumed as being in parallel with the resistance, as in series) is then compensated for by the detuning of the variable condenser. The radio frequency method here shown then indicates directly what happens in the receiving circuit.