A. THREE-CM TRAVELING-WAVE AMPLIFIER TUBES

Two tubes are under construction at the present time. One of these uses the glass-wool supports mentioned in previous progress reports, and the other uses a glass tube for supporting the helix.

The glass-wool supports have been successfully sintered in a furnace at about 750°C for seven or eight minutes. The resulting pieces contain very little glass and are quite soft, though sufficiently firm to handle. A tube has been built using these supports but, because of mechanical difficulties in assembly and misalignment of the electron gun, this tube was unsatisfactory. A second tube, in which these troubles are being rectified, is now being built.

The other tube in progress, using a glass tube around the helix, has been delayed by various mechanical difficulties and accidents, but its completion is expected soon.

The measurements of helix phase velocity have been summarized in Technical Report No. 93.

B. VELOCITY-MODULATED-INPUT TRAVELING-WAVE AMPLIFIER TUBE

Work in the last three months has been directed toward the construction of the tube so that r-f tests might begin.

A second Pierce-type electron gun has been designed and built, and tests on it are in progress.

An output-coupling arrangement which gives a good match to the helix has been obtained.

Jigs have been built for the attachment of the long glass outer envelope (which will support the tube holding the helix, the output matching post and the collector) to a molybdenum flange mounted in the cavity. It is essential that this tube be concentric with the electron-gun axis.

An attempt has been made to braze together the cavity resonator, the waveguide, the molybdenum flange and a Kovar cylinder. (The Kovar cylinder is attached to the electron-gun side of the cavity, and will allow sealing of a glass press for bringing out the electron-gun leads. The work has been delayed by a series of mishaps, but it seems at present that these can be remedied, and that a useful piece of apparatus will result.
C. **LOW-VOLTAGE THREE-CM TRAVELING-WAVE AMPLIFIER TUBE**

An attempt is being made to extend the work of Kompfner on low-noise tubes to the 3-cm region. Figures VIII-1 and VIII-2 illustrate the construction of the tube and its appearance in the complete circuit. The tube is intended to operate at about 350 volts with a beam current of 50 microamperes. The helix is made of 0.003-inch-diameter tungsten wire, wound on a 0.35-inch I.D., 200 turns/inch. It is mounted within a quartz capillary tube, selected for the proper bore, which is in turn located within the outer glass envelope. The matching slugs and final anode are made of molybdenum. This permits these parts to be made a relatively close fit within the glass tube without incurring the danger of cracking the glass due to thermal expansion. (Kovar could not be used because of its magnetic properties.) The tube shown uses a cathode assembly intended for the Raytheon 2K33 tube, and about 90 per cent of the cathode current is collected on a limiting aperture. A Pierce-type gun has been designed and is being built.

![Image of a low-voltage X-band traveling-wave amplifier tube.](image-url)

The construction of the helix presented very serious difficulties since it is necessary to hold the pitch to a tolerance of only a few per cent from its nominal value of 0.005 inch. Through the kind help of Mr. O. H. Biggs, we were able to get the helix wound on the automatic machinery at the Sylvania Lamp Division.

The velocity of propagation on this helix in free space at $\lambda = 3.3$ cm is computed to be $v = 0.045c$. The velocity of propagation along a helically conducting sheath imbedded in an external dielectric medium, $\varepsilon = 3.8$, is $v' = 0.027c$. On the basis of the experimental results on an actual helix in an external dielectric, it was estimated that the velocity on this helix
would be $v = 0.037c$. This corresponds to a beam voltage $V_o = 352$ volts. The two tubes constructed have shown maximum gain at about 350 volts. The gain parameter $C$ was computed for the free-space helix for a beam diameter 0.8 of the helix diameter, and a value $C = 0.017$ was found for a current of $10^{-4}$ amp. On the basis of the observed slowing of the wave, the change in the ratio of power slowing outside and inside the helix was estimated and a new value of $C = 0.014$ was arrived at, which would mean about 47 db of gain in a 2 3/4-inch helix.

The noise figure was computed using Pierce's equation

$$F = 80\gamma^2 V_o C = 377\gamma^2$$

for $V_o = 350$ volts, $C = 0.014$. If we estimate $\gamma^2 = 0.03$, this gives a noise figure of 10.5 db.

Actual experimental results have been as follows. Two tubes have been made. One had the helix copper-plated over half its length and had a cold-insertion loss of 20 db. The gun was tipped in assembly so that it was possible to get only 10 microamperes of collector current with 100 microamperes of helix current, which brought the net gain of the tube up to 0 db.
The second tube had a better gun, and the helix intercepted only about half the current. The curve of gain versus helix voltage showed two peaks about 20 volts apart, indicating that the helix had been stretched in assembly. Neither of the peaks showed any net positive gain. This tube is being cut open in order to replace the helix.

D. ANALYSIS OF DENSE ELECTRON BEAMS IN AN AXIAL MAGNETIC FIELD

In order to gain a clearer understanding of the electron-beam character in such tubes as the traveling-wave tube and electron-wave tube, an analysis of the beam behavior in an axial magnetic field has been undertaken.

As a beginning, axial symmetry has been assumed, and the axial component of the space-charge force has been neglected. It is also assumed that electrons in the beam do not cross each other radially. Certain special initial conditions have been treated and these indicate an axial periodicity in the character of the beam. In particular, it is found that it is possible to have a stable beam, uniform in diameter and density, and twisting as a unit about the axis with the Larmor frequency. This result has been obtained previously by other investigators (1).

Reference