VIII.   TUBE RESEARCH AND DEVELOPMENT

A.   MAGNETRON DEVELOPMENT

Prof. S. T. Martin   D. L. Eckhardt
A. G. Barrett   R. R. Moats
R. J. Renfrow

1.   High-Power 10.7-Cm Magnetron

a. Testing and design

Tests with the MF-5 magnetron have been concluded after a few hours of operation with a 5-μsec pulse. With this pulse length, sparking is more severe and begins at a lower applied voltage than in the 1-μsec pulse tests described in the Progress Report, July 15, 1950. The emission of this magnetron appears to have decreased in the course of these tests. No further tests are contemplated because the r-f test facilities have been changed over to work with the new series of magnetrons. The tube may be cut open at a later date for examination.

The problem of making a ceramic window which withstands reheating to 800°C has been solved by changing the ceramic from ZI-4 to AI-200, both of which are body types made by the Coors Porcelain Company. The AI-200 ceramic is a better match to the kovar cup in terms of coefficients of expansion, expecially at temperatures above 600°C, and is, in addition, a stronger material than ZI-4. Because of the higher dielectric constant of AI-200 the new window is 0.080 inch thick; the ZI-4 window was 0.100 inch thick.

The first model of the redesigned magnetron MF-7B has been successfully assembled and placed on the vacuum system. Processing will begin immediately. Complete sets of parts are on hand for three more tubes of the same design. They will be assembled and processed.

Complete revision of detail and of assembly drawings of the magnetron is in process to bring them up to date with the many design changes which have been made during the past year. Changes have been made in the output transformer, the waveguide output section, ceramic cathode leads, ceramic window, and stainless-steel end plates.

b.   Thoria Cathodes

All parts for a new test diode are on hand except for a ceramic cathode lead to replace a lead which was broken by accident. Tests of the new thoria cathode have also been delayed pending the repair of the transformer that supplies heating power to the cathode.

c.   Auxiliary equipment

Satisfactory life tests have been completed on the control circuits for the tube-processing vacuum system.

The new 20-Mw pulse transformer wound with a 3:1 turns ratio has been received and tested with a dummy load on the 20-Mw modulator. The test results indicate that good performance may be expected in actual magnetron service.

Both sets of fixed and moving electrodes in the rotary gap of the 20-Mw modulator have been replaced with new tungsten electrode pins as a part of the present maintenance program. During the realignment process excessive misfiring and general instability were encountered. These phenomena were traced to "hunting" in the synchronous driving motor, which in turn was caused by slight eccentricities in the motor shaft and aggravated by a commutator running out of true alignment on the same shaft. After correction of these difficulties there has been no further trouble with the rotary gap.

The baking oven for processing the magnetrons has been redesigned to eliminate the steel liner which had become severely oxidized during previous use. The new oven, patterned after suggestions made by Prof. Vinal of the Department of Metallurgy, is now under construction.

A simple control panel has been constructed and tested to operate the 3500-gauss electromagnet from a 220-volt d-c line. With this panel the field strength range for a 5 1/8-inch spacing between pole faces is 850 to 2150 gauss. This range is believed to be adequate for operating the magnetrons while on the vacuum system, especially at high pulse currents and with long pulse durations.

In order to secure stable pulse voltages in the range from 8 to 10 kv, line-type modulator model 16, serial No. 1, has been reconditioned and tested, and is ready for service. A vacuum-tube, reverse-current relay has been installed so that this unit is identical with similar modulators having higher serial numbers. This modulator will be used for the most part in processing magnetrons on the vacuum system.

2. Magnetron Research

a. Mode interaction in magnetrons

Work on this program has been completed. The results will be published in forthcoming Technical Report No. 171.

b. Noise properties of the pre-oscillating magnetron

Work on this subject has been resumed. Failure of a crucial amplifier in the noise test set has held up experiments for several weeks. A substitute amplifier is being adapted for use in making measurements.

B. MICROWAVE TUBES

L. D. Smullin   H. J. Krusemeijer

L. A. Harris   H. E. Rowe

H. Haus   L. Torstensson

1. Theory of Noise in Traveling Wave Tubes

A preliminary study has been made of various systems of reducing the magnitude of the growing wave excited by the noise power in the beam. The systems examined fall into two classes: a) possible methods of reducing the noise energy in the beam, and b) methods for arranging the phase and magnitude of the velocity and current modulations in order to cause the smallest excitation of the growing wave in the helix.

The first system involved an examination of possible interaction circuits to determine whether it was possible to make all of the three forward waves have negative real exponents (attenuating). It is possible to write the characteristic equation for a traveling wave tube in terms of the radial admittance seen looking out from the beam to the interaction circuit. If the beam is thin, we can write

$$a \approx \pm \sqrt{\frac{\omega_1^2/v_0^2}{-2Y_0/j\omega\varepsilon d}} \tag{1}$$

where $j\lambda = j\beta - a$, v_0 is the actual propagation constant, $\beta = \omega/v_0$, $\omega_1^2 = e\rho_0/m_\varepsilon = $ plasma frequency of beam, $2d = $ thickness of beam, and $Y_0 = $ radial admittance of the external circuit as seen from the beam. Then the problem is to find the required dependence of Y_0 upon a that will result in attenuated waves only (negative, real a's). A form was assumed for a lossless circuit

$$Y_0 = jA \frac{(ja - \rho_1)(ja - \rho_2) \cdots}{(ja - \rho_{n+1})(ja - \rho_{n+2}) \cdots} \tag{2}$$

where A and ρ_n are real. If Eqs. 1 and 2 are combined, the result is a polynomial in a with alternating real and imaginary coefficients. The roots must be purely imaginary or in pairs with equal positive and negative real parts. Thus attenuated and growing waves always coexist if the circuit is lossless.

For a lossy circuit, Eq. 2 was replaced by

$$Y_0 = jA \frac{a + \sigma' + j(\beta' - \beta)}{a + \sigma'' + j(\beta'' - \beta)} \quad . \tag{3}$$

Where $\mathrm{Im}(A) \approx 0$, $\mathrm{Re}(A) > 0$, σ' and $\sigma'' > 0$, then Eqs. 1 and 3 give

$$\left(\frac{\alpha}{j\beta C}\right)^3 + \left(\frac{\beta'-\beta}{\beta C} - \frac{j\sigma'}{\beta C}\right)\left(\frac{\alpha}{j\beta C}\right)^2 - \frac{\alpha}{j\beta C} - \left(\frac{\beta''-\beta}{\beta C} - \frac{j\sigma''}{j\beta C}\right) = 0$$

where

$$C = \sqrt{\frac{J_o d}{4 v_o \beta^2 A}}$$

The conditions under which $\mathrm{Re}\,(\alpha) < 0$ for all roots are:

$$\sigma' > 0$$

$$\frac{\sigma'}{\beta C} > \frac{\sigma''}{\beta C}$$

$$\frac{\sigma''}{\beta C}\left[\frac{\sigma'}{\beta C} - \frac{\sigma''}{\beta C}\right]^2 - \frac{\sigma'}{\beta C}\left[\frac{\sigma'}{\beta C}\left(\frac{\beta'-\beta}{\beta C}\right) - \frac{\sigma''}{\beta C}\left(\frac{\beta''-\beta}{\beta C}\right)\right]^2 \geqslant 0 \quad .$$

A helix with arbitrary phase velocity and diameter can not satisfy these requirements if the loss is due to the resistance of the helix wire. It may be that frequency selective loss can be utilized by placing lossy material beyond the helix in order to attenuate low frequencies more than the high ones; no careful examination of this has yet been made.

The second system, that of introducing a circuit to minimize the excitation of the growing wave, is based on the fact that the equation for the growing wave indicates that it can be made zero.

$$E_{1n} = \frac{\dfrac{2V_o}{j\beta_o}\dfrac{q}{J_o}\delta_2\,\delta_3 + \dfrac{\mu_o V}{\eta}(\delta_2 + \delta_3)}{(1 - \delta_2/\delta_1)(1 - \delta_3/\delta_1)}$$

where q and v are the noise convection current density and velocity modulations. Can we thus devise a circuit that will produce the required value of q/v at the start of the main helix? Numerical computations are being made of the action of a short helix, with and without loss. The work, thus far, indicates that it is impossible to get the required value of q/v to make $E_{1n} = 0$, with a structure consisting of the gun; a first drift tube; a helix of arbitrary loss, phase velocity, and length; a second drift tube; and the main helix. It is not yet possible to say whether such a structure will give a better noise figure than is possible without the prehelix.

The conclusions of these two investigations are, tentatively, that there is no way of reducing the noise modulation of the beam by attenuation, and that it is impossible to get the exact cancellation necessary to make $E_{1n} = 0$ by means of a prehelix.

H. Haus, L. D. Smullin

2. 3-Cm Traveling Wave Tube Construction

A fair part of the time has been spent in teaching construction techniques to new members of the group. An improved centering device for locating the tube in the solenoid made it possible to get 97 percent of the current through the helix to the collector (1 ma at 1000 volts). Three tubes with gains of 8 to 15 db were built, but no noise measurements were made.　　　　　　　L. Torstensson, H. E. Rowe, L. D. Smullin

3. Dense Electron Beams in Axial Magnetic Fields

This work has been completed. It is described in forthcoming T. R. No. 170.

L. A. Harris