

## VI. TUBE RESEARCH AND DEVELOPMENT

### A. MAGNETRON DEVELOPMENT

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#### 1. High-Power 10.7-Cm Magnetron

##### a. Testing and design

Operating tests have been renewed with the magnetron designated as MF-5 (ref. 1). The total operating time for this tube now exceeds 65 hours.

Although efforts to secure more than a 3-Mw peak output from this tube after a year of shelf life have been unsuccessful, the test results have directed attention to an apparent "ceiling" in  $\pi$ -mode operation, and to reasons for the sparking which accompanies attempts to penetrate this barrier. The "ceiling" effect is particularly noticeable when operating the tube without an iris at the ceramic window. The cold resonance curve for this condition has a double hump form, and also indicates an external Q of much less than the desired value of 230. The iris had been used in order to increase the external Q.

Any attempt to increase the input pulse voltage over a critical value of approximately 30 kv results in internal sparking and corona in the cathode leads and end spaces, and in loss of output power. Variation of magnetic field strength from a critical value of approximately 1200 gauss produces similar results. When the field strength is increased to between 2500 and 3000 gauss, and there is no oscillation, the tube will withstand at least 38 kv without serious internal sparking.

It has been suggested that this "ceiling" effect results from a combination of factors which include the presence of positive ions due to the breakdown of residual gas and the field emission of electrons from sharp points and edges which remain inside the tube after fabrication.

The importance of this second factor has been investigated in a series of high potential tests conducted at the Insulation Research Laboratory through the courtesy and cooperation of Mr. Dean A. Powers. Anode to cathode breakdown voltage and anode to cathode lead breakdown voltage were measured at atmospheric pressure with a d-c high voltage supply. The results of these tests show that the new ceramic cathode leads have at least a 50-percent higher voltage breakdown strength in air than the glass lead construction. In addition, rounding and smoothing the vane tips at both ends of the MF-7 anode block also increased the anode-cathode breakdown voltage in air by 50 percent.

Anode to cathode d-c breakdown voltages were measured on the MF-5 magnetron for both polarity conditions and no magnetic field. In either case, breakdown occurred at

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approximately 18 kv. It is significant that these static tests produced sparking and corona phenomena essentially identical to those obtained with pulsed operation.

The observed difference between d-c and pulsed operation breakdown voltages is believed to be due to the following factors which are present in the latter case.

1. Voltage is applied for such short intervals (1  $\mu$ sec) and so infrequently (120 pps) that conduction due to collision ionization and field emission cannot get started until relatively high voltages are applied to the tube.

2. The modulator is a low impedance source which can maintain a relatively high voltage while supplying corona and sparking losses.

3. The axial magnetic field tends to lengthen the electron paths and thereby to increase the breakdown voltage.

Preliminary experiments with straight butt-type metal-ceramic seals for use in cathode leads met with variable success as explained in the Quarterly Progress Report, January 15, 1950. The reason for the cracking of the ceramic was traced to a discontinuous expansion characteristic of the type 430 stainless steel used as the metal part of the seal (2). A 28-percent chrome-steel alloy closely matches the expansion of the ceramic, ALSIMAG 243, and has a smooth and reversible expansion characteristic. This alloy is made by the Allegheny Ludlum Steel Corp. and is known as SEALMET No. 1.

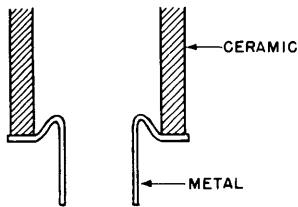


Fig. VI-1 Design of metal-ceramic seal.

As a stop-gap for use until the SEALMET No. 1 tubing could be obtained, the design of the metal portion of the seal was modified to minimize the effect of the 430 stainless steel expansion characteristic. The redesigned metal-ceramic seal is shown in Fig. VI-1. Since this modification was made, twelve metal-ceramic seals of this type have been made successfully. All have been vacuum-tight and one has been baked to a maximum temperature of 750°C.

The anode of the high-power magnetron has been redesigned towards simplifying the construction of the tube. In the new design, the final sealing up of the tube will be a welding operation instead of the previously used operation of resistance brazing. Two stainless steel rings are soldered to the ends of the anode during the operation in which the output, anode and window assemblies are soldered together. During this process, stainless steel spinnings for cathode and pumping leads are also soldered to the anode.

Four anodes and eight output assemblies for the high-power magnetron have been completed. Construction of four additional anodes has been started and will be completed when the design of the thoria cathode has been standardized. The necessary cathode leads, windows and pumping leads for all eight tubes are in the process of construction.

Prior to the first assembly operation on the complete magnetron, the information gained from the high voltage breakdown tests, previously mentioned, is applied to each

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anode. The vane tips at both ends of the anode block will be rounded off as standard practice on all future magnetrons.

b. Thoria cathodes

The end-mounts for mounting thoria cathodes in the magnetron have been redesigned in order to give good high-voltage design and to minimize the overall length of the cathode assembly.

A full-sized cathode was mounted in a diode, the construction of which approximated that of the magnetron, and tests on cathode power vs. temperature were conducted. The diode was then pulsed to 7000 volts at 1600°B. Measurements indicated that the cathode resistance was lower than anticipated by a factor of 5, and the emission was well below the space charge limitation value.

The cathode failed after about 36 hours of operation. Examination of the cathode, when the tube was opened, showed that a hot spot had existed at a point on the cathode outside the range of observation, and that this had boiled a considerable amount of molybdenum away at that point, causing failure. The failure was apparently caused by stratification of the cathode by vibration of the die during loading in the manufacturing operation. The hot spot appeared at a thoria-rich section of the cathode, where the resistance was high. In the future, the die will be loaded without vibration in packing the powder into the die.

c. Auxiliary equipment

The new inductor for the 1- $\mu$ sec pulse-forming network has been constructed, installed, tested and put into service in tests of the MF-5 magnetron.

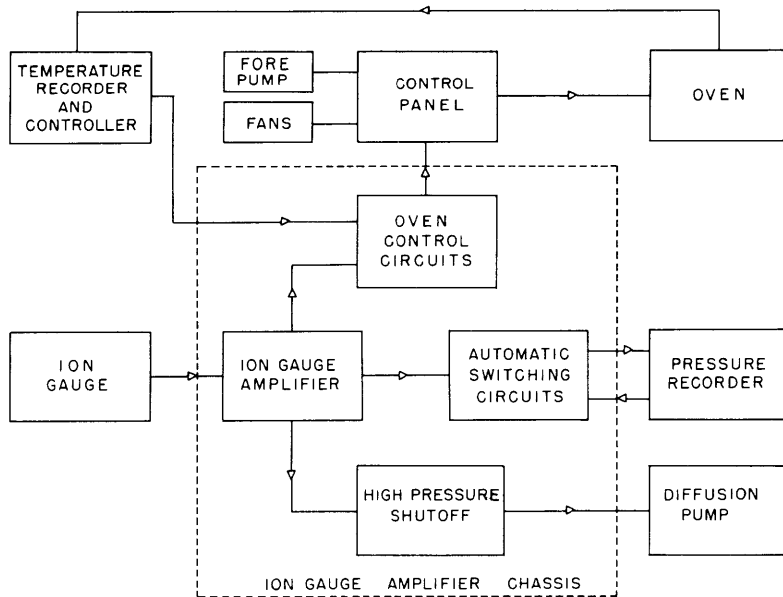


Fig. VI-2 Control circuits of the tube processing vacuum system.

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A new 20-Mw pulse transformer wound with a 3:1 turn ratio has been ordered. Except for the turns ratio, this transformer is identical with the 4:1 transformer mentioned in a previous progress report.

The control circuits for the tube processing vacuum system have been redesigned and rebuilt. Fig. VI-2 is a block diagram of the components used in the complete system.

A Brown Instrument Co. recorder and controller is used to regulate the temperature of the "bake-out" oven. An oven control circuit turns off the oven if pressure in the vacuum system rises above  $2.5 \times 10^{-4}$  mm Hg. When the pressure falls to  $1 \times 10^{-4}$  mm Hg, this circuit turns on the power to the oven. Should the pressure for any reason rise to a value higher than  $5 \times 10^{-4}$  mm Hg, or if there should be a temporary power failure, the high pressure shut-off circuit will turn off the ion gauge amplifier, diffusion pump and oven. These units must then be turned on manually.

A Celect Ray four-channel recorder is used to record pressure in the vacuum system over a range of four decades. The automatic switching circuits on the ion gauge amplifier chassis determine the sequence and frequency with which pressure on the four different ranges is read by the recorder.

The use of a standard S-band waveguide output on the magnetron has made necessary a change in the r-f test equipment for testing the tubes. Part of this equipment has been constructed; all of it will be available for processing and testing the next tube.

### 2. Magnetron Research

#### a. Mode interaction in magnetrons

Interaction tests of the type described in the Quarterly Progress Report, January 15, 1950 have been performed for another 718-EY magnetron, first for normal loading, and then for a more lightly loaded  $\pi$ -mode. Power measurements were made for each condition of loading for the same applied voltage, and relative r-f voltages on the magnetron anode were computed.

Theoretical considerations (3) for non-linear oscillators suggest that oscillation in one mode should tend to load any other mode, and that the greater the amplitude of oscillation, the greater should be this effect. Therefore, in the tests described above, the loading of the  $n = 3$  mode produced by the presence of  $\pi$ -mode oscillation should be greater for the lightly loaded  $\pi$ -mode, where the magnitude of r-f voltage within the magnetron is greater, than for the normally loaded  $\pi$ -mode. The standing-wave measurements of the  $n = 3$  mode in the presence of  $\pi$ -mode oscillations, normally loaded, led to various values of loaded Q for  $n = 3$ , depending on the method of calculation. Two methods of calculation showed that the smaller amplitude of  $\pi$ -mode oscillation had more effect upon loading the  $n = 3$  mode, while another gave opposite results which agreed

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more nearly with those predicted theoretically.

Oscillation in this 718-EY magnetron was found to be relatively weak and inefficient, and at the same time very noisy. X-ray photographs showed that the cathode was considerably off center. The experiment is being repeated, using a 2J32 magnetron.

A mode shift test has been made, using the 2J54, an eight hole-and-slot, single-strapped, tunable S-band magnetron. This magnetron was found to oscillate in the  $\gamma = 5$  component of the  $n = 3$  mode ( $5/3/8$ ) for low input currents under some conditions. The shift from the  $5/3/8$  mode to the  $\pi$ -mode ( $4/4/8$ ) was examined and photographed; the output of a wide-band diode detector directly on the plates of a P-5 synchroscope was used in order to observe the r-f envelope of the magnetron output. No cessation of oscillation was observed during the transition. This observation seemed to indicate some degree of competition between modes. It was further observed that this mode shift is primarily a function of conditions in the  $\pi$ -mode, the final mode in the mode shift, rather than of the original mode. The latter observation is in contrast to results obtained previously with a low-power rising-sun magnetron (4).

The non-linear oscillator theory discussed above (3) may be consistent with a mode change depending primarily on either the original mode or the final mode. In the 2J54, oscillation in the  $5/3/8$  mode has little vitality. However, synchroscope observations of the r-f envelope (e. g. Fig. VI-3) show that if the  $5/3/8$  mode can start ahead of the

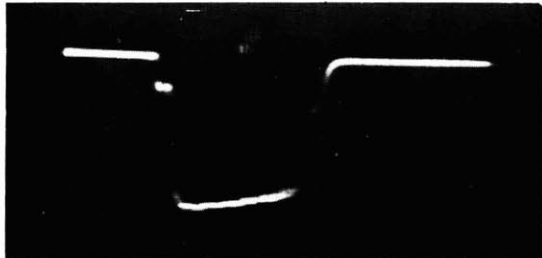


Fig. VI-3 R-F envelope, 2J54 magnetron. Oscillation starts in  $5/3/8$  mode, then shifts to  $\pi$ -mode ( $4/4/8$ ). Pulse duration approximately  $2 \mu\text{sec}$ .

$\pi$ -mode, it will delay the starting of the  $\pi$ -mode appreciably. Thus, here is an example of one mode merely being delayed in starting, rather than being suppressed, by the presence of oscillation in another mode.

The contemplated use of the micro-oscillograph for observation of mode transitions has been postponed indefinitely, due to leaks in the vacuum system. A P-5 synchroscope used in combination with a broad-band diode detector, as described above, has been used as a substitute with some degree of success. The time constant of the detector is estimated to be considerably less than the time constants usually observed for build-up and decay of oscillations in S-band magnetrons.

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b. Mode identification in magnetrons

The rotating probe experiment for identifying the resonant frequencies of the anode used in the high power magnetron has been completed. The method used for identifying the various resonant frequencies is explained in detail in R. L. E. Technical Report No. 99. A plot of the Hartree voltages calculated from these measured frequencies is shown in Fig. VI-4.

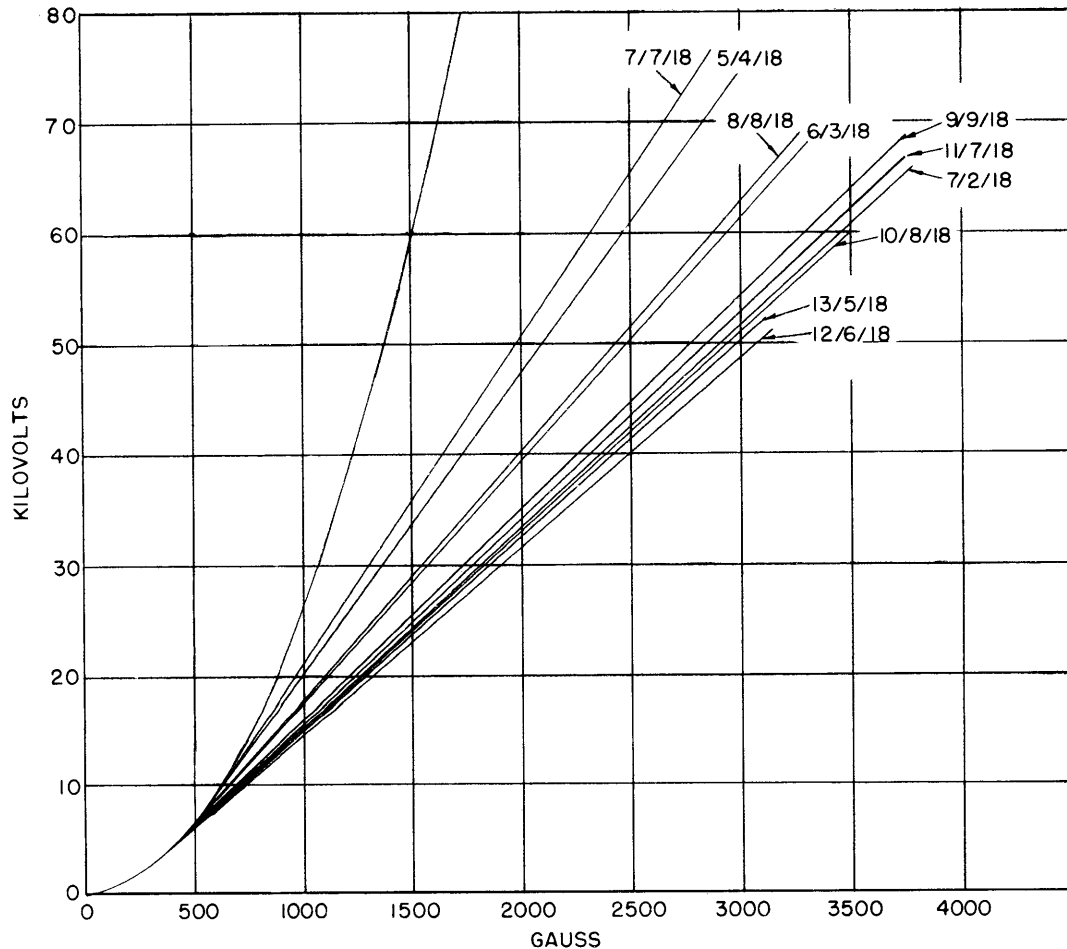


Fig. VI-4 Hartree plot for MF-7 anode.

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3. B. van der Pol: Phil. Mag. 43, 700-719 (1922).
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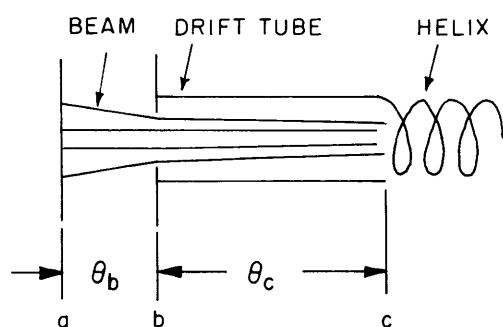
## B. MICROWAVE TUBES

L. D. Smullin      G. W. Zeoli  
L. A. Harris

## 1. Microwave Noise Studies

This work has been completed and submitted as a Master's thesis in the Electrical Engineering department by Mr. Karp.

## 2. Theory of Noise in Traveling-Wave Tubes



The analysis of noise in traveling-wave tubes has been extended by taking account of the space charge in the drift section between the anode and the start of the uniform section of the helix. This is handled according to the methods of Hahn (1) and Ramo (2). The anode cathode region is still treated by the infinite parallel plane method of Llewellyn. The current density and velocity fluctuations at the anode plane are

$$q_b = j \frac{J_o}{u_o} v_a \theta_b e^{-j\theta_b} \quad (1)$$

$$v_b = -v_a e^{-j\theta_b} \quad (2)$$

where  $J_o$  is the d-c current density,  $u_o$  is the d-c velocity corresponding to  $\sqrt{2\eta V_o}$ ,  $\theta_b$  is the transit angle in the gun, and  $v_a$  is the velocity fluctuation of the electrons leaving the cathode. According to Rack (3),  $v_a$  has a mean squared value

$$\overline{v_a^2} = \frac{\eta k T_c B}{I_o} (4 - \pi) \quad (3)$$

Within the drift tube the fluctuation current density and velocity at plane c are given by

$$q_c = q_b \cos \delta\theta_c + j v_b \frac{J_o}{\delta u_o} \sin \delta\theta_c \quad (4)$$

$$v_c = j q_b \frac{\delta u_o}{J_o} \sin \delta\theta_c + v_b \cos \delta\theta_c \quad (5)$$

where  $\delta$  defines the velocity of the two electron waves in the drift tube

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$$\beta = \frac{\omega}{v_o} (1 \pm \delta)$$

and is defined explicitly in ref. 2.

Using Eqs. 1 and 2, Eqs. 4 and 5 may be rewritten

$$q_c = j \frac{v_a J_o}{u_o \delta} (\delta \theta_b \cos \delta \theta_c - \sin \delta \theta_c) \quad (6)$$

$$v_c = -v_a (\delta \theta_b \sin \delta \theta_c + \cos \delta \theta_c) \quad (7)$$

The growing wave excited in the helix by these components is

$$E_1 = \frac{2\beta_o C \frac{V_o}{u_o} \left[ \frac{q_c C u_o}{j J_o} \left( \frac{1}{2} - j \frac{\sqrt{3}}{2} \right) - v_c \left( \frac{\sqrt{3}}{2} - \frac{j}{2} \right) \right]}{3 \left( \frac{1}{2} + j \frac{\sqrt{3}}{2} \right)} \quad (8)$$

$$= \frac{2\beta_o C \frac{V_o v_a}{u_o} \left[ C \left( \theta_b \cos \delta \theta_c - \frac{\sin \delta \theta_c}{\delta} \right) \left( \frac{1}{2} - j \frac{\sqrt{3}}{2} \right) + (\cos \delta \theta_c + \delta \theta_b \sin \delta \theta_c) \left( \frac{\sqrt{3}}{2} - \frac{j}{2} \right) \right]}{3 \left( \frac{1}{2} + j \frac{\sqrt{3}}{2} \right)} \quad (8)$$

The mean square value of this is

$$|\bar{E}_1|^2 = \frac{4\beta_o^2 C^2 V_o^2 v_a^2}{9u_o^2} |A|^2 \quad (9)$$

where

$$|A|^2 = \frac{1}{2} (1 + \sigma^2)(1 + \rho^2) + \left[ (1 - \rho^2)(1 - \sigma^2) + 2\sqrt{3} \rho \sigma \right] \cos 2\delta \theta_c + \left[ 2\rho(1 - \sigma^2) + \sqrt{3} \sigma(\rho^2 - 1) \right] \sin 2\delta \theta_c \quad (10)$$

and

$$\sigma = \frac{C}{\delta}, \quad \rho = \delta \theta_b$$

The minimum and maximum values of  $|A|^2$  will occur at

$$\tan 2\delta \theta_c = \frac{2\rho(1 - \sigma^2) + \sqrt{3} \sigma(\rho^2 - 1)}{(1 - \rho^2)(1 - \sigma^2) + 2\sqrt{3} \rho \sigma} \quad (11)$$

so that



$$|A|_{\min}^2 = \frac{1}{2}(1 + \rho^2) \left[ (1 + \sigma^2) \pm \sqrt{1 + \sigma^2 + \sigma^4} \right] \quad (12)$$

max

The noise figure of the amplifier is defined by the ratio

$$F = \frac{\overline{|E_1|_T^2} + \overline{|E_1|_T^2}}{\overline{|E_1|_T^2}}$$

where  $\overline{|E_1|_T^2}$  is the noise power induced from the antenna resistance. Then we get

$$F = 1 + \frac{0.215 T_c}{T} \frac{|A|^2}{C} \quad (13)$$

where  $T_c$  and  $T$  are the temperatures of the cathode and of the antenna impedance; and

$$F_{\min} = 1 + \frac{0.215 T_c}{T} \frac{(1 + \rho^2) \left[ (1 + \sigma^2) - \sqrt{1 + \sigma^2 + \sigma^4} \right]}{C} \quad (14)$$

From this we find that for the best noise figure  $\rho = \delta\theta_b$  and  $\sigma = C/\delta$  should be small, while  $C$  should be large. For ordinary geometries and currents  $C$  and  $\delta$  are of the same order of magnitude, about 0.01 to 0.02.  $\rho$  can be made small by decreasing  $\theta_b$ , which amounts to reducing the cathode area, if the voltage and current are held constant.

Fig. VI-5 is a plot of the variation in  $|A|^2$  with distance along the drift tube. The assumed parameters are:  $\lambda = 3.3$  cm,  $V_0 = 1000$  volts,  $I = 1$  ma,  $C = \delta = 0.018$ , ( $\sigma = 1$ ),

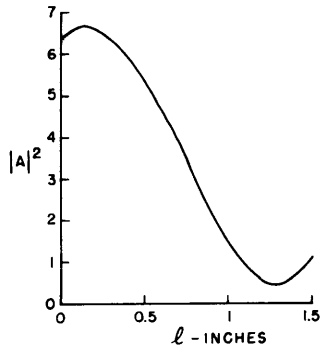


Fig. VI-5 Effect of drift-tube length on traveling-wave-tube noise figure.

$\theta_b = 89$  radians, ( $\delta\theta_b = 1.6$ ). The minimum value of  $|A|^2$  occurs at  $\delta\theta_c = 103^\circ$ , or  $\theta_c = 5730^\circ$  (measured in terms of the electron wavelength  $\lambda_e = \lambda(u_0/c)$ ).

L. D. Smullin

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### 3. Electron Wave Solution for Space-Charge-Limited Diode

The linear, small-signal analysis of the infinite parallel plane diode may be carried out as a wave problem. The results are the same as those found by Llewellyn (1) but the method of solution is one that presumably can be extended to other geometries, such as a cylindrical beam.

Using the treatment now commonly applied to traveling wave tubes, the velocity, current, charge density and potential are written as

$$v_1 = v_o + ve^{j\omega t}, \text{ etc.}$$

where the d-c velocity  $v_o \gg v$ . All quantities except  $q_o$ , the d-c current density, are functions of the distance  $z$ . From equations of force, conservation of charge, and Poisson's equation, one finally gets a differential equation for the a-c convection current density

$$\frac{\partial^2 q}{\partial z^2} + \frac{\partial q}{\partial z} \left( \frac{2j\omega}{v_o} + \frac{3}{v_o} \frac{\partial v_o}{\partial z} \right) + q \left( \frac{-\omega^2}{v_o^2} + \frac{2j\omega}{v_o^2} \frac{\partial v_o}{\partial z} + \frac{\eta q_o}{\epsilon v_o^3} \right) = \frac{\eta \rho_o j\omega}{v_o^2} E \quad (1)$$

where  $\eta = e/m$ , and  $E$  is the uniform a-c field that would exist in the diode in the absence of the electrons, due to an impressed voltage.

If we assume space-charge-limited flow, then  $v_o = kz^{2/3}$ ,  $\rho_o = q_o/(kz^{2/3})$ , and Eq. 1 becomes

$$\frac{\partial^2 q}{\partial z^2} + \frac{\partial q}{\partial z} \left( \frac{2j\omega}{kz^{2/3}} + \frac{2}{z} \right) + q \left( \frac{-\omega^2}{k^2 z^{4/3}} + \frac{4j\omega}{3kz^{5/3}} + \frac{2}{9z^2} \right) = \frac{\eta q_o j\omega E}{k^3 z^2} \quad (2)$$

The homogeneous solution of Eq. 2, ( $E = 0$ ) is of the form

$$q = A z^a e^{bz^{1/3}} \quad (3)$$

which results in

$$q = (A_1 z^{-1/3} + A_2 z^{-2/3}) e^{-j\theta} \quad (4)$$

where  $\theta = 3\omega z^{1/3}/k$  is the transit angle in space-charge-limited flow. The velocity fluctuation is given by

$$v = \frac{v_o}{q_o} \left( q + \frac{v_o}{j\omega} \frac{\partial q}{\partial z} \right) \quad (5)$$

or

$$v = \left[ A_1 kz^{1/3} + A_2 k \right] e^{-j\theta} \quad (6)$$

If we assume an initial  $q_s$  and  $v_s$  at a plane  $z = s$ , then we can evaluate the constants,

and the result is

$$q = \left\{ q_s \left[ 2 \left( \frac{s}{z} \right)^{1/3} - \left( \frac{s}{z} \right)^{2/3} \right] + \frac{3j\omega q_o}{k^2} v_s \left( z^{-1/3} - \frac{s^{1/3}}{z^{2/3}} \right) \right\} e^{-j\phi} \quad (7)$$

$$v = - \left[ \frac{2q_s}{q_o} \frac{k^2}{3j\omega} \left( s^{1/3} - \frac{s^{2/3}}{z^{1/3}} \right) + v_s \left( 1 - \frac{2s^{1/3}}{z^{1/3}} \right) \right] e^{-j\phi} \quad (8)$$

where  $\phi = \theta - \theta_s = \frac{3\omega}{k} (z^{1/3} - s^{1/3})$ .

We have assumed small signal conditions, i. e.  $v \ll v_o$ . Since  $v_o = kz^{2/3}$ , we cannot let  $z = 0$  and still have a finite  $v_s$ . However, we can let  $s \ll z$ , in which case

$$q \simeq v_s \frac{3j\omega q_o}{k^2 z^{1/3}} e^{-j\phi} = \frac{v_s}{v_o} q_o j\theta e^{-j\theta} \quad (9)$$

$$v \simeq -v_s e^{-j\phi} \quad (10)$$

These are, of course, the same results which Llewellyn obtains.

The inhomogeneous solution ( $E \neq 0$ ) may be found by standard methods (2), and again the results are like Llewellyn's. Although the results thus far are not new, it is hoped that this method eventually may be extended to the case of a cylindrical beam or even of a conical beam.

L. D. Smullin

#### References

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#### 4. Traveling-Wave Tube Construction

3-cm, 1000 volt, 1-ma tube. A new r-f coupling section has been designed. It consists of the usual helix-to-waveguide transition followed by a waveguide-to-coax (type N) transition. This arrangement allows the entire assembly to be placed within a solenoid 2 5/8 inches in diameter with the coaxial leads coming out of one end. The focusing solenoid is completely iron encased, and the magnetic field acting on the beam can be made constant over the length of the helix. In the first tube tested in this assembly 80 percent of the beam current reached the collector after passing through the helix which is 0.050 inch in diameter and 6 inches long; about 15 watts of magnet power were required for this condition.

Six new tubes are under construction for further tests in this system.

G. W. Zeoli

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### 5. Dense Electron Beams in Axial Magnetic Fields

#### a. Theory

The theoretical work is essentially complete and is being written up. Explicit design formulae for the various special cases of practical interest are derived and the numerical values for the proposed experiments are computed from these formulae.

#### b. Experiment

The electron gun for the experiments has been tested and found satisfactory and suitable for all of the experiments. The transmission efficiency is over 90 percent, and the design current of 0.5 amp is drawn with an anode voltage of 1000 volts. Another test is planned to determine the effect of some added lens plates.

The vacuum system has caused considerable delay because of its low pumping speed; modifications are in progress.

A pulsed power supply is complete and functions satisfactorily, operating the tube with a duty ratio of 0.01. The measuring circuits are being built into a panel unit.

Drift tubes, collectors, centering rings, insulators and other hardware for use in the tubes are almost completed. After the transition regions are designed, all the apparatus should be ready for the completion of the tests.

L. A. Harris

### 6. Operation of Pulsed Magnetrons into High Q Loads

It was decided to investigate the behavior of pulsed high-power magnetrons working into a high Q cavity with the purpose of building up a strong electromagnetic field such as is desired for standing-wave acceleration of electrons in resonant cavities. A round cylindrical cavity has been designed and has been built in such a way that it can be excited only in the  $E_{010}$  mode, in the frequency band of 10.7 cm, with an unloaded Q of  $2 \cdot 10^4$ . Provisions have been made so that a plunger can be inserted into the cavity through the cylindrical wall in order to change the frequency of the cavity over a few percent of range whenever this might be desirable; for example, when working with fixed tuned magnetrons. The cavity was attached and matched to a piece of 1.5-inch by 3-inch waveguide and the equivalent plane of the assembly determined. A system has been set up using a hard tube modulator, a Raytheon RK5586, 10.7-cm tunable magnetron, the cavity with vacuum system to evacuate it, and a variable load in parallel with the cavity. A hard tube modulator is used instead of the less bulky, line-type modulator because the pulse shape and height produced by the latter is actually a function of the impedance of the magnetron with the result that the actual conditions under which the magnetron works become a function of the behavior of the magnetron itself. This seems to be especially important in the case of this experiment where misfiring of the magnetron is liable to

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happen with the consequences, when using a line-type modulator, of voltage overshoot, sparking of the magnetron and damaging the cathode.

A first objective of the experiment is to determine the building-up of the cavity field as a function of the shunt load. When the most favorable working conditions of the magnetron and the attached circuits are established, the experiments will be repeated with the line type modulator.

H. Krusemeijer

### 7. Thoria Coated Tungsten Cathodes

In the course of some attempts to make an indirectly-heated, thoria-coated, button cathode, it was discovered that a mixture of thoria and tantalum fuses into a dense, glassy substance when heated in hydrogen at about 1800°C. This mixture flows on, and bonds to tungsten. The good mechanical properties of this compound as compared to a sprayed coating of thoria led us to try it as an emitter. Preliminary tests indicated that an activation temperature of 1900°C to 2000°C was required, and space-charge-limited current densities of 1 amp/cm<sup>2</sup> were attainable at operating temperatures of about 1750°C.

A number of cylindrical test diodes were made using 0.007-inch tungsten wire for the base of the coating, and having 1/4-inch diameter Ta anodes and guard rings. The percentage of Ta and ThO used in the coating was varied between about 20 percent to 50 percent Ta. The coatings were usually sprayed on to the tungsten wire, and then bonded by flashing the wire in a hydrogen bell jar to about 1600°C. This resulted in a strong coating, but left the wire fairly ductile.

Almost all of the tubes had approximately the initial properties described above. The life tests were more disappointing. After times of about 100 hours, the coating had disappeared due to evaporation, where the initial brightness temperature had been set at 1700°C. The thermal conductivity of the material is quite low. This was made apparent by the fact that wherever the coating was broken off so that the base metal could be seen, the tungsten appeared to be several hundred degrees hotter than the surface of the coating, which was only a few thousandths of an inch thick.

Some mixtures of Ta, ThO, and Mo were tried. These apparently formed some low melting alloy with the tungsten, since all of the cathodes of this type failed on life test by burning out the filament, even though the initial brightness temperature had been adjusted to 1750°C.

A few tubes were tried in which the Ta was replaced by TaH, and the filament flashed in vacuum in the actual tube assembly. These coatings were never as strong as those described above, and the emission properties were not very different. No life tests were made.

F. Rosebury, L. D. Smullin

(VI. TUBE RESEARCH AND DEVELOPMENT)

C. THE GENERATION OF MILLIMETER AND INFRARED RADIATION BY  
ACCELERATED ELECTRONS

The microwave cavity accelerator has been operated with one of the newly constructed klystron tubes. High x-ray intensities were produced when the electron beam was allowed to strike a target while preparing to measure the energy spectrum distribution.

Preliminary measurements indicated electron energies between 1 Mev and 1.25 Mev. While shielding parts of the apparatus with lead bricks, the klystron tube was broken so that further work will be delayed for some weeks.

P. D. Coleman

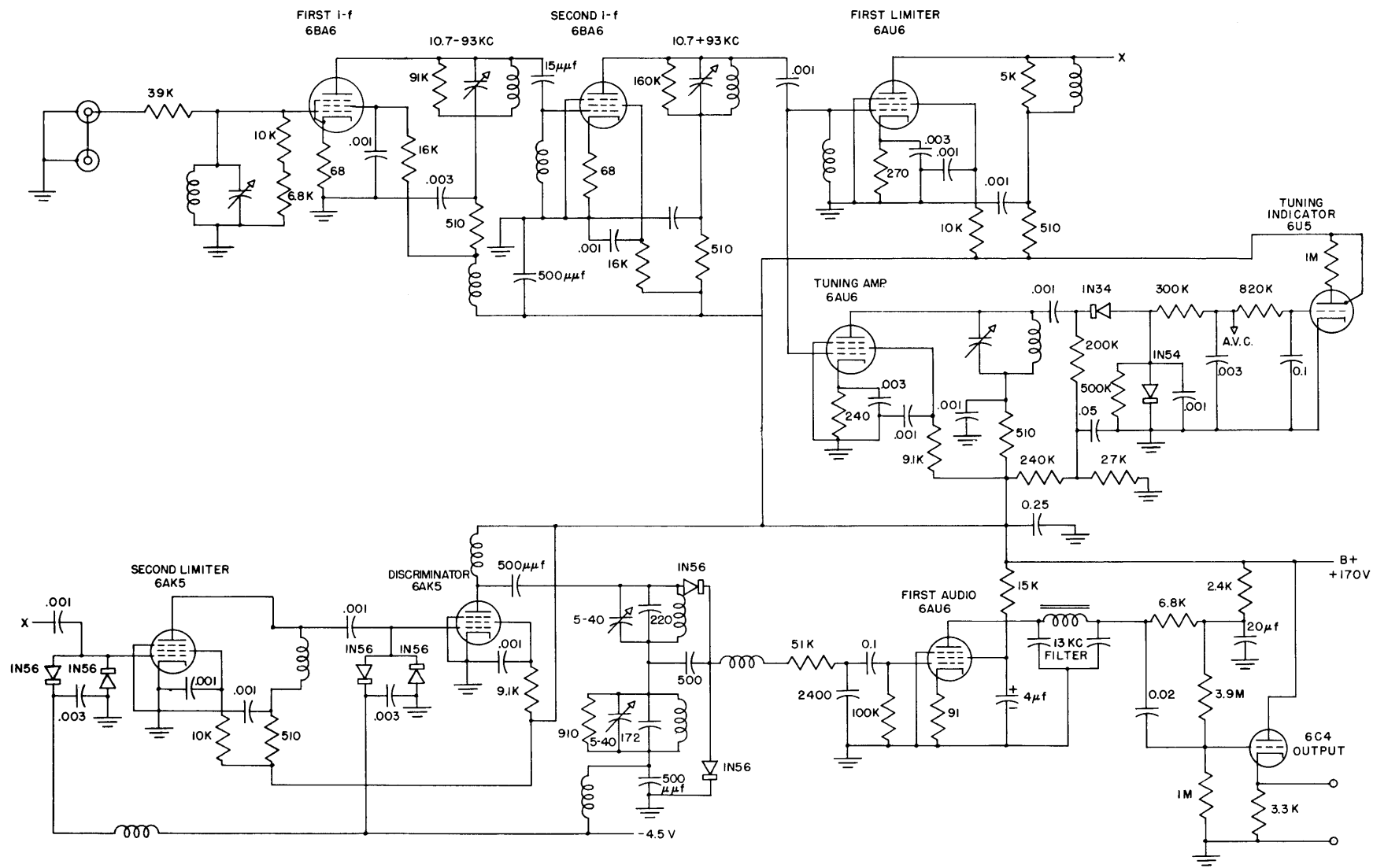


Fig. VII-1 Diagram of simplified receiver.