VIII. MICROWAVE TUBE RESEARCH

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A. NOISE IN ELECTRON BEAMS

A number of noise measurements have been made on confined-flow electron beams produced by a parallel Pierce gun with the following parameters: perveance, 0.07×10^{-6} amp/volt$^{3/2}$; cathode diameter, 0.040 inch. The experimental procedure and setup used in these measurements was similar to that used in the case of convergent-flow electron beams and described in the Quarterly Progress Reports of April 15 and July 15, 1953.

Noise power measurements were performed under both pulsed (unneutralized) and steady current (neutralized) conditions. The curves of Figs. VIII-1 and VIII-2 show the results of pulsed beam measurements for space-charge-limited and temperature-limited emission, respectively.

While growing noise waves could be observed at all times under pulsed conditions, the measurements performed on steady current beams have not given any indication of growing noise waves. Changes in the magnetic field (above a certain minimum value required to collimate the beam) seemed to have little effect on the noise under both pulsed and steady current operation. This result, of course, could be expected when the nature of electron paths in a confined-flow beam is considered.

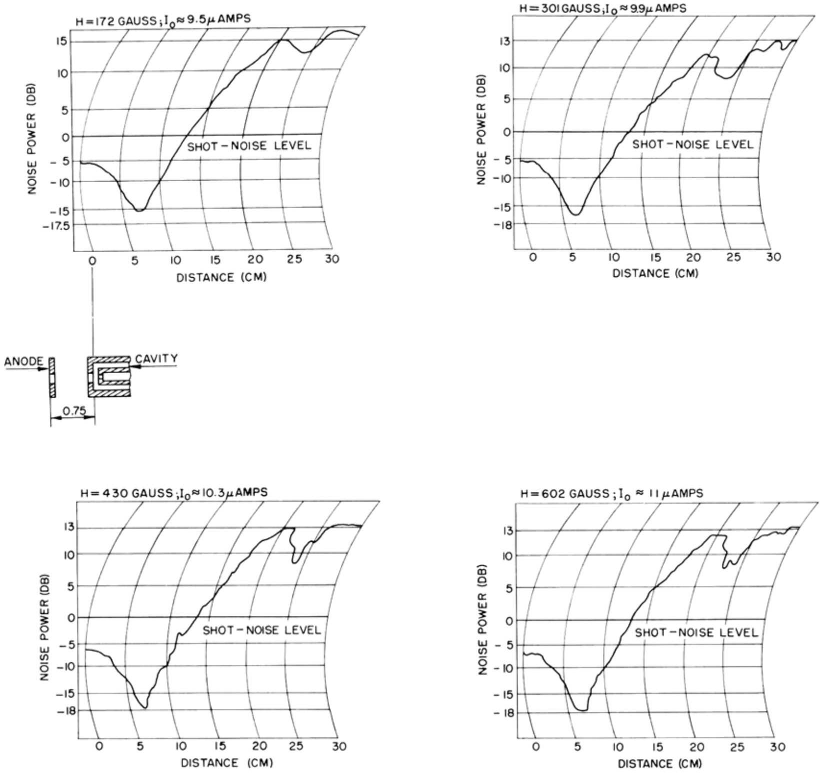
With steady current operation, saturation of the cathode emission occurred. It was probably caused by the poor quality of the nickel-base alloy of the oxide coating. Since neither the emission nor the noise curves were satisfactorily reproducible the measurements will be repeated with more carefully built guns.

Since the sensitivity of the present equipment seems to be inadequate for measuring the noise minima, the use of synchronous detection will be tried out in a manner similar to that used by Dicke for the measurement of thermal radiation at microwave frequencies. (See R. H. Dicke: The Measurement of Thermal Radiation at Microwave Frequencies, Rad. Lab. Report No. 787, August, 1945.)

C. Fried

B. PROPAGATION OF SIGNALS ON ELECTRON BEAMS

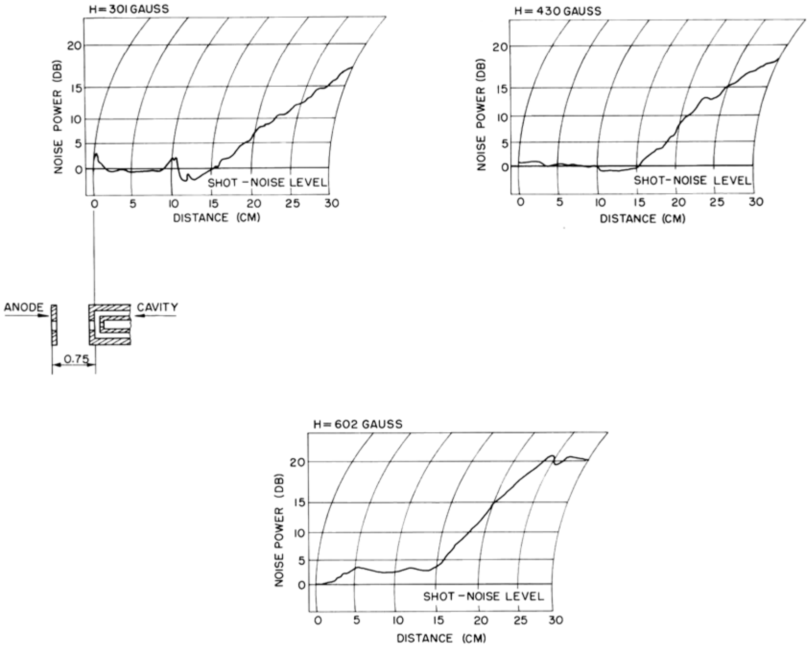
An experimental setup was used which was essentially the same as that described in the Quarterly Progress Report of July 15, 1953. Briefly, it consisted of a movable buncher and movable catcher cavity through which passed an electron beam 40 cm long in a magnetic focusing field. The electron gun was of the magnetically shielded, single-anode, converging type. Both small and large signals were applied to the buncher cavity at a frequency of 3000 Mc/sec.



V_0 = 1500V; PRESSURE ≈ 4×10^{-7} MM

Fig. VIII-1

Noise power vs cavity position for space-charge-limited, confined-flow, pulsed electron beam.



V_0 = 1500; $I_0 \approx 0.9\mu$ AMPS; PRESSURE ≈ 4×10^{-7} MM

Fig. VIII-2

Noise power vs cavity position for temperature-limited, confined-flow, pulsed electron beam.

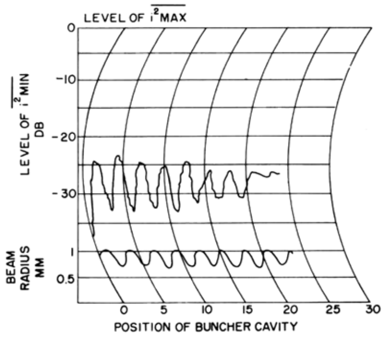


Fig. VIII-3

Variation of standing-wave minimum: beam voltage, 1 kv; beam current, 1.9 ma; magnetic field, 246 gauss; pressure, 8×10^{-7} mm hg.

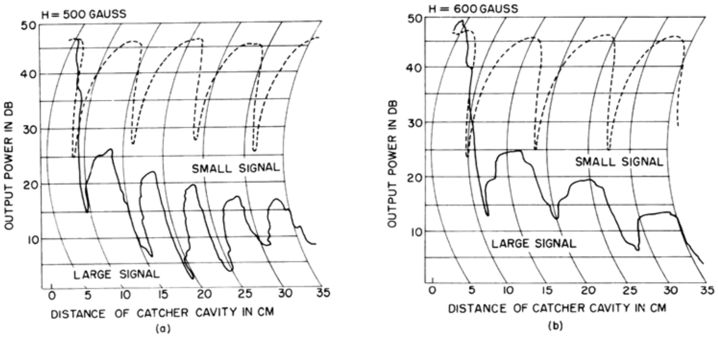


Fig. VIII-4

Standing-wave pattern of rf beam current: beam diameter (computed), 0.83 mm; drift-tube diameter, 57 mm; reference level of large signal plot, 20 db above that of small signal plot. (a) Small signal, 11 volts peak across buncher gap; large signal, 600 volts across buncher gap; beam voltage, 1.5 kv; beam current, 3.5 ma. (b) Small signal, 11 volts across buncher gap; large signal, 480 volts across buncher gap; beam voltage, 1 kv; beam current, 1.9 ma.

1. Small Signal Operation

Attention was devoted to the behavior of the radiofrequency beam-current standing wave as a function of the magnetic field and the beam voltage. The observed plasma wavelength and the level of the current standing-wave maximum checked closely with the existing small signal theory. (See E. Feenberg: Notes on Velocity Modulation, Sperry Gyroscope Company, Report No. 5221-1043, 1945.) The level of the standing-wave minimum and the distance between minima was found to be a function of the position of the buncher cavity with respect to the entrance of the beam into the magnetic focusing field. A typical curve of the current standing-wave minimum as a function of position of the buncher appears in Fig. VIII-3. On the same figure a plot of the beam radius is shown as measured by a shutter placed in front of the buncher cavity. It can be observed that the periodicity of the beam scallops coincides with that of the minimum-variation. The scallop wavelength was found to be equal to the cyclotron wavelength. This observation indicates that the beam was completely neutralized by ions and that therefore the Brillouin flow could not have been realized.

The level of the current maximum varied only negligibly with a change in the position of the buncher. This variation could be attributed to a periodic change in the coupling coefficient as a function of beam radius.

An increase of the magnetic focusing field caused a decrease in the current standing-wave ratio. A theory was developed that took into account the velocity spread in the beam caused by the magnetic field and its influence upon the standing-wave minimum. It checked only qualitatively with the experimental data.

2. Large Signal Operation

One watt of radiofrequency power fed to the buncher cavity produced a computed 425 volts peak-to-peak across the bunching gap. The radiofrequency current in the beam was recorded as a function of distance from the buncher cavity at different beam voltages. In Fig. VIII-4, two curves are shown for two different beam voltages. The dashed lines are the experimental small signal current curves. The magnetic focusing field was relatively high in order to keep the beam focused under large signal operation.

It is apparent from the figures that space-charge effects play a subordinate role. The number of current maxima is roughly inversely proportional to the dc voltage, a property characteristic of kinematic bunching.

H. A. Haus

C. INTERNALLY COATED CATHODES

Research is being conducted toward an understanding of the peculiar behavior of internally coated cathodes. As described in previous Quarterly Progress Reports, the most striking features of these cathodes are the large current densities that may be drawn (up to 100 amp/cm^2, based on the hole area) and the emission characteristic which is never space-charge-limited and does not behave according to Child's Law.

1. Electron Microscope Studies

Two microscopes were constructed. The first was a spherical type with a spherical-capped cathode 1/8 inch in diameter and a 0.015-inch hole. The cathode was placed in a 5-inch cathode-ray tube envelope, as shown in Fig. VIII-5. An image whose size was nearly independent of anode voltage was produced on the fluorescent screen. At low cathode temperatures (approximately 800°C) the image showed emission all over the area of the hole. At higher temperatures a bright ring, indicating a definite concentration of current around the edges, was formed.

A second, three-electrode microscope (Fig. VIII-6) was built, but its behavior is not yet understood.

2. Volt-Ampere Characteristics

A series of four different cathodes was constructed. These were all 1/8 inch in diameter, with sleeves of varying height, ranging from 0.00 inch to 0.150 inch above the flat surface. (See Fig. VIII-7.) Figure VIII-8 shows the V-I curve for the cathode without a sleeve. It is the familiar Child's Law curve, showing space-charge and temperature-limited regions. Figure VIII-9 shows

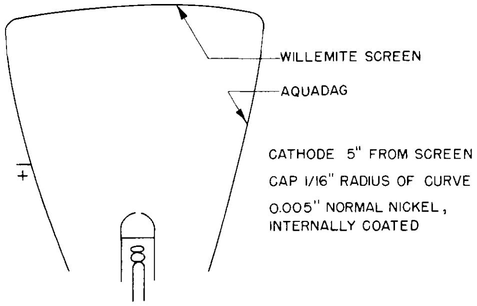


Fig. VIII-5
Projection microscope for viewing cathode emission.

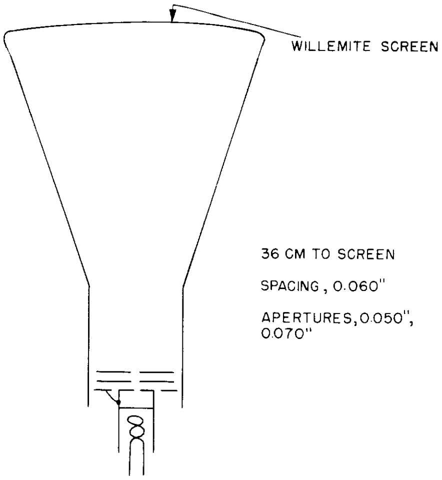


Fig. VIII-6
Lens microscope for viewing cathode emission.

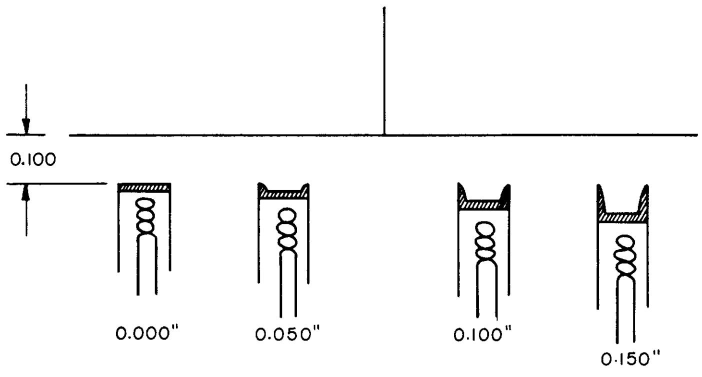


Fig. VIII-7
Hollow cathodes with varying cavity depths.

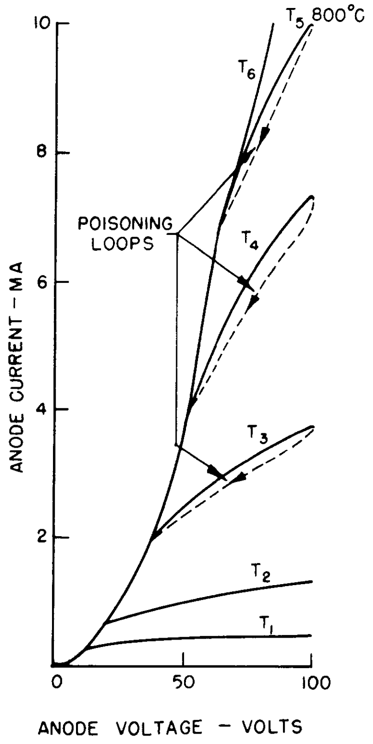


Fig. VIII-8
V-I curve for a conventional plane diode.

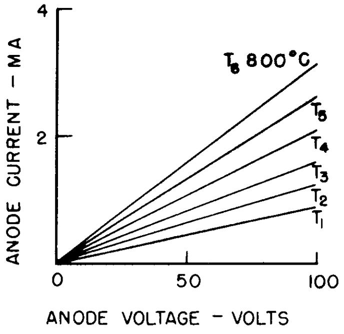


Fig. VIII-9
V-I curve for a hollow cathode, plane diode.

the V-I curve for the cathode with a 0.050-inch sleeve. This shows the now familiar lack of space-charge limitation and the nearly linear V-I curve. The cathodes with longer sleeves had similar characteristics, but with increased emission.

H. Shelton

D. HELIX-HELIX COUPLINGS

A study has been initiated of the helix-helix couplings described by Kompfner (private communication from R. Kompfner to L. D. Smullin.) Preliminary experiments have been made on a coupling for a backward wave oscillator of 3000-6000 Mc/sec.

A. Lichtenberg