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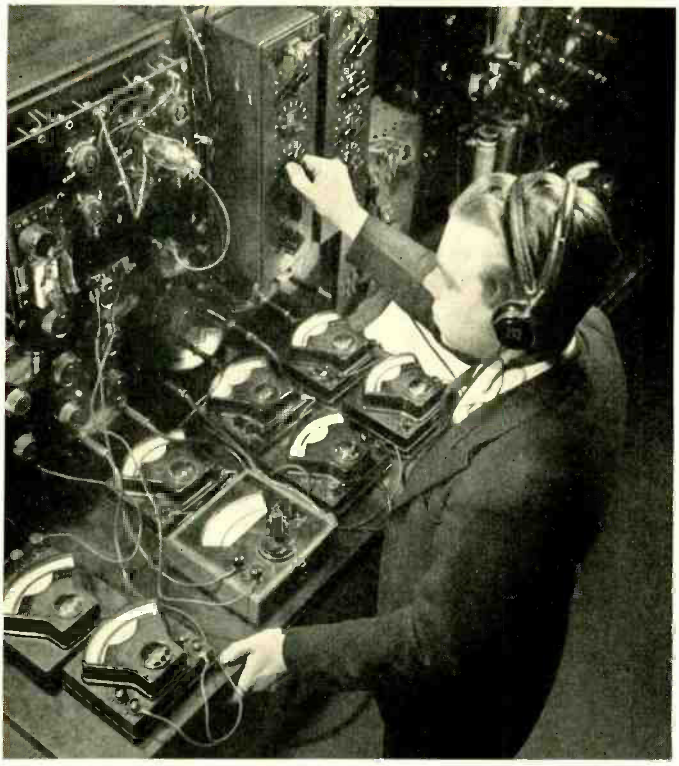

New Tubes for Carrier Systems

By J. O. McNALLY
Vacuum Tube Development

WIDER frequency ranges and the use of repeaters and terminal amplifiers stabilized by feedback are being planned for new carrier systems. These features have placed special and exacting requirements on the vacuum tubes used, with the result that it has been necessary to develop four new types, which differ from the familiar repeater tubes now used throughout the telephone system in that they all contain indirectly heated or equipotential cathodes and are of the pentode rather than the triode type. Two of the tubes have been designed as high-gain voltage amplifiers. They are identical in electrical characteristics except for the operating heater voltages and currents. The other two tubes are of the power output type and are also identical electrically, except for heater voltages and currents.

The use of equipotential cathodes overcomes some circuit difficulties because it is no longer necessary to maintain the cathodes at the potential of the filament or cathode supply battery. The more compact structure of the equipotential cathode tube is also an advantage where the physical size of the tube has to be maintained at a minimum, which is desirable in the carrier services. The rigid cathode also

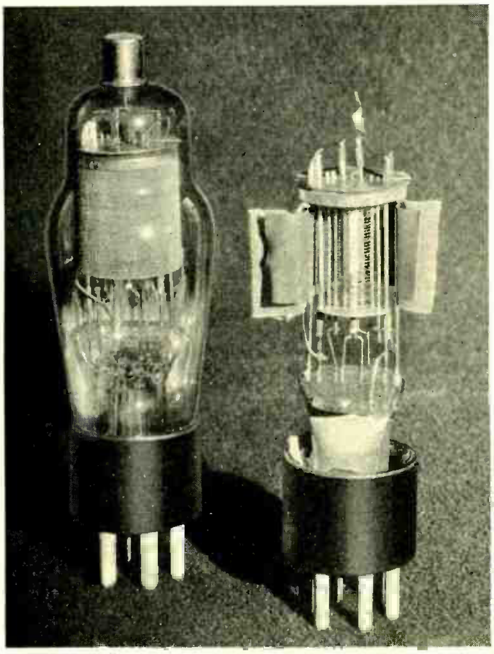

Fig. 1—The 310A amplifier tube complete and also dissected by folding back the outer screen and plate to expose inner elements

permits the use of smaller spacings between the cathode surface and the innermost grid. This inherently means that the equipotential cathode structure may be made to have a high mutual conductance and therefore a high gain. The equipotential cathode has the additional advantage that electrostatic shielding may be simplified and the inter-electrode capacities made smaller than in the filamentary type. Although this type of cathode is generally heated by alternating current, direct current will be used for the majority of applications in the telephone plant.

The elements in the two high-gain voltage-amplifying tubes, coded 310A and 328A, are normally obscured from view by the outer screen, which provides electrostatic shielding of the plate from the control grid. In Figure 1, however, they are shown by cutting part of the outer screen and the plate away. Next to the cathode is the control grid, on which the signal is applied. This grid normally operates at a potential of three volts negative with respect to the cathode. The next grid outside of the control grid is the screen, which is operated with a fixed positive voltage of approximately 135 volts to accelerate the electrons toward it from the cathode. Only about twenty per cent of the electrons, however, are intercepted by this screen grid and the remainder pass through to the plate.

The screen of the tube also provides electrostatic shielding between the control grid and the plate. This is accomplished by tying the screen grid to the cathode through a condenser, thereby effectively grounding this grid at voice and carrier frequencies. Additional shielding of the control grid is provided by the upper and lower shields and the cylindrical shield external to the plate. Between the screen and the plate is the suppressor grid which is held at approximately the potential of the cathode. The purpose

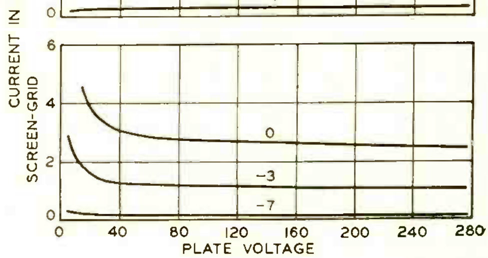

Fig. 2—Static characteristics of the 310A and 328A repeater tubes

of this grid is to prevent secondary electrons, knocked out of the plate by the impact of the arriving electrons, from being carried to the screen when the plate is at a lower potential than the screen.

When the above voltages are applied on the grids of the 310A and 328A tubes, and when the plate voltage is 135 volts, the plate current is about 5.5 milliamperes. Under these conditions the mutual conductance is approximately 1800 micromhos. A resistance load of 100,000 ohms gives a ratio of output voltage across the load to signal voltage on the grid of about 159 or a voltage gain of 44 db. It is of interest to compare this value with that for the 102F type at present used as a voltage amplifier tube in voice frequency repeaters. A load resistance of 100,000 ohms for the 102F tube gives a voltage step-up of 19.5 fold and increasing the resistance load to several hundred thousand ohms gives a maximum possible step-up of only 30 times. With a single-frequency power output twice that of the 102F the harmonics of all three tubes constitute approximately the same percentage of the output. The inputs necessary to give these outputs are about three and one-half times as great in the 102F as in the other two tubes. Static characteristic curves for the 310A and 328A are given in Figure 2.

The power tubes, coded 311A and 329A, when working with a control grid bias of −15 volts and a plate and screen voltage of 135 volts give an average plate current of approximately thirty milliamperes. Characteristic curves for these tubes are shown in Figure 4. The mutual conductance is approximately 2800 micromhos and the power output obtained with a resistance load of 4000 ohms and an input of fifteen peak volts is approximately 1.8 watts. This is approximately nine times the output of the 104D type which is the power tube used in existing carrier systems. The third harmonic is about thirty-five db greater in the new

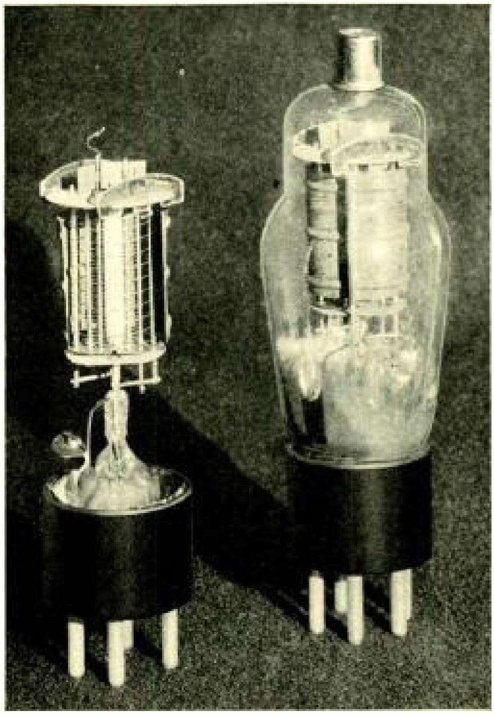

Fig. 3—The 311A power tube

tubes but this is permissible since the new carrier systems use feedback and the third harmonic is thereby reduced to an acceptable value.

The normal heater voltage for the 310A tube is ten volts and the average heater current is 0.32 amperes. The 328A tube has a 7.5 volt heater which takes 0.425 ampere. In the 311A tube the heater requires ten volts at 0.64 amperes and in the 329A tube, 7.5 volts at 0.85 amperes. This particular arrangement of heater voltages and currents was decided upon so that two 310A heaters, connected in parallel, could be operated in series with the heater of one 311A tube. The group, which requires twenty volts, can then be operated economically in "regulated" offices where the battery voltage is maintained close to twenty-four volts. The heater voltages of the 328A and 329A tubes were selected as the most economical for operation in "un-

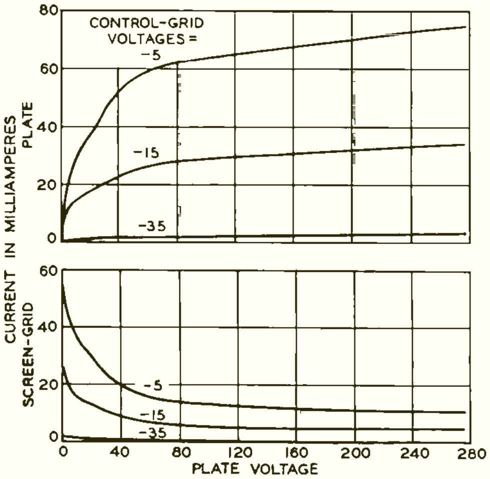

Fig. 4—Static characteristics of the 311A and 329A repeater tubes

regulated" offices where the battery voltage may vary from twenty to twenty-eight volts and where it is necessary to use ballast lamps in series with the heaters to maintain currents within sufficiently narrow limits.

All of these tubes have been designed to meet the severe demands of telephone service. Since insulation leaks between the control grid and any of the other elements could cause trouble the mica insulators at the top and bottom of the structure contain slots between the mounting holes for the control grid and other elements, to make the insulation paths longer across the surface of the mica. In addition the insulators are sprayed with a ceramic material to further improve the insulation, and the small metal plates used for electrostatic shielding are formed to act as baffles to prevent material sprayed from the surface of the cathode from being deposited on the insulators and causing leaks.

Inter-electrode capacities are usually not considered of great importance in a tube of the general type of the 311A and 329A. However, for carrier uses it has been necessary to reduce the capacities, particularly that between control grid and plate, to a minimum. In these tubes the average value is 0.07 micromicrofarads instead of approximately 1.0 as it is in the more usual tube of this size. It has been necessary moreover to reduce the variations in this capacity from tube to tube. During the development of the tubes too wide a variation was traced to a peculiar and curious "island" effect caused by a capacitance-resistance network across the mica insulators between control grid and plate. The effect was eliminated by removing the plate supports entirely from the mica insulators.

It is necessary to have the longest possible life for tubes in this type of service. With this in view a series of experiments has been undertaken to try various types of active material on the cathode and different means of processing the parts and pumping. Already there are indications that the adoption of some of these methods may greatly increase the useful life of the tubes.

These new tubes not only fulfill the more exacting requirements imposed by new carrier systems but they are more effective than those now in use and give promise of reducing appreciably the cost of maintenance.