average velocity of emission accordingly increases with the cathode temperature, just as does the average velocity of gas molecules.

27. Current Flow in a Two-electrode Tube—Space-charge Effects.—When an electron-emitting cathode is surrounded by a positive anode (*i.e.*, plate electrode) to form a two-electrode vacuum tube (or diode), the relation between the plate current (*i.e.*, the number of emitted electrons that are attracted to the anode) and the plate potential has the character shown in Fig. 50, which gives the results obtained in a typical tube for several cathode temperatures. It is seen that at high anode

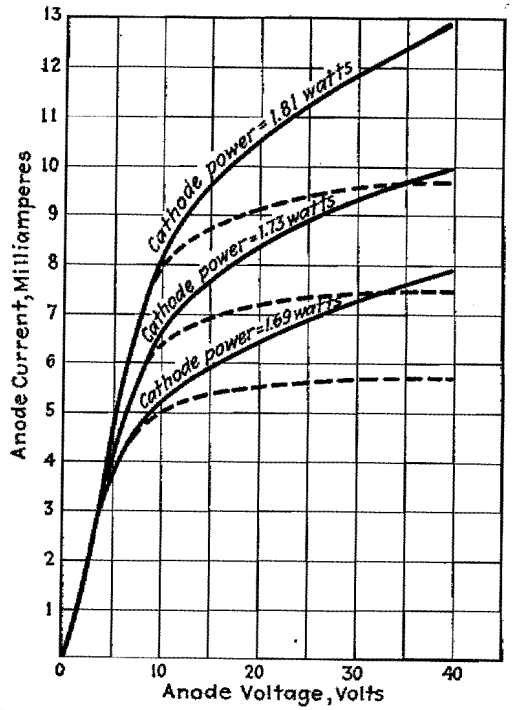

FIG. 50.—Anode current as a function of anode voltage in a two-electrode tube for three cathode temperatures. The solid lines are the characteristics actually obtained using an oxide-coated cathode, while the dotted lines show the type of curve that is given by tungsten and thoriated-tungsten cathodes.

voltages the electron current is largely independent of anode voltage, being determined primarily by the cathode temperature, while at low anode voltages the current is controlled by the anode voltage and is independent of cathode temperature. When the plate is negative it repels electrons and the plate current is then zero.

The behavior observed at high anode voltages is a result of the fact that a high anode potential draws the electrons away from the filament as fast as they are emitted, which makes the anode current equal the total electron emission from the cathode. Under these conditions the

anode current is given by Eq. (55), and the tube is said to be operating at voltage saturation.[1]

Space-charge Effects.—At low plate (*i.e.*, anode) voltages the anode current is limited by the repelling effect which the negative electrons already in the space between anode and cathode have on the electrons just being emitted from the cathode. The electrons in the interelectrode space constitute a negative space charge (*i.e.*, a negative charge distributed in space) and at any instant the number of electrons that are in transit between electrodes cannot exceed the number that will produce a negative space charge that completely neutralizes the attraction which the positive plate exerts upon the electrons just leaving the cathode. All electrons in excess of the number necessary to neutralize the effect of the plate voltage are repelled back into the cathode by the negative space charge of the electrons in transit, so that the anode current will be independent of the electron-emitting power of the cathode, provided the cathode is capable of emitting enough electrons to produce a full space charge. When a full space charge is present the plate current depends upon the plate voltage, since with higher voltages the electrons travel from cathode to anode more rapidly, making the rate of arrival greater in proportion to the total number in the space between anode and cathode at any instant. Increasing the plate voltage thus causes the electron flow to increase until a point is reached where the total electron emission of the cathode is being drawn to the plate, after which further increases in voltage will produce practically no additional current because of voltage saturation. The anode current for a given anode voltage has its greatest possible value when the current flow is limited by the space charge, and will be less than the maximum if voltage saturation is present. On the other hand with a given cathode temperature the maximum current is obtained when the plate potential is sufficiently high to give voltage saturation with the electron emission present.

The energy that is delivered to the tube by the source of anode voltage is first expended in accelerating the electrons traveling from cathode to anode and so is converted into kinetic energy. When these swiftly moving electrons strike the anode this kinetic energy is then transformed into heat as a result of the impact and appears at the anode in the form of heat that must be radiated to the walls of the tube.

When the anode current is limited by space charge the negative charge of the electrons in transit between cathode and plate will be sufficient to give the space in the immediate vicinity of the cathode a

[1] The sharpness with which voltage-saturation effects appear differs greatly with the type of emitter. Thus the anode current with cathodes of tungsten or thoriated tungsten have a characteristic such as shown by the dotted lines in Fig. 50, in which the saturation effect is almost complete, while in emitters of the oxide-coated type, the saturation effect takes place more gradually, as shown by the solid lines of Fig. 50.