The Cunningham Radio Tubes Manual

TECHNICAL SERIES
No. C-10

PRICE 25 CENTS

E. T. Cunningham, Inc.

HARRISON, NEW JERSEY

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THE

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Printed in U.S.A.

FOREWORD

The CUNNINGHAM RADIO TUBE MANUAL has been prepared especially to supply technical information regarding the characteristics and operation of Cunningham tubes to those who work or experiment with radio tubes and circuits.

Careful consideration has been given to the selection of material which presents general and specific tube information in the most useful and helpful form.

Tube types have been arranged in numerical sequence on the basis of the last two digits of model number designations. This is in accordance with our program of generally utilizing a two digit system for identifying tubes as evidenced by the new type numbers, i.e., 46, 56, 57, 58, and 82. Eventually, the two digit system will be extended to practically all of the older models by dropping the first digit of the present three digit designations.

This Manual will be found valuable by radio service men, radio technicians, experimenters, radio amateurs, and those who have an interest in the technical aspects of radio tubes.

Commercial Engineering Section
E. T. CUNNINGHAM, INC.
Harrison, New Jersey

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INDEX OF TUBE TYPES

The Cunningham Radio Tubes MANUAL

Electrons and Electrodes

The radio tube is a marvelous device. Although it appears to be a fragile affair constructed of metal and glass, in reality it is a rugged instrument that makes possible the performing of operations, amazing in conception, with a precision and a certainty that is astounding. It is an exceedingly sensitive and accurate instrument—the product of coordinated efforts of engineers and craftsmen. Its construction requires materials from every corner of the earth. Its use is world-wide. Its future possibilities, even in the light of present day accomplishments, are but dimly foreseen, for each development opens new fields of design and application.

A radio tube consists of a cathode and one or more additional electrodes—all enclosed in an evacuated glass bulb—with their electrical connections brought to exterior terminals. The cathode supplies electrons while the other electrodes control and collect them.

The importance of the radio tube lies in its ability to control almost instantly the flight of the millions of electrons supplied by the cathode. It accomplishes this with a minimum of control energy. Because it is almost instantaneous in its action, the radio tube can operate efficiently and accurately at electrical frequencies much higher than possible with rotating machines.

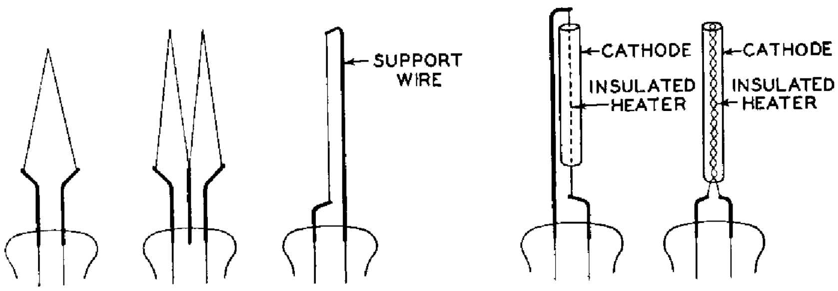
All matter exists in the solid, liquid, or gaseous state. These three forms of matter consist entirely of minute divisions known as molecules. Molecules are assumed to be composed of atoms. According to a present accepted theory, atoms have a nucleus which is a positive charge of electricity. Around this nucleus revolve tiny charges of negative electricity known as "electrons." Scientists have estimated that these invisible bits of electricity weigh only 1/46 billion, billion, billion, billionths of an ounce since they may travel at speeds of thousands of miles per second.

Electron movement may be accelerated by the addition of energy. Heat is one form of energy which can be conveniently used to speed up the electron. For example, if the temperature of a metal is gradually raised, the electrons gain velocity. When the metal becomes hot enough to glow, some electrons may acquire sufficient speed to break away from their nuclei. This action is utilized in the radio tube to produce the necessary electron supply.

CATHODES

A cathode is an essential part of a radio tube since it supplies the electrons necessary for tube operation. In general, heat is the form of energy applied to the cathode to release the electrons. The method of heating the active material of the cathode may be used to distinguish between the different forms of cathodes. For example, a directly-heated cathode, or **filament-cathode**, is a wire heated by the passage of an electric current. An indirectly-heated cathode, or **heater-cathode,** consists of a filament, or heater, enclosed in a metal sleeve. The sleeve carries the active material on its outside surface and is heated by radiation and conduction from the heater.

A filament-, or **directly-heated cathode,** may be further classified by identifying the filament or electron emitting material. The materials in regular use are, tungsten, thoriated-tungsten, and metals which have been coated with alkaline earth oxides. Tungsten filaments are made from pure metal. Since they must operate at high temperatures (a dazzling white) to emit sufficient electrons, a relatively large amount of filament power is required. Thoriated-tungsten filaments are drawn from tungsten slugs which have been impregnated with thoria. Due to the thorium, these filaments liberate electrons at a more moderate temperature (a bright yellow) and are, therefore, much more economical of filament power than are pure tungsten filaments. Alkaline earths are usually applied by coating a nickel alloy wire or ribbon with a mixture containing the materials. This coating, which is dried into a substantial layer on the filament, requires only a very low temperature (a dull red) to produce a copious supply of electrons. Coated filaments operate very efficiently and require relatively little filament power. However, each of these cathode materials has special advantages which determine the choice for a particular application. In general, tubes made with filament-cathodes or heater-cathodes and designed for use in radio receivers, utilize the coated construction.



DIRECTLY HEATED CATHODES (FILAMENT TYPE)

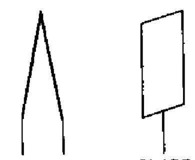
INDIRECTLY HEATED CATHODES (HEATER TYPE)

Filament-cathode types of tubes are particularly well suited for operation from a steady source of filament supply voltage such as a battery. Tubes for this service can be designed with cathodes which give economical production of electrons and, consequently, economical set operation. Tubes constructed primarily for economical battery operation are not very satisfactory for use with alternating current filament supply, due to the variation in electron emission and potential in the space charge region which occurs with each alternation of the current. This variation is amplified by the tube and produces hum in the loudspeaker. When filament-cathode types of tubes are to be used on a-c filament supply, special precautions are taken in the design to reduce hum disturbances to a point where the hum will not be troublesome. These precautions include such features as the utilization of massive filaments which minimize temperature fluctuations, the use of filaments which have sufficient excess electron emission so that a very large temperature change is required to reduce the emission below the value needed for normal tube operation, and the proportioning of tube parts to minimize the electrostatic and magnetic effects produced by a.c. on the filament. The '26 is an example of a filament-cathode type of tube particularly useful for operation on a.c.

Heater-, or **indirectly-heated cathodes,** comprise an assembly of a thin metal sleeve coated with active material and a heater contained within and separated from the sleeve. The heater is made of tungsten wire and is used only for the purpose of heating the sleeve and its coating to an electron-emitting temperature. The tungsten wire is operated at a moderate temperature and supplies the energy for heating the sleeve.

The heater-cathode construction is well adapted for use in radio tubes intended for operation from a-c power lines. The use of separate parts for emitter and heater functions, the electrical insulation of the heater from the emitter, and the shielding effect of the sleeve may all be utilized in the design of the tube to prevent the a-c heater supply from causing hum. Representative types are the '24-A, '27, and '35. From the viewpoint of circuit design, the heater-cathode construction offers advantages in connection flexibility due to the electrical separation of the heater from the sleeve and active cathode surface. This feature, in conjunction with the freedom from electrical disturbances which might be introduced through the filament supply lines, has led also to the use of this construction in a series of tubes ('36-'39) designed particularly for automobile or d-c line radio sets.

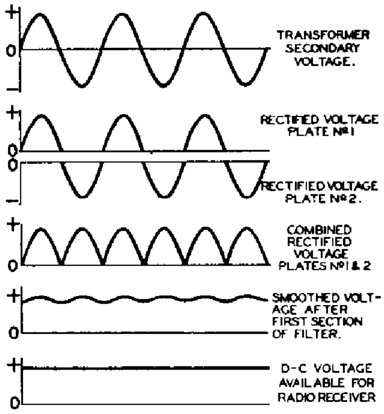
DIODES



Electrons are of no value in a radio tube unless they can be put to work. A radio tube is designed with the necessary parts to utilize the electron flow. These parts consist of a cathode and one or more supplementary electrodes. The simplest form of radio tube contains two electrodes, a "cathode" and a "plate" and is often called a "diode," the family name for two-electrode tubes.

The electrodes are enclosed in a bulb with the necessary connections brought out through air-tight seals. The air is removed from the bulb to allow free movement for the electrons and to prevent injury to the emitting surfaces. When the cathode is heated, electrons leave the cathode surface and form an invisible cloud in the space around it. Any positive electric potential within the evacuated bulb will offer a strong attraction to the electrons (unlike electric charges attract; like charges repel). In a diode, the positive potential is applied to the second electrode, known as the anode. The potential is supplied by a suitable electrical source connected between the plate terminal and a cathode terminal. Under the influence of the positive plate potential, electrons flow from the cathode to the plate and return through the external plate battery circuit to the cathode, thus completing the circuit. This flow of electrons is known as the plate current and may be measured by a sensitive current meter.

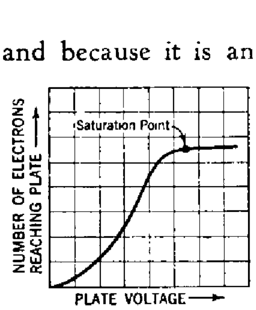
If a negative potential is supplied to the plate, the free electrons in the space surrounding the cathode will be forced back to the cathode, and no plate current will flow. Thus, the tube permits electrons to flow from the cathode to the plate but not from the plate to the cathode. If an alternating voltage is applied to the plate, the plate is alternatingly made positive and negative. Plate current flows only during the time when the plate is positive. This phenomenon makes the tube useful as a rectifier of alternating current, that is, to provide a current flow always in the same direction. Rectifying action is utilized in a-c receivers to convert a.c. to d.c. for supplying "B," "C" and screen voltages to the other tubes in the receiver circuit. Rectifier tubes may have one plate and one cathode. The '81 is of this form and is called a **half-wave rectifier,** since current can flow only during one-half of the alternating-current cycle. When two plates and one or more cathodes are used in the same tube, current may be obtained on both halves of the a-c cycle. The '80 is an example of this type and is called a **full-wave rectifier.**



FULL-WAVE RECTIFICATION

Not all of the electrons emitted by the cathode reach the plate. Some return to the cathode while others remain in the space between the cathode and plate for a brief period to form an effect known as **space-charge.** This charge has a repelling action on other electrons which leave the cathode surface, and impedes their passage to the plate. The extent of this action and the amount of space-charge is greatly dependent upon the cathode temperature and the plate potential. The higher the plate potential, the less is the tendency for the space electrons remaining to repel others. This effect may be noted by applying increasingly higher plate voltages to a tube operating at a fixed cathode voltage. Under these conditions, the maximum number of available electrons is fixed, but increasingly higher plate voltages will succeed in attracting a greater proportion of the free electrons.

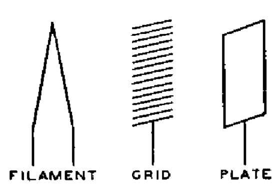
Beyond a certain plate voltage, however, additional plate voltage has little effect in increasing the plate current because all of the electrons emitted by the cathode are being drawn to the plate. This maximum current is called **saturation** current, and because it is an indication of the total number of electrons emitted, it is also known as the **emission current**, or, simply, **emission.** In most types of tubes, it is impossible to obtain this value by measurement, since the current flow is sufficiently large to change the emitting conditions, or, to damage the tube. As a result, emission values in practice are determined at some lower voltage which will not harm the tube. Different results will be obtained if a different cathode voltage or temperature is chosen, since the cathode temperature determines the number of available electrons.



If space-charge effects were not present, it follows that the same electron flow could be produced at a lower plate voltage. One method of reducing the space-charge effect is utilized in several types of rectifier tubes, represented by the mercury-vapor rectifier 82. This tube contains a small amount of mercury which is partially vaporized when the tube is operated. The mercury vapor consists of tiny mercury atoms permeating the space inside the bulb. These atoms are bombarded by the electrons on their way to the plate. If the electrons are moving at a sufficiently high speed, the collisions will tear off electrons from the mercury atoms. When this happens, the mercury atom is said to be "ionized," that is, it has lost one or more electrons and, therefore, is charged positive. When ionization due to bombardment of mercury atoms by electrons leaving the filament occurs, the space-charge is neutralized by the positive mercury ions so that increased numbers of electrons are made available. A mercury-vapor rectifier has a small voltage drop between cathode and plate (about 15 volts). This drop is practically independent of current requirements up to the limit of emission of electrons from the filament but is dependent to some degree on bulb temperature.

TRIODES

When a third electrode, called the grid, is placed next to the cathode, the tube is known as a "triode." This is the family name for three-electrode types. The grid usually consists of a wire mesh or grating, the appearance of which suggests its name. Its construction allows practically unobstructed flight of the electrons from the cathode to the plate.



When the grid of a tube is made positive or negative with respect to the cathode, the plate current correspondingly increases or decreases. The grid is located much nearer the cathode than the plate so that a small voltage change on the grid will have the same effect on the plate current as a larger voltage change on the plate. A grid requires very little power, serving merely as a valve to control the plate current.

A negatively charged grid tends to force the space electrons back toward the filament. This action decreases the plate current. Plate current, in fact, may be reduced to zero (cut-off) by making the negative grid charge sufficiently large. On the other hand, when a positive charge is applied to the grid, the electrons are accelerated and increased plate current results.

It should be noted that this control action of the grid permits the use of the tube as an amplifier. A small grid voltage change produces a much larger plate current than would the same change in plate voltage. Typical three-electrode tubes are the '20, '27, 56, and '45.

The **control grid circuit (input circuit)** includes any device or devices connected between the control grid and cathode of a tube for the purpose of impressing an input or signal voltage on the control grid. It may consist of an antenna coupling coil, a transformer secondary, or any unit having one or all the factors of inductance, resistance and capacity. Since it is usually desirable to maintain the grid at some negative voltage (called grid bias) with respect to the cathode, the grid circuit will, in such cases, also include a source of voltage supply for that purpose. The grid bias supply (C-supply) may be a battery or other source of d-c voltage.