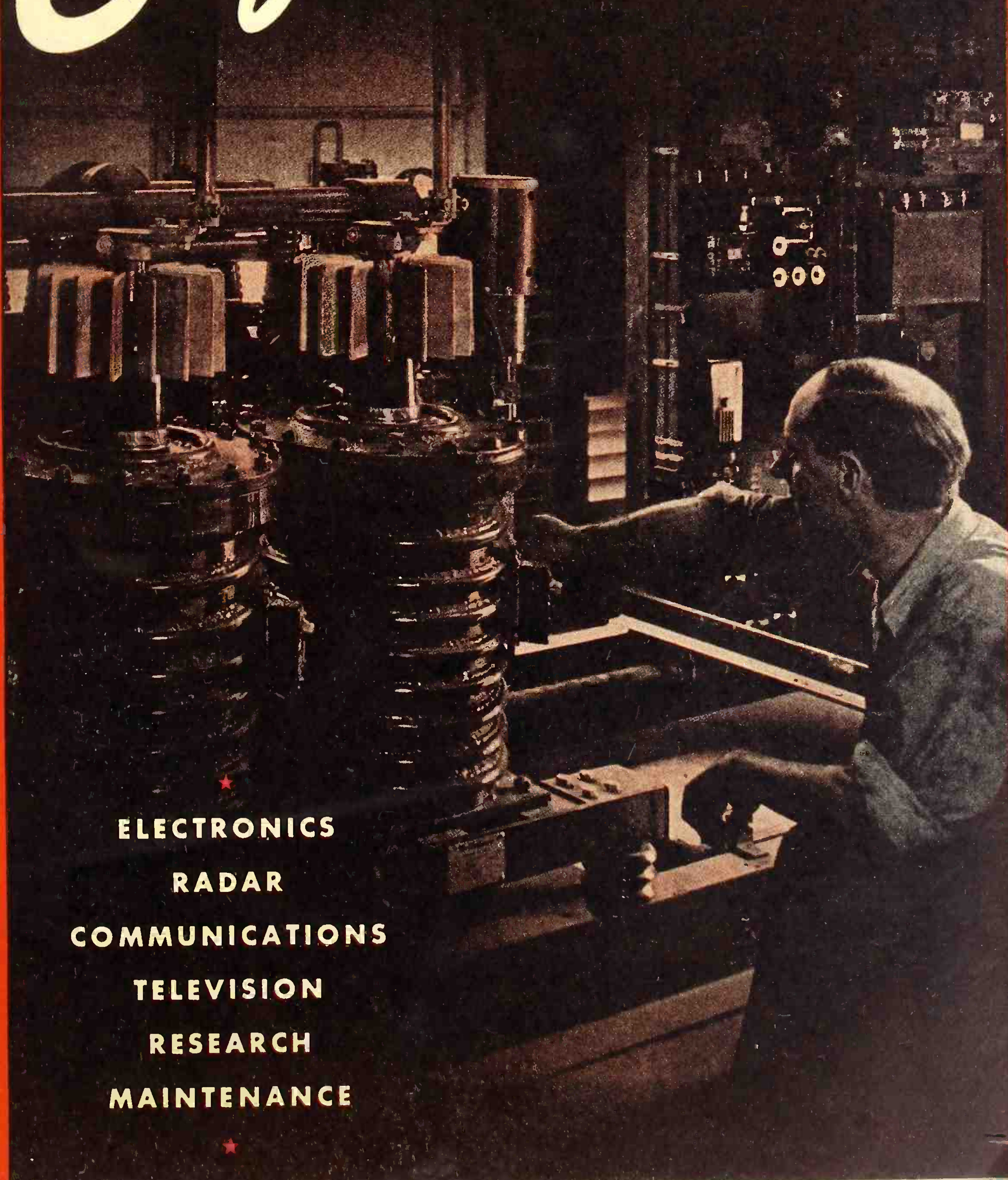
RADIO NEWS

RADIO-ELECTRONIC Engineering DEPARTMENT

APRIL 1944



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COVER PHOTO—BY WESTINGHOUSE

Making adjustments on the large air-cooled ignitrons used in industrial applications. These tubes are used as rectifiers supplying power to general industrial loads and to small isolated loads in cities using a-c networks.

ULTRA HIGH FREQUENCY EQUIPMENT

Copper horn and reflector for UHF transmission.

By R. E. SORIA
Illinois Institute of Technology

The characteristics of cavity resonators, horns and UHF generators applied to the transmitting and receiving of 3000 megacycle waves.

WITH the comparatively recent application of frequencies well above 30 mc/s it has become necessary for the engineer to become familiar with the factors involved at ultra-high-frequencies. The engineer having a knowledge of audio-frequency circuits is not too much concerned with skin effect, lead inductance, transit time, and the other ultra-high-frequency phenomena. However, now it is essential for the engineer to become acquainted with these effects by means of clearly designed and instructive equipment.

To perform any kind of work in the ultra-high-frequency range a stable generator of sufficient output is essential. Starting with oscillators the following will present a brief outline of the important ultra-high-frequency equipment used in this work.

Negative Grid Oscillators

Ordinary vacuum-tube oscillators when modified for ultra-high-frequencies are commonly called negative grid oscillators. The tubes used are almost always triodes. The high grid to plate capacitance is ordinarily undesirable in amplifiers, but may be made to serve as part of the resonant circuit of an oscillator. The additional grids in the pentode although decreasing the grid to plate capacitance raise to total shunt capacitance and thus reduce the maximum possible frequency of oscillation.

The frequency range of ordinary triodes used for ultra-high-frequency oscillators is limited primarily by three factors. With increase in frequency the lead inductance and interelectrode capacitance become appreciable, and the transit time of the electrons from cathode to plate becomes of the same order of magnitude as the period of oscillation. The high lead inductance and interelectrode capacitance produce a high input conductance and thus a large power loss. The electron transit time causes the input shunt resistance to drop to a low value, decreasing the effective Q of the resonant circuit and therefore also absorbing power. In addition the transit time affects the phase angle of the transconductance, the plate current no longer being 180° out of phase, the grid voltage at high frequencies. If it is desired to fix some frequency limit of the negative grid triode oscillator we can say that below about 20 centimeter wave length the output power will have dropped to less than 1/10 of a watt which is insignificant to be of any practical use. Experiments with the physical construction of negative grid triode oscillators have conclusively shown that a reduction of all physical dimensions and direct anchorage of the electrode leads in the glass envelope reduces both the interelectrode capacitances and the lead inductances, and also reduces the effect of the transit time. Reducing the dimensions of the tube, on the other hand, reduces the power capacity because of the smaller cathode-emitting surface and the smaller heat-dissipating capacity of the plate. It becomes necessary, therefore, to use as efficient an external resonant circuit as possible. Ordinary lumped inductance and capacitance tuned circuits lose their identity at ultra-high-frequencies, their Q drops to an insignificant value. A tank circuit with a much higher Q may be obtained by using a quarter wave length long transmission line short-circuited at one end. Above 300 mc/s coaxial lines should be used to avoid excessive radiation losses, a ratio of 3.6 between the radii of the outer and the inner conductor giving maximum Q.

Fig. 1 shows the laboratory set up of an ultra-high frequency oscillator using a 955 acorn tube. The resonant transmission line is shorted by two condensers (to prevent shorting the d-c supply). The condensers are spaced a quarter wave length to reduce the effect of the mutual coupling to the right of the first shorting capacitance. The radio-frequency chokes isolating the supply voltages consist of 25 turns of No. 14 wire on a form one-half inch in diameter. The turns should be spaced the diameter of one conductor in order to decrease interwinding shunt capacity. The variation of the wave length λ with the length of the short-circuited line may easily be found and plotted as in Fig. 11, proving the fact that the interelectrode capacitances act as part of the line.

The power supply is completely shielded in a metal box. Oscillations may be detected by means of a General Radio 758A wavemeter. A hairpin turn may be used to couple loosely to the line. Loose coupling is necessary as otherwise the heavy loading affects the frequency of oscillations.

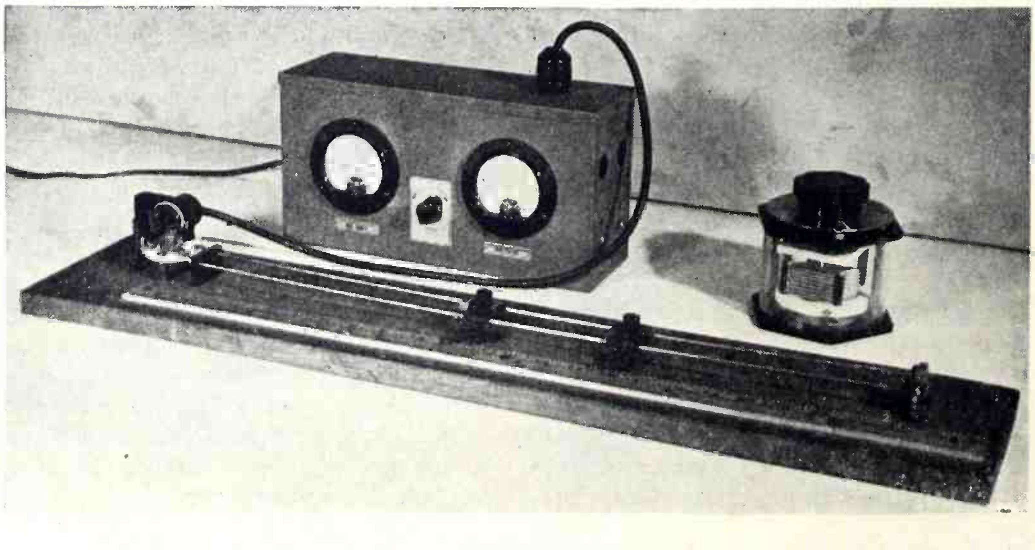
An oscillator suitable for operation at 600mc/s consists of an 8012 tube placed at the center of a half-wave length concentric line, thus dividing the tube losses between the two quarter wave sections. Tandem tuning is provided by a movable shorting bar. The shorting capacitors below keep the radio frequency currents confined to the coaxial line tank circuit. Fig. 3 represents the circuit diagram of the ultra-high-frequency oscillator. The oscillator is used in connection with a Lecher wire system. It is thus possible to study the variation of current and voltage along the Lecher wire system, to investigate the radiation from antennas, and the matching by means of stubs.

An oscillator using a 316A tube continuously variable from 200mc/s to 600mc/s is illustrated in Fig. 2. The metallic outer surface acts as a shield and part of the coaxial-resonant circuit. The frequency is varied with the aid of a shorting plug that changes the length of the plate and grid circuit resonant lines in tandem. Fig. 4 gives the circuit diagram. Commercially, this type oscillator is available as the General Radio 757A Peterson oscillator.

Positive Grid Oscillators

Barkhausen and Kurz published in 1920 the results of experiments with high power triodes. In ordinary triodes used as ultra-high-frequency oscillators the transit time determines the upper frequency limit. A triode operated with negative or zero potential on the plate and a positive grid potential may be used to generate ultra-high-frequency oscillations that are dependent on the electron transit time. The positive grid sets up a retarding field and the electrons oscillate back and forth between the plate and cathode. A Lecher wire system can be used as a resonant load, but does not affect the frequency of oscillation. Depending on the geometry and the applied voltages oscillations between 300 mc/s and 2000 mc/s

Fig. 1. UHF oscillator using a 955 acorn tube with resonant transmission line.



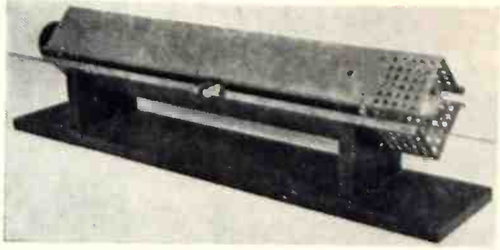


Fig. 2. A variable frequency oscillator.

may be produced. However, the efficiency and the power output of the positive grid oscillator is very low, being of the order of 5% and 5 watts or less, respectively. The tube geometry for oscillations requires cylindrical electrodes and a straight axial filament. A type RK38 tube satisfies these requirements and may be set up as a positive grid oscillator with a short circuited transmission line as a tuned tank circuit. For intermittent operation the maximum allowable grid current is about 70 milliamperes. To prevent the grid current from rising above this value it may be necessary to reduce the filament voltage. Oscillations may occur at different frequencies; therefore careful adjustment of the Lecher wire load is required. When the Lecher wire load tuned to about twice the period of one excursion of electrons is connected between grid and cathode, the tube will oscillate. Care must be taken that the losses in the oscillatory circuit do not become excessive. The presence of oscillations is detected on a secondary Lecher wire system loosely coupled to the load by means of a suitable crystal or vacuum tube detector.

Magnetron

To a certain degree the magnetron is similiar to the positive grid oscillator. The magnetron is usually constructed as a diode consisting of a cylindrical longitudinally split anode and an axial filamentary cathode. Again a retarding field causes the electrons to oscillate back and forth between plate and cathode, but this time the retarding force is set up by a magnetic field parallel or nearly parallel to the cathode. At least three distinct frequency ranges in which a magnetron will oscillate are well known. However, the one depending entirely on the electron transit time will produce the highest frequencies and is of main interest. As a matter of fact the shortest continuous waves yet recorded, of the order of several millimeters, have been produced with a split anode magnetron oscillator. The magnetron will operate at considerably higher efficiency then the positive grid oscillator since it does not contain a grid that collects a large part of the emitted electrons.

The electrons are emitted radially from the axial filamentary cathode and assume a curved path depending on the strength of the magnetic field. For a certain magnetic field strength the electrons just fail to reach the anode. This is called the cut-off field. Usually the field is adjusted to a value slightly above the cut-off. If in addition, an alternating voltage is impressed between the two sections of the split anode an electron of favorable phase will make a number of revolutions between the cathode and plate before eventually striking the plate. In each successive revolution the electron delivers a decreasing amount of energy to the a-c voltage until the phase shift becomes such that the electron absorbs energy. An electron of unfavorable phase will absorb energy from the a-c voltage and return to the cathode after one revolution. If the electrons giving off energy are allowed to make several revolutions, but are removed before they begin to absorb energy, more energy will be delivered to the a-c voltage than is absorbed. Since the electrons may give energy to an a-c voltage under favorable conditions of magnetic field and plate potential, oscillations can be produced by connecting a resonant Lecher wire load between the two halves of the split anode. The tuning of the load affects only slightly the frequency of oscillations. A suitable load will greatly increase the frequency stability which depends primarily on constant magnetic field and anode voltage. For proper operation at the highest frequencies a strong magnetic field is necessary. Approximately 100,000 ampere-turns per meter (1200 gauss) is required at a frequency of 3000 mc/s. For experimental work it is convenient to use an electro-magnet to produce the magnetic field. To keep the magnetic field constant some kind of control must be employed. A current regulator may be used to keep the current through the field coils constant as the coil temperature or the line voltage changes, provided the coil is of high resistance requiring a small current at a high voltage. The circuit diagram of the magnetic field regulator is shown in Fig. 9. The circuit makes use of the fact that in certain ranges of voltage and plate current beam power pentodes exhibit small variations of plate current for large changes in plate voltage. Additional stabilization results from the use of a cathode biasing resistance, which increases the grid bias with increase in plate current.

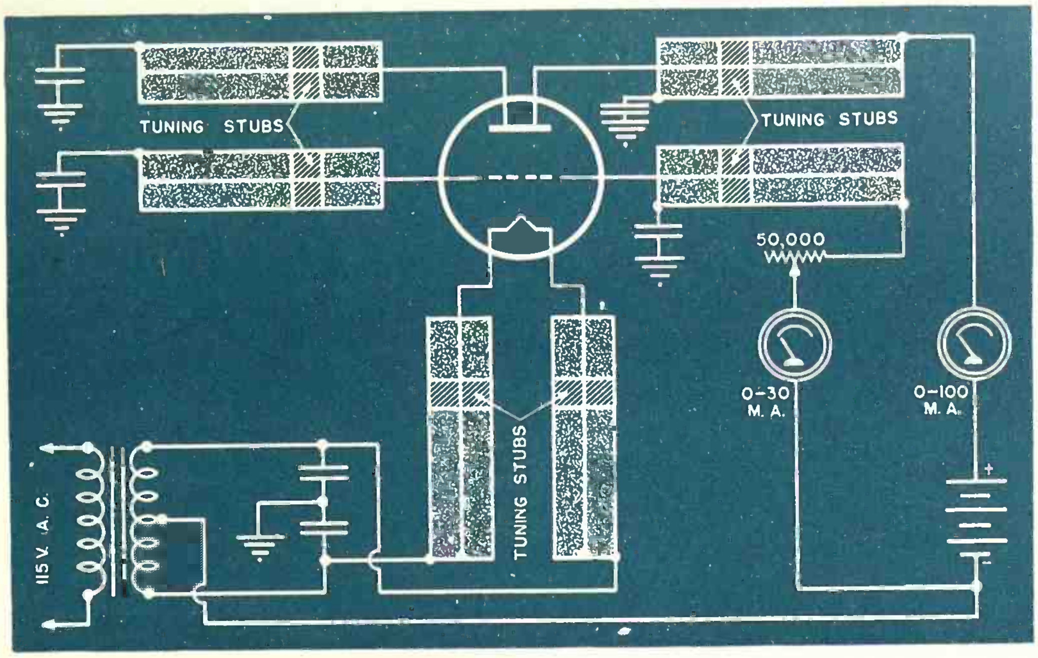


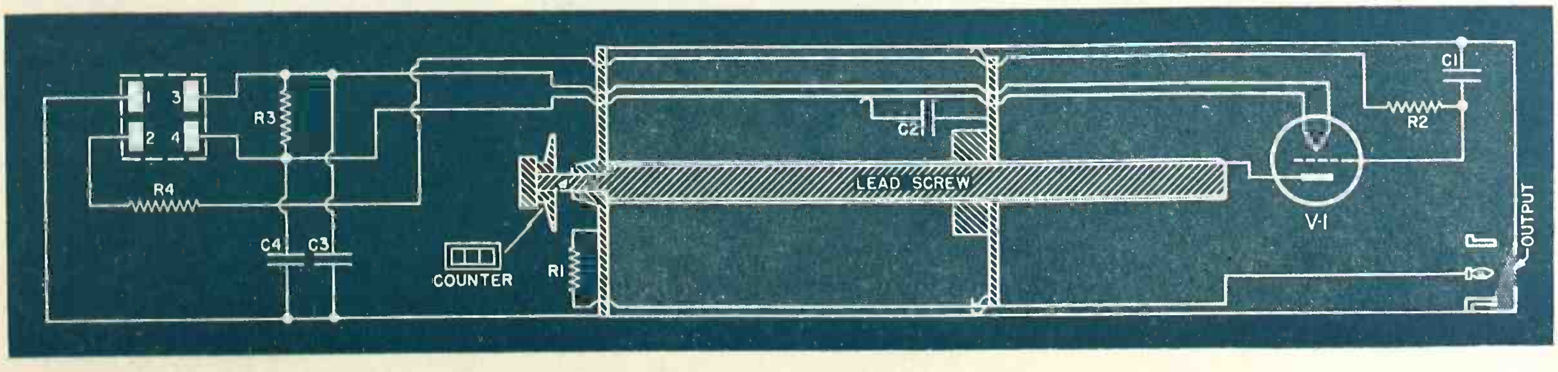
Fig. 3. An 8012 tube connected to the center of a half-wave concentric line.

Special attention must also be given to the proper operation of the filament and plate voltages. Experimentally it has been found that the filament of a magnetron oscillator should be adjusted so that the current in the tube is emission limited, or at least so that the space charge is small. However, in a transit time magnetron the plate current and cathode and plate temperature tend to rise cumulatively because of the bombardment of the cathode by some high velocity electrons returning from the anode region. Under certain conditions, most likely to occur when the circuit is adjusted to maximum output, the cumulative increase in the cathode temperature may become excessive and result in the destruction of the cathode. Thus a regulating device is necessary that keeps both the anode voltage and the cathode temperature constant under all operating conditions. An appropriate circuit that will perform both functions is illustrated in Fig. 8. The filament current is kept constant by a conventional thyratron phase-control circuit. The anode voltage is stabilized by a voltage-regulated degenerative power supply of low output impedance. Fig. 8 illustrates the detail connections of the 884 tube in a current controlled unit. Measurements of the change of wave length with magnetic field and with plate voltage can easily be performed. A load may be coupled to the Lecher wire system by means of a hairpin turn. Oscillations are indicated on a suitable detector.

Klystron

It was shown that in the magnetron oscillator electrons of unfavorable phase absorb energy. An increased efficiency would be expected therefore, if it is possible to accelerate or retard these electrons so that they fall in phase with the electrons of favorable phase. This is accomplished in the electron-velocity-modulated tubes. Velocity modulation of electrons may be achieved by superimposing on the steady velocity component due to some direct accelerating voltage, an alternating component due to some small modulating voltage. Thus depending on the time phase of each electron some will be speeded up, others slowed down on account of the modulating voltage. If the electrons are allowed to drift into an equipo-

Fig. 4. Layout of variable frequency oscillator shown in Fig. 2. The metallic shield also acts as part of a coaxial-resonant circuit.



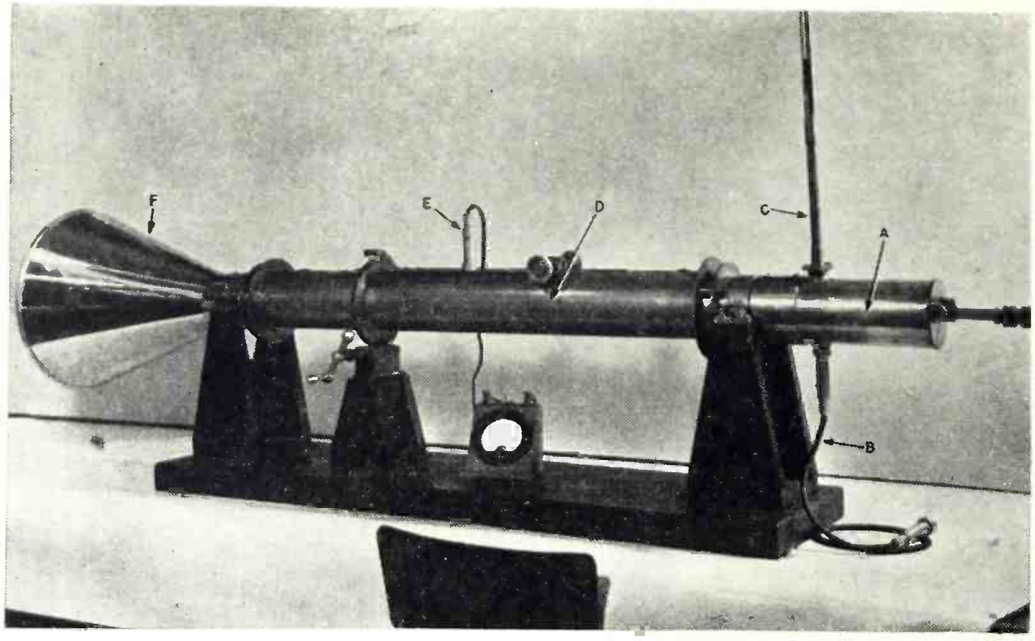


Fig. 5. A cylindrical wave guide for 10 centimeter-wave measurements.

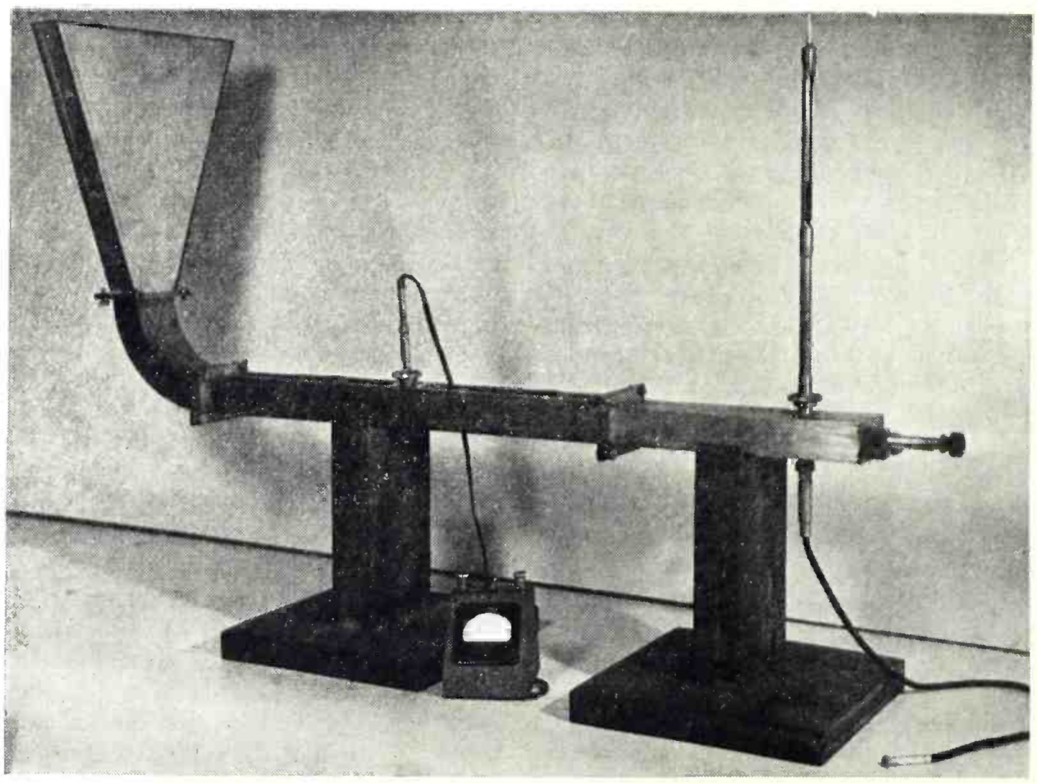
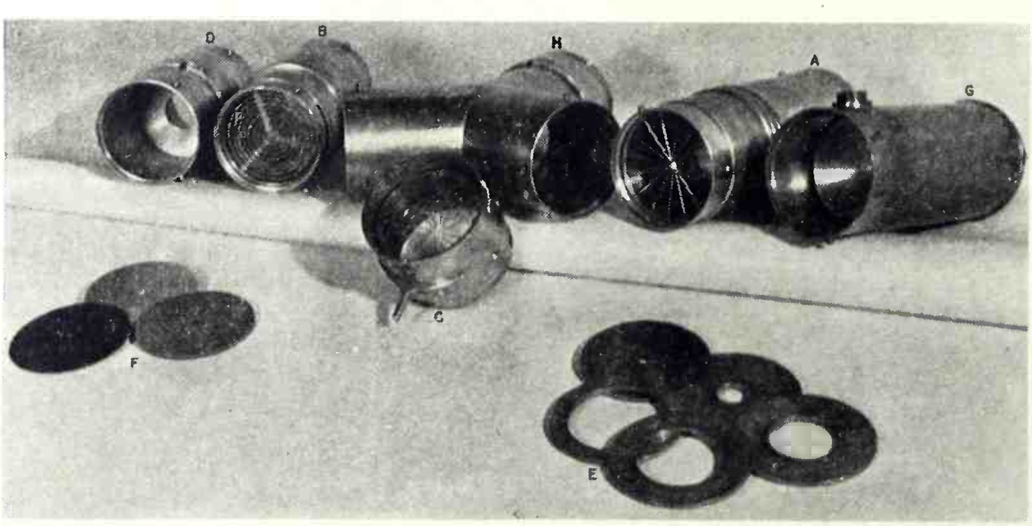


Fig. 6. A rectangular wave guide for 10 centimeter-wave measurements using a silicon crystal as a square-law detector to 100 microamperes.

Fig. 7. Typical sections introduced in circular wave guides to produce filtering action. Radial or circular fields may be eliminated by A or B.



tential space after they pass through the modulating potential they will collect into bunches. These bunches of electrons may be compared to the current pulses in a class C amplifier. A suitable resonant tank circuit will absorb sufficient energy to make up for the losses and oscillation will occur.

One of the velocity modulated tubes that is particularly important is the Klystron. Its main advantage compared to the other ultra-high-frequency oscillators discussed is that it may be used as an amplifier, detector or oscillator. The tube consists of a cathode, a control grid, two resonant chambers, known as the buncher and catcher separated by the drift space, and an end cap or target. The cathode supplies a uniform electron stream. The control grid serves to focus the electrons and control the electron flow. The buncher consists of two closely spaced grids that are part of a resonant cavity. An alternating field between the grids accelerates the electrons during one half of the cycle and decelerates the electrons during the other half of the cycle. After the electrons have passed through the buncher the fast ones will catch up in the drift space with those that have been slowed down. If the accelerating voltages and the spacing between buncher and catcher are of the proper values the electrons will arrive at the catcher in bunches. The catcher is similar in structure to the buncher, consisting of two closely spaced grids part of a resonant chamber. The bunched electrons will induce an alternating electromagnetic field in the catcher, and the cavity will oscillate at its resonant frequency. Energy may be taken from the catcher with the aid of a hairpin-shaped antenna entering the resonant chamber. The buncher field may be set up by impressing a signal of the proper frequency on a similar antenna in the buncher chamber. An amplification of about 10 may be realized at a frequency of 3000 mc/s. A self-excited oscillator is obtained by feeding a signal back from the catcher to the buncher through a coaxial cable. Both chambers must be tuned to the same frequency for the Klystron to oscillate. A tuner is provided with the Klystron that allows changing the size of the two resonant chambers.

The circuit diagram of a Klystron oscillator is shown in Fig. 10. The control grid is positive with respect to the cathode. The metal resonant chambers are at a high positive potential with respect to the cathode. Since it is necessary to adjust their size for oscillation it is customary to ground the positive terminal of the voltage supply. The accelerating voltage is rather critical for oscillations and also for good frequency stability and therefore it is necessary to regulate the plate supply voltage. The regulated power supply for the Klystron is illustrated in Fig. 10. Oscillations may be observed by a crystal detector connected to a hairpin antenna in either the catcher or buncher chamber. A coaxial output terminal fed from an antenna loop in the catcher chamber is usually provided.

Wave Guides

At ultra-high-frequencies the losses in a conventional coaxial transmission line become rather excessive and the efficiency of coaxial lines may be greatly increased by omitting the center conductor. A transmission line of this type is called a hollow wave guide. Radiation losses are practically nonexistent in a wave guide since the energy is completely confined to the interior of the guide. Conduction losses can be appreciably reduced by silver coating the interior surface of the wave guide.

A cylindrical wave guide is set up in Fig. 5. For use with a 10 centimeter wave length generator the cylindrical wave guide should have an inside diameter of approximately 3 inches, permitting only the lowest order transverse electric wave to be propagated. The wave guide is built up of several solid brass sections joined by flanges and fastened together by a pin and slot arrangement. Each section has a particular function and will be considered separately. The transfer section (A) is used to feed a signal to the wave guide by means of an antenna rod, or to receive energy that

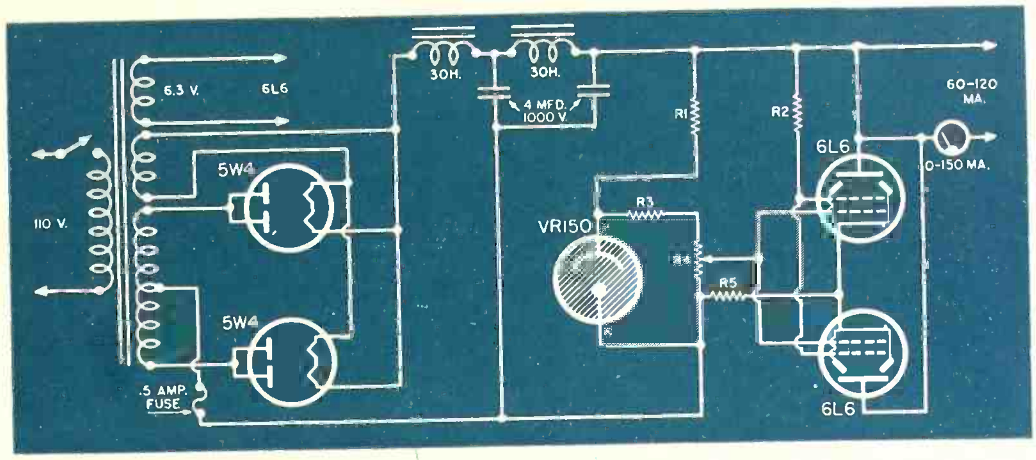
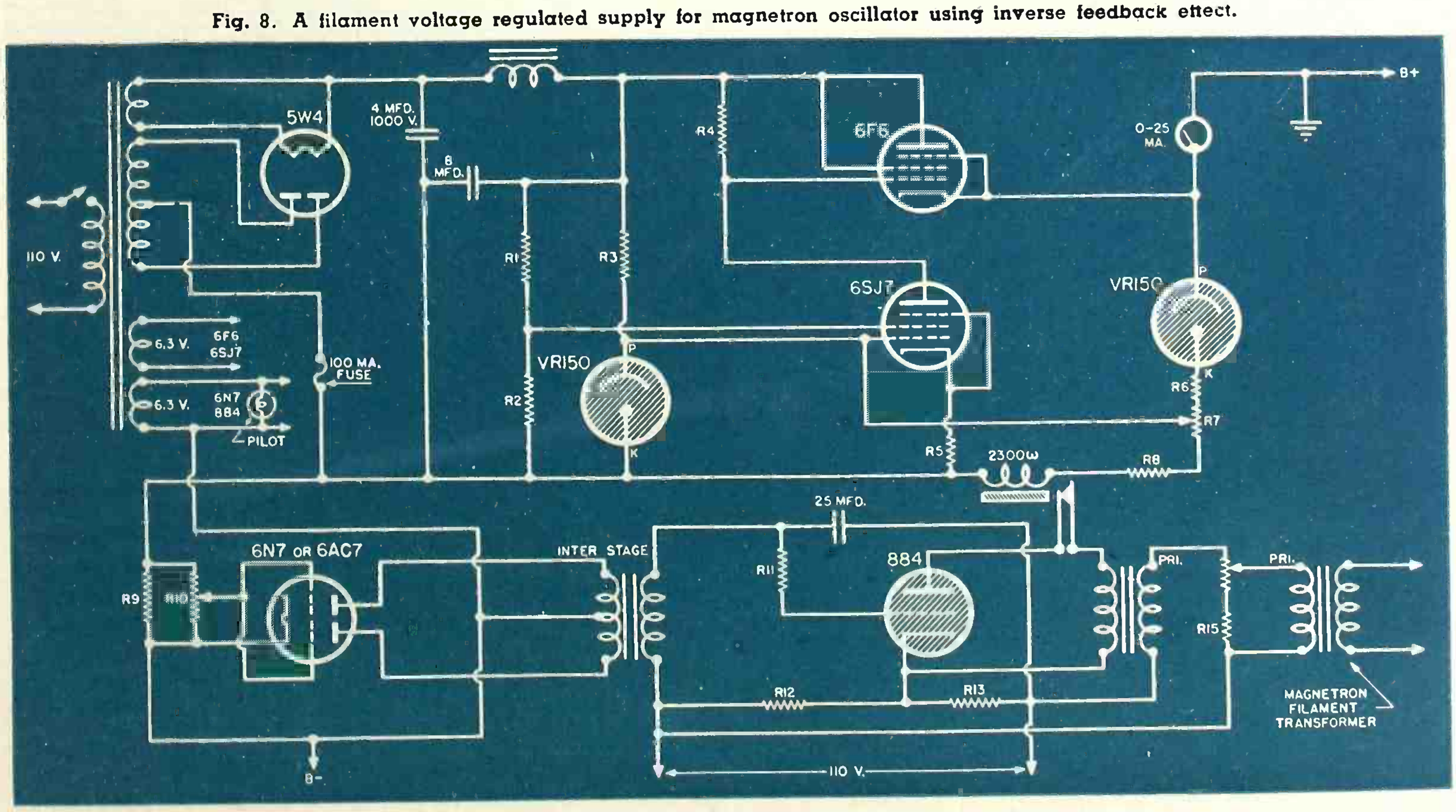


Fig. 9. A current regulated supply for magnetron electromagnet.

is being propagated through the guide. The antenna rod is part of the coaxial line (B) coming from the generator or leading to the receiver respectively. The antenna rod is terminated in a coaxial tuner (C), consisting of an adjustable short-circuited stub. Thus it is possible to match the antenna to the coaxial line. The transfer section (A) is terminated by a movable piston which can be displaced through a rack-and-pinion arrangement. The movable brass piston is provided with a large number of spring brass fingers to obtain good contact with the walls of the section which makes the termination more definite. The adjustable piston assures that the radiation from the antenna in the back direction will be reflected in the proper phase. Thus the piston allows matching the antenna to the guide. The traveling detector section (D) is used to explore the wave patterns in the guide. The section (D) is mounted on roller bearings, allowing a complete revolution without changing the position of the attached sections. Approximately 24 inches of this section are slotted and a detector unit (E) is allowed to move along the length of the slot to explore the field. The detector unit (E) may consist of a straight pickup rod or a pickup loop connected to a crystal detector and microammeter. Either iron pyrite or silicon crystals are suitable for detectors. The d-c detector current follows approximately the square law if the d-c current is held below 100 microamperes. When no deflection is observed as the detector unit (E) is moved along the slotted section, it is safe to assume that no waves are reflected. No reflections will occur if the wave guide is terminated by a proper impedance. A flared section of guide, referred to as an electromagnetic horn (F), serves as a termination which effectively matches the characteristic impedance of the guide to that of free space.

Fig. 8. A filament voltage regulated supply for magnetron oscillator using inverse feedback effect.



The effect of obstructions in the wave guide may be studied by inserting plates or rods and wire meshes. A few typical sections are demonstrated in Fig. 7. Section (A) consisting of a radial wire mesh will strongly attenuate a radial electric field. Section (B) consisting of circular concentric wires held in place by a polystyrene rod eliminates almost entirely a circular electric field. These two sections may be considered as wave filters. Section (C) may be called a wave transducer. A radial-electric field impinging on the wire mesh will produce a current flow from the radial conductors to the circular conductors, simulating a continuous ring of current flow. Therefore, a radial-electric field is changed into a circular electric field. Section (D) provides for the insertion of various diameter iris apertures (E) or plates of different dielectric materials (F). Thus the reflection from the iris apertures or the absorption of energy in the dielectric materials may be studied. Section (D) may also be used with section (G) to form a resonant chamber, bounded on one side by an iris aperture and on the other by a movable piston. The resonant chamber has many applications. When sucn a chamber is excited by ultra-high-frequency waves and the piston moved, resonance will occur at certain successive positions as indicated by a crystal detector. The distance between the resonance points gives data for the determination of the wavelength. The resonant chamber may also be used in connection with an ultra-high-frequency oscillator replacing the conventional Lecher wire system. Sometimes the chamber serves as an element in a receiver, thereby impressing on a detector a maximum of the received wave power. Such a resonant chamber has a high Q. The Q is reduced as the iris aperture is made larger, yet values of Q of several thousand are entirely possible.

A rectangular wave guide, for use with a 10 centimeter generator, is illustrated in Fig. 6. Multiplex transmission in hollow wave guides can be realized with a special arrangement. Section (H) serves to connect one wave guide to two wave guides that have been excited by antennas that are oriented at right angles to each other. The perpendicularly polarized waves do not interfere with each other and the system thus provides for two communication channels through the same wave guide.

Horns and Parabolic Reflectors

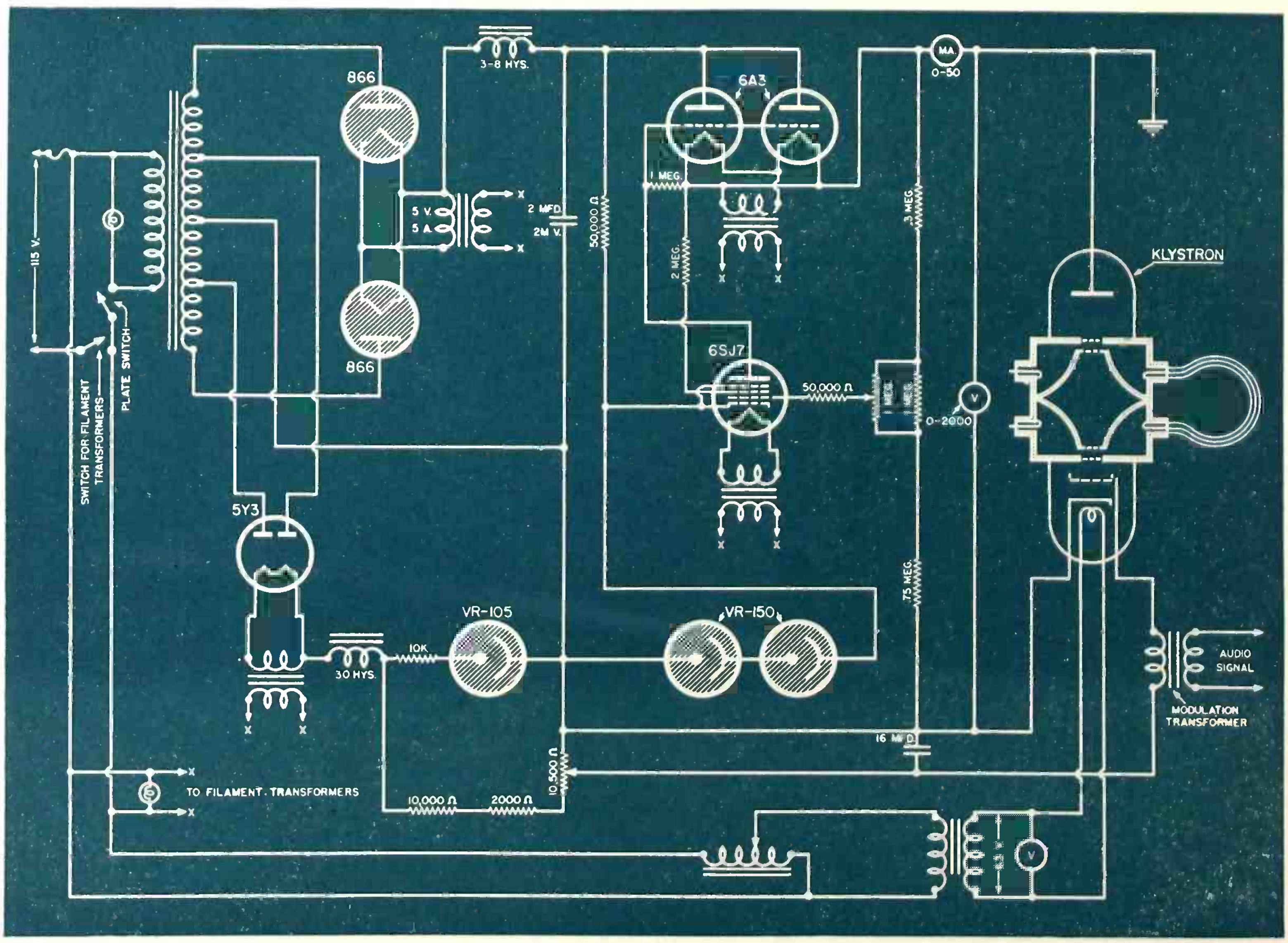
The hollow wave guide has been found highly efficient to transmit energy at frequencies above 1000 mc/s. In analogy to acoustics for effective radiation it was suggested to flare the ends of the wave guide into a horn-shaped radiator. Such horns increase the directivity of the radiation and provide the proper matching between the wave guide and free space.

For cylindrical wave guides a circular horn is used, as illustrated in Fig. 5. Increase of the horn length results in a steady improvement in the gain and directivity. However, the increase in cost of material and the difficulty in handling set a practical limit to the length of horns used. The directivity and gain also increase with the flare angle, an optimum being secured with an angle of about 50°. The resulting radiation pattern is a symmetrical ellipsoid of revolution.

Electromagnetic waves are excited in the wave guide by an appropriate antenna near the closed end. A piston arrangement adjusts the distance

(*Continued on page* 40)

Fig. 10. A high-voltage regulated power supply using the inverse feedback principle to provide a Klystron oscillator with constant voltage.



Phosphors for Electron Tubes

By H. W. LEVERENZ

Research Engineer, RCA Laboratories

A resumé of the theory of fluorescence and its application to phosphor chemicals in radio-electron tubes.

THE correlation of optical energy and radio-wave energy has been attempted by scientists with the aid of the electromagnetic theory of light. This theory alone, however, is inadequate to explain the conversion of kinetic energy of a high velocity electron to optical energy by impact upon a phosphor chemical. This action seems to be best explained by applying the quantum theory, an application of which was first noticed by Einstein when analyzing photo-chemical changes.

Practical applications of this theory are found in such commercial items as television Kinescopes, fluorescent lamps, oscilloscopes and indicating tubes such as the Magic Eye. In these tubes the final step of their operation comprises the conversion of electron energy into light or optical energy.

In accordance with the quantum theory, the quantity of optical energy depends upon the frequency as shown by:

$$E = h\nu \quad \text{..........................(1)}$$

where:

λ = wavelength in cm.
ν = frequency in cycles per second
c = velocity of light = $3 \cdot 10^{10}$ cm. per second
h = Planck's constant = $6.55 \cdot 10^{-27}$ erg sec.

and the relation between the wavelength, frequency and velocity is given by the equation:

$$\lambda \cdot \nu = c \quad \text{..........................(2)}$$

To obtain a comparison of the amounts of energy in radio-wave and light-wave quanta, consider the energy of a quantum of radiation from station WEAF, whose frequency is 660 kc.

$$E_{WEAF} = 6.55 \cdot 10^{-27} \cdot 6.6 \cdot 10^{5} = 4 \cdot 10^{-21} \text{erg.}$$

The lower part of the optical spectrum chart shows that orange light has a wavelength of 6100 Angstroms where 1 Angstrom is 10^{-8} cm. Hence, the energy of a quantum of orange light is

$$E_{ORANGE} = h\nu$$
$$E_{ORANGE} = h\nu = 3.2 \cdot 10^{-12} \text{ erg}$$

By comparing the above two calculations, it is apparent that the quanta of orange light are $80 \cdot 10^{6}$ times as great as the quanta radiated from WEAF.

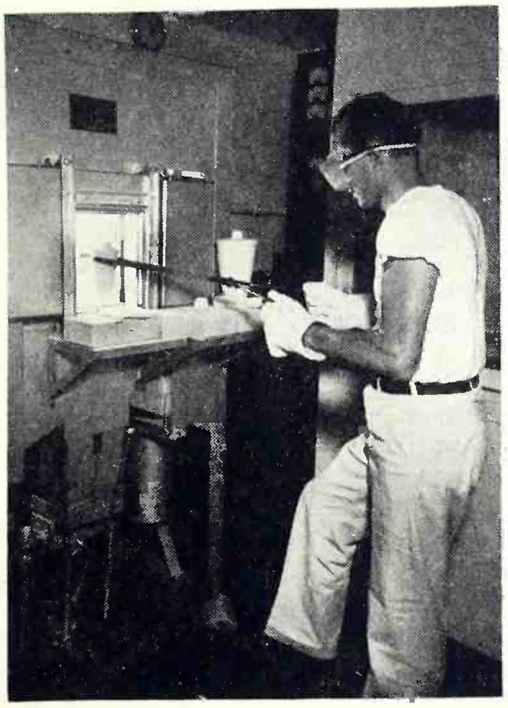


Fig. 1. High temperature treating of phosphors.

This simple calculation gives a quantitative comparison between the energies in two very different portions of the electromagnetic spectrum. In accordance with the Law of Conservation of Energy, the kinetic energy of a moving electron upon impact with a phosphor chemical is converted into heat and light energy. If, for this particular computation, it is assumed that the efficiency of conversion to light energy is 100 percent, then it is evident that a 2 volt electron would produce light of an orange color which would be visible to the human eye. The kinetic energy of such an electron is:

$$E = m v^2/2$$
$$E = e \cdot V \text{ ergs} \quad \text{....................(3)}$$

where:

v = electron velocity in cm. per second
m = electron mass in grams
e = electron charge of $4.77 \cdot 10^{-10}$ e.s.u.
V = accelerating potential in e.s.u. of potential

Since 300 practical volts are equivalent to 1 e.s.u. of potential, the numerical value of the kinetic energy for a 2 volt electron is:

$$E = \frac{4.77 \cdot 10^{-10} \cdot 2}{300} = 3.2 \cdot 10^{-12} \text{ erg}$$

By comparing the above calculations, it is seen that a quantum of orange light has the same energy as a two volt electron.

Contrary to the general conception of the form of electrons as particles and light as waves, modern wave mechanics assigns a simultaneous undulatory and corpuscular character to both electrons and light. For practical purposes, electron energies and light quanta are related by:

$$\lambda_{min} = \frac{1.234 \cdot 10^{4}}{V} \text{ Angstroms} \quad \text{.......(4)}$$

where λ_{min} is the wavelength, in Angstroms, which would be produced by 100 percent conversion of the energy of an electron, accelerated by V volts, into one quantum of electromagnetic radiation. Since most phosphor chemicals have efficiencies of conversion well below 100 percent, the actual wavelengths produced will be considerably longer than the λ_{min} given by equation (4).

There is a constant number of electrons for use in matter, but the number of light quanta may be increased or decreased. This situation may be represented by the notation of a reversible action as:

Fast electron $\rightleftarrows$ Slow electron + Light quantum ....(5)

When invisible radiations such as ultraviolet, X-rays or cathode rays, having quantum energies greater than about 10^{-12} erg, impinge upon matter, there is a great probability that the irradiated material may emit electrons or light or both as tabulated below:

a. Shortwave light + Matter ⟶ Free electrons
b. Shortwave light + Matter ⟶ Long-wave Light
c. Fast Electrons + Matter ⟶ Slow electrons + Free electrons + Light

Effect (b) is used in fluorescent lamps wherein invisible ultraviolet radiation from an electrical discharge through tenous mercury vapor is efficiently transformed by phosphors into visible light.

Effects (a) and (c) are ingeniously

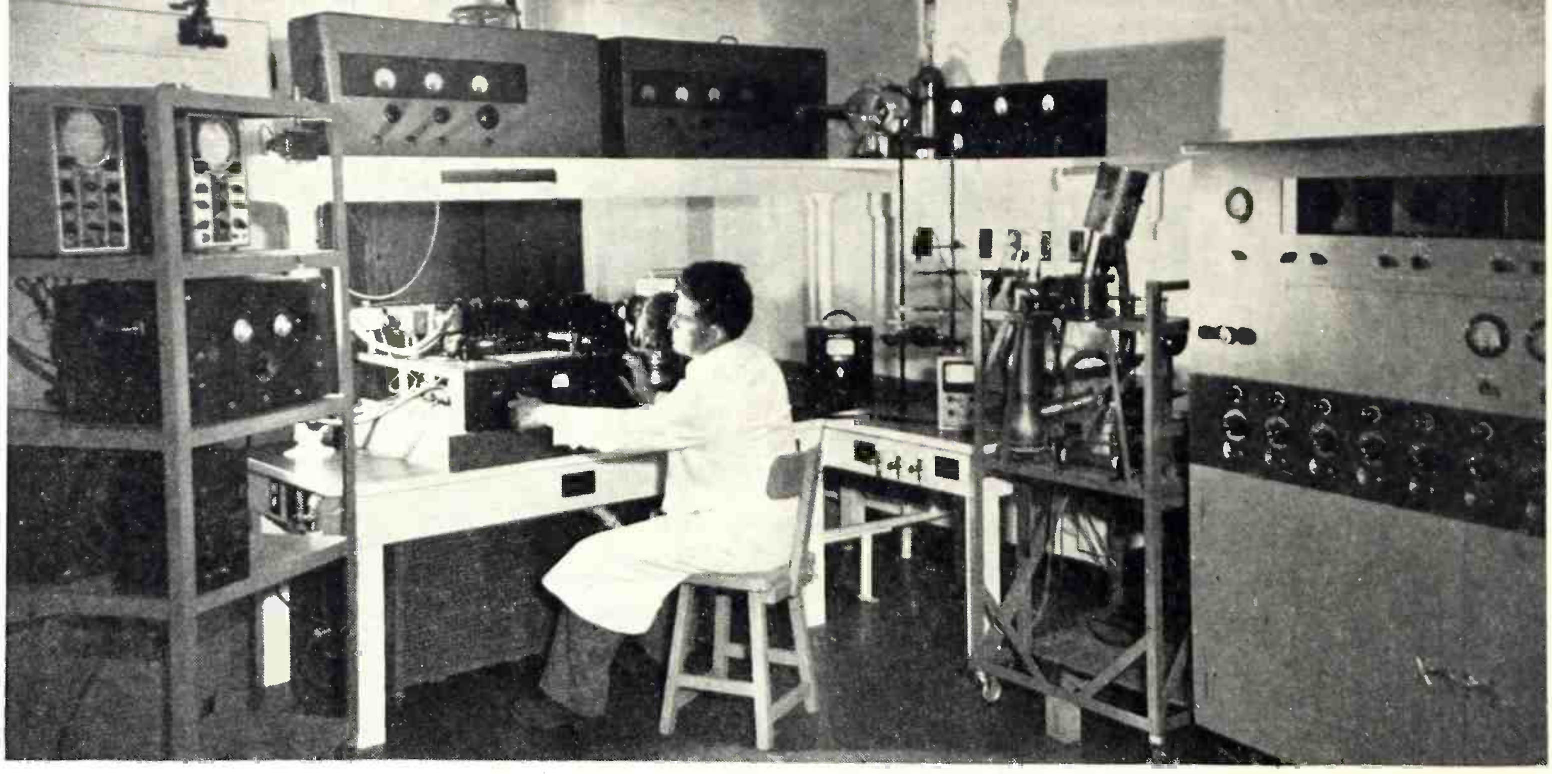


Fig. 2. A research physicist tests completed phosphors with special electronic equipment.

applied to ultra-short-wave radio to produce electronic television as sketched in Fig. 5. When high-speed electrons penetrate the phosphor coating in a Kinescope, the fast electrons give up their energy in about 30 volt bits until each original electron is finally reduced to a negligible speed and energy after buffeting through the atomic maze. A 10,000 volt primary electron upon impact ejects one 5—15 volt secondary electron and produces about 330 quanta of visible light from an efficient phosphor crystal.

According to Fig. 5 a televiewer observes light emitted by a coating of phosphor material which is being struck by a beam of electrons. Obviously the televiewer must be pleased by what he sees, that is, the phosphor must cater to the human eye.

Referring to Fig. 6, it may be ascertained that the eye demands that energy be supplied from within a one octave range although there are sixty octaves included between the radio wave and X-ray portion of the spectrum. The portion shown in Fig. 6 shows the eye sensitivity to reach maximum in the center of the visible spectrum and minimum at the ends. Actually, the selectivity of the eye requires that the electromagnetic radiations lie within an energy band of only

$$\Delta E = \frac{hc}{10^8}\left(\frac{1}{5000} - \frac{1}{6500}\right)$$

$$\Delta E = 10^{-13} \text{ erg}$$

wide for reasonable visual efficiency. In this sense, a phosphor must transform invisible energy into visible light just as a radio set must transform inaudible radio waves into audible sounds.

Having restricted the visible energy region, the human eye further requires that the light within that narrow span be broadly distributed to simulate white light. A blue-white, such as daylight, seems to be the most desirable color for television or illumination because the eye psychologically associates bluish tints with high briliancies. For color television, the same fidelity of white reproduction must be maintained in addition to portraying at least the three primary colors, blue, green and red.

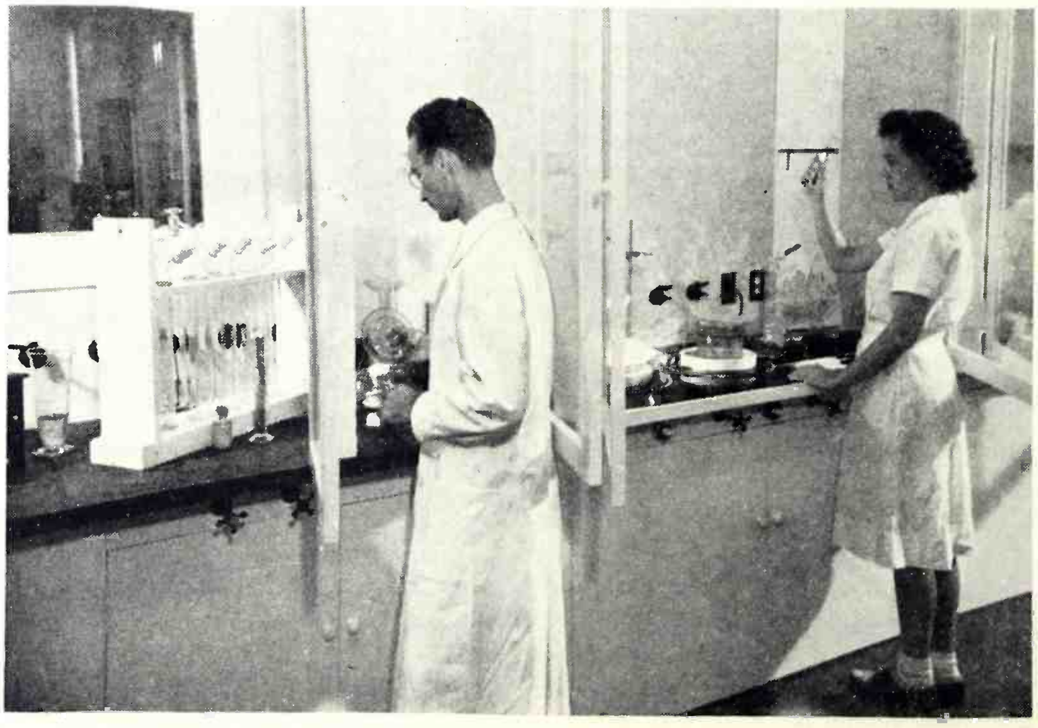
In both television Kinescopes and fluorescent lamps, phosphors must be placed within an evacuated envelope in order to utilize free electrons as the primary agent in producing luminescence. From the physical standpoint, phosphors for electron tubes must pass all of the following tests.

1. Have a luminescent efficiency greater than 5% (i.e., emit more than 30 lumens per watt).
2. Adhere well to glass.
3. Withstand heating to about 400°C in air and vacuo.
4. Have long operational life.

There are many other stringent physical requirements for phosphors, especially for those used in television Kinescopes. For example, Kinescope phosphors must emit at least one secondary electron for each incident primary electron or the screen potential will drop below the applied potential and may eventually cause the phosphor screen to repel further primary electrons.

Now that the requirements of phosphors has been presented, a quick test of all the materials known to man is given in order to find the best ones for use as phosphors in electron vacuum tubes. In other words, having sources of cathode rays, or of 2537 Angstrom ultraviolet, in a vacuum and it becomes desirable to transform these invisible radiations into visible light

Fig. 3. Research chemists purify and compound phosphor chemicals.



while satisfying the previously enumerated requirements.

There are about 500,000 known materials, which may be roughly classified as follows:

1. All organic substances and materials (about 400,000).
2. All inorganic substances prepared by ordinary chemical methods not involving high temperatures (about 30,000).
3. All natural minerals and the members of group 2 which have been subjected to high heat.

Group 1 is rejected "en masse" because none of the organic materials can withstand heating in a vacuum.

Group 2 also fails since none of the pure unheated inorganic substances has satisfactory efficiency.

Group 3 is tested by a strong source of cathode rays and ultraviolet light. There are only a few minerals which pass all the tests. The better luminescent minerals and heated substances may be found by analysis to be:

Willemite = zinc silicate plus about 1% of manganese.

Sphalerite = zinc sulphide plus about 0.01% of copper.

Scheelite = calcium tungstate (no impurity).

Those materials which passed the tests did so with a C— average—barely passing. From the half million experiments, however, it has been found that

1. a good phosphor is an inorganic crystalline material which has been subjected to high temperature (1000° C or higher); and
2. small amounts of certain elements, such as manganese and copper, when added to phosphor base materials may enhance luminescent efficiency.

It was with this type of empirical information that modern phosphor research started in the early days of electronic television.

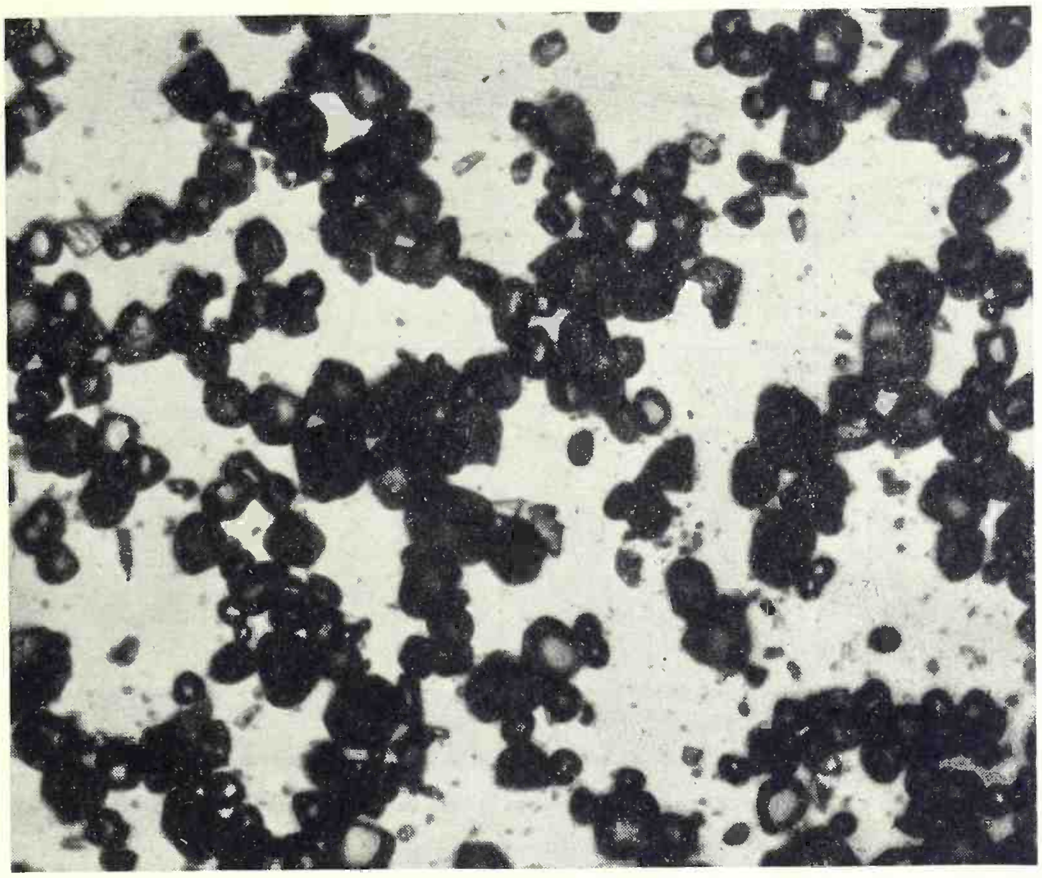


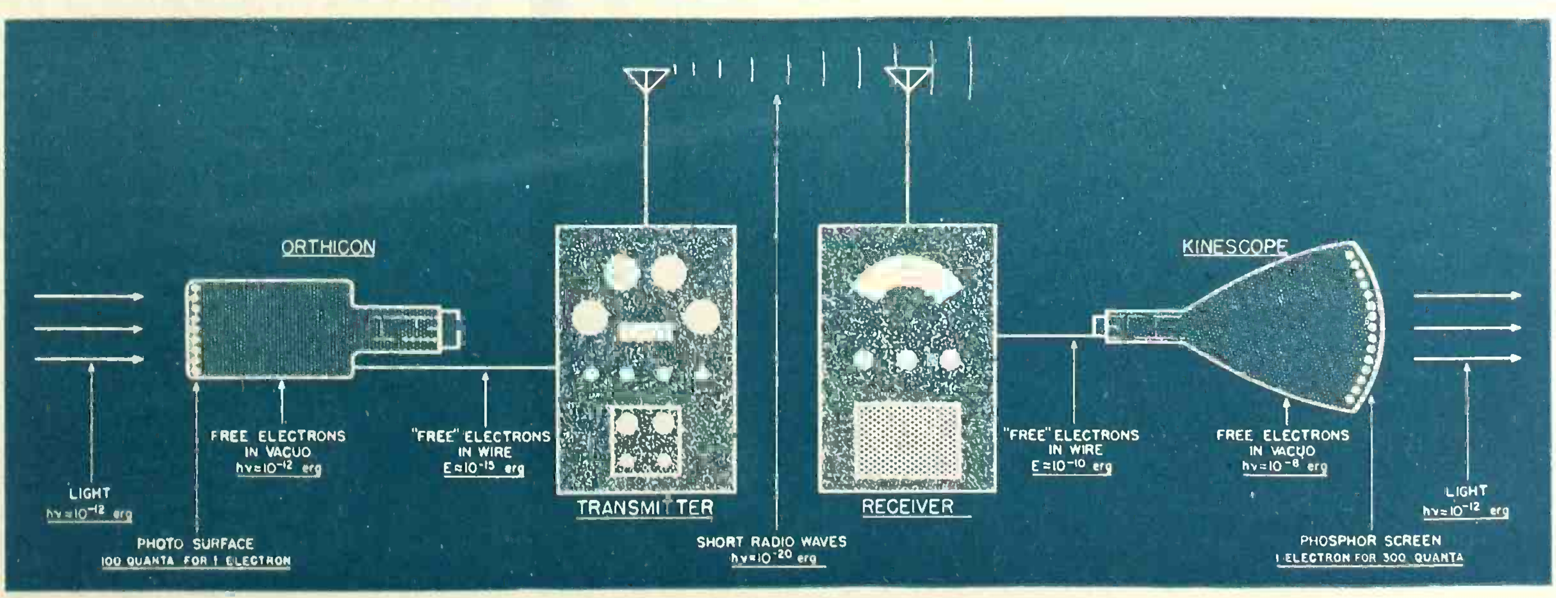
Fig. 4. A photomicrograph of phosphor crystals.

Some of the best phosphors are so sensitive to impurities that as little as a part per million of some foreign elements suffice to drastically alter color, efficiency, or persistence of luminescence. Hence phosphor research is conducted in dust-free laboratories such as shown in Fig. 3. The laboratory air passes through electrostatic precipitators to remove even submicroscopic dust, while the laboratory personnel must change to clean white clothing before entering the phosphor preparation rooms.

The essential step of high-temperature crystallization is accomplished in special electric furnaces, one of which is shown in Fig. 1. Here, the painstakingly purified phosphor ingredients, placed in quartz or platinum crucibles, are subjected to white heat until the heterogeneous pulverulent mass is converted into myriad tiny crystals such as those shown in Fig. 4.

After the crystals have been cooled, they are tested with complex electronic apparatus, some of which is shown in Fig. 2. The visible absorption or emission spectrum of a phosphor, measured in wavelength units of 10^{-8} cm., may be determined in one minute with the recording spectroradiometer pictured in the center of Fig. 2. With the oscillograph equipment at the left of Fig. 2, measurements of a phosphor's light output as a function of time may be made from times as brief as a few millionths of a second to times longer than a day. This instrument, an electronic phosphoro-

Fig. 5. Electron and quantum energies involved in television transmission.



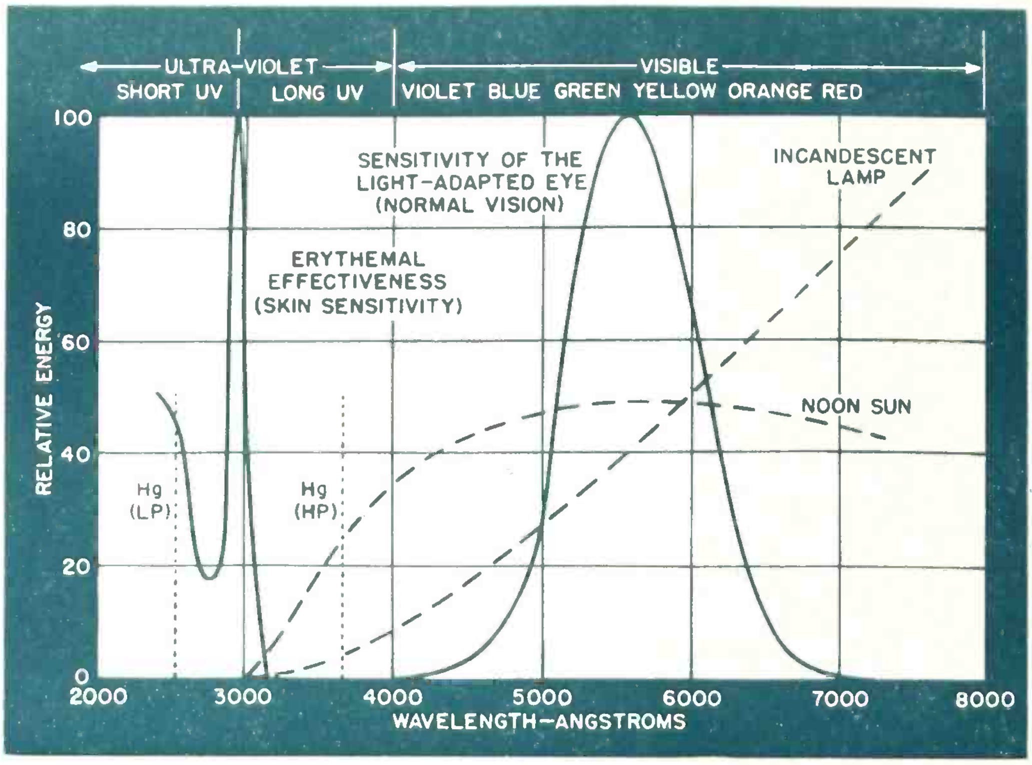


Fig. 6. Special cases of electromagnetic response curves in the ultraviolet and visible regions.

scope, encompasses a light intensity range of over 1,000,000 to 1.

Michael Faraday once remarked that one successful experiment out of 300 was a good average for research.

Thousands of new phosphors have been synthesized during phosphor research of the past decade. Results may be evaluated by considering the progress made in lighting and television.

Incandescent lamps, the general illuminant up to a few years ago, had efficiencies expressed in watts per candlepower. Phosphors developed during television research had efficiencies expressed in candlepower per watt. The lighting industry became cognizant of this more efficient means of converting electric power into light and evolved modern fluorescent lighting.

The esthetically undesirable green and black images of early television have been superseded by white-and-black or even color television. This was accomplished by devising several efficient phosphor systems wherein practically any color could be custom made. An example of such a variable color system is the zinc-cadmium sulphide series shown in Fig. 10. White light for either television or fluorescent lighting is produced by mixing blue-luminescing and yellow-luminescing phosphors which add their individual luminosities to afford a resultant white as shown in Fig. 7.

During the development of more efficient and colorful phosphors for electronics, the brilliancies of phosphors was greatly increased. Instead of requiring darkened rooms for observation, phosphors may now be made to luminesce with intensities much greater than the eye can view with comfort. Brilliancies of several thousand foot-lamberts may be had with reasonable operational life, while brilliancies of over 1,000,000 foot-lamberts may be produced for short times.

The following simplified description of luminescent action has been deduced from what has been learned about phosphors, including much which has not been mentioned here for lack of space.

Fig. 8 shows the allowed energy bands in a tiny portion of a phosphor crystal. By "allowed" is meant that electrons may exist in certain energy ranges (viz. B_0 or B_1) while other energies are "forbidden."

When the crystal is in its ground (unexcited) state, each atom or ion in the crystal has its normal complement of electrons firmly bound to it and the lowest energy state B_0 is then completely full as represented in Fig. 8 by cross-hatching. If a quantum of extraneous radiation, having an energy greater than about 10^{-12} erg $(= B_1 - B_0)$, traverses the crystal, then one or more of the most loosely bound electrons would be summarily ejected out of the "at rest" band, B_0, and raised into the higher allowed energy band, B_1.

In the higher energy region, B_1, electrons are no longer tied to some parent atom or ion, but are free to wander throughout the crystal, i.e., laterally in the diagram, until they are either caught in some imperfection (shown as traps T_1 and T_2) or until they chance near one of the few activator atoms, (viz. copper or manganese shown as A^+). In the latter case, the wandering electron may drop into A^+ and emit a quantum of light with energy

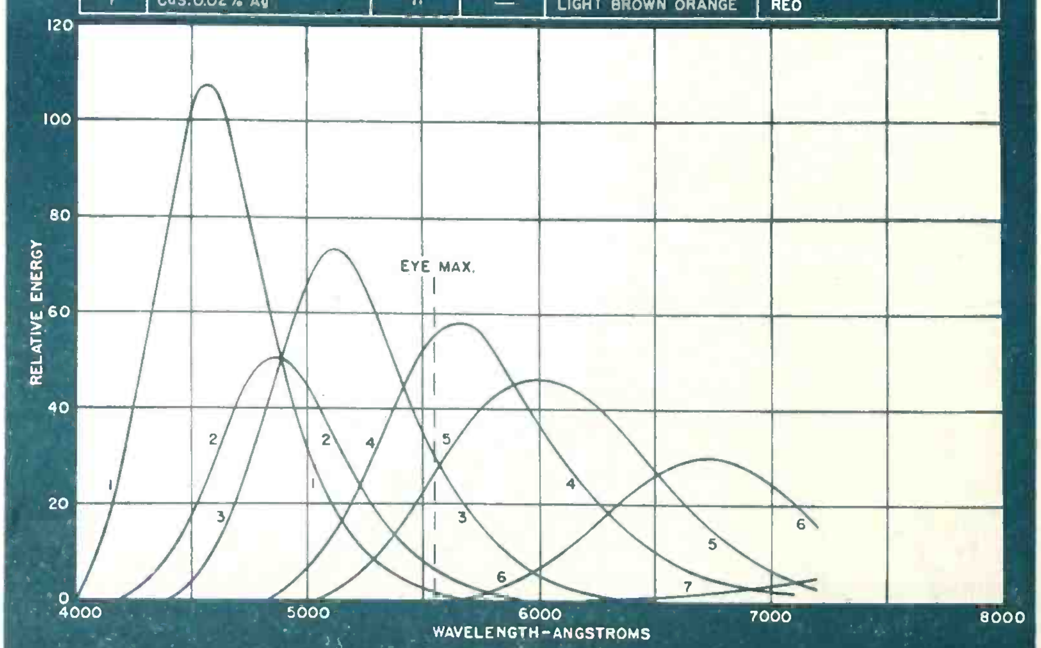
$$E = h\nu = B_1 - A^+ \qquad (6)$$

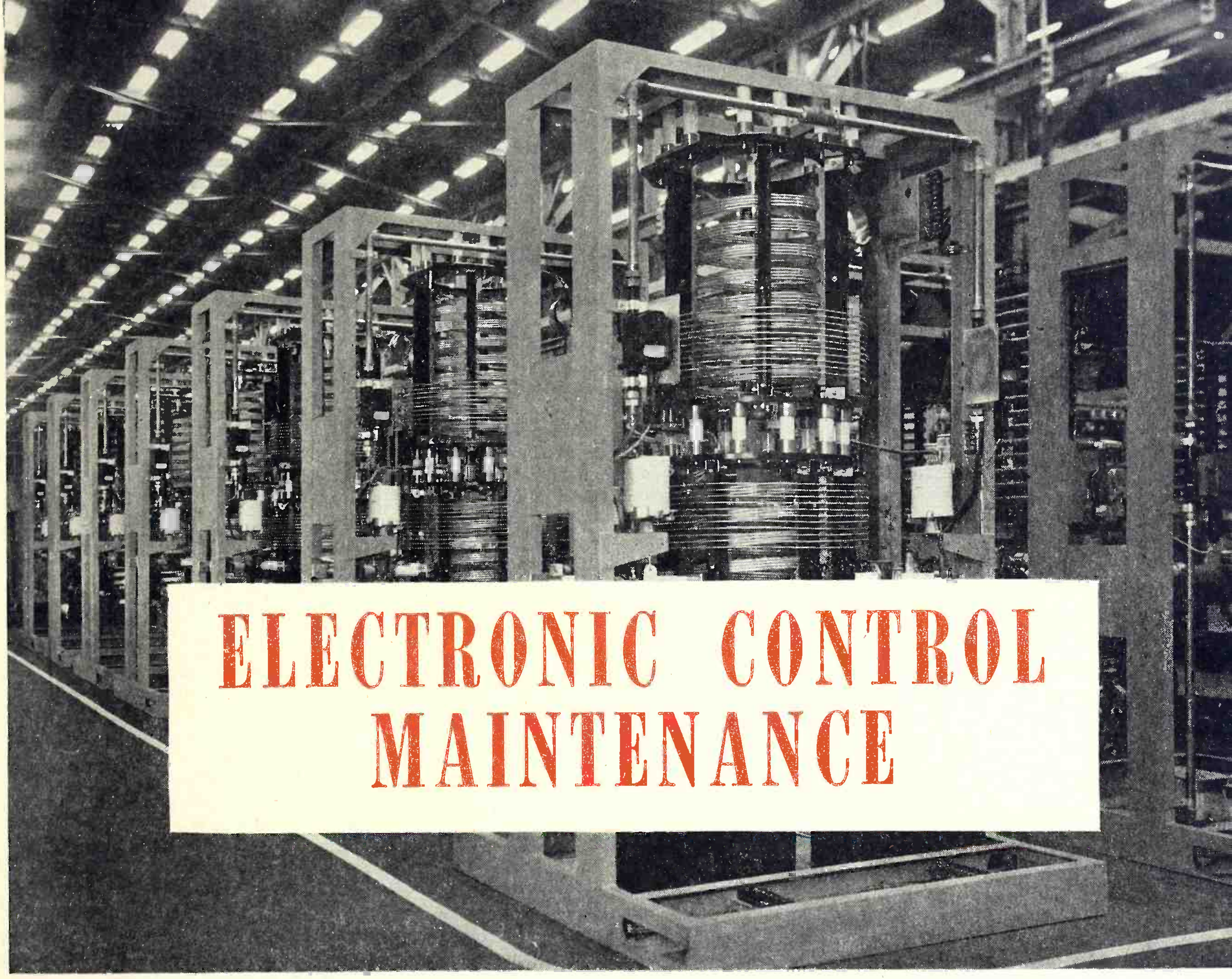
This action takes place in about 10^{-8} to 10^{-6} second and is termed fluorescence. Electrons which have been trapped in T_1 or T_2, however, must await liberation by latent heat vibrations before they may wander again in search of a receptive A^+ atom into which they may drop while liberating

(Continued on page 36)

Fig. 7. Energy diagram used in interpreting the mechanism of luminescence in phosphors.

CURVE	PHOSPHOR	TEMP. °C	WESTON	NATURAL COLOR	LUMINESCENCE COLOR
1	ZnS:0.008% Ag	940–2hr	43.6	WHITE	LIGHT BLUE
2	ZnS(80) CdS(20):0.01% Ag	"	63.4	LIGHT GREEN WHITE	VERY LIGHT BLUE GREEN
3	ZnS(60) CdS(40): "	"	156.0	VERY LIGHT GREEN	VERY LIGHT CREAM GREEN
4	ZnS(50) CdS(50): "	"	235.0	LIGHT YELLOW	LIGHT GREEN YELLOW
5	ZnS(40) CdS(60): "	"	150.0	LIGHT CREAM YELLOW	LIGHT YELLOW ORANGE
6	ZnS(20) CdS(80): "	"	22.0	TAN ORANGE	LIGHT RED
7	CdS:0.02% Ag	"	—	LIGHT BROWN ORANGE	RED





ELECTRONIC CONTROL MAINTENANCE

A production line of 1400 kw. industrial heating units for electronic tin fusing.

By R. H. SCHAAF
National Radio Institute

An analysis of industrial electronic control equipment and important maintenance procedures for continuous operation.

SINCE Pearl Harbor, the need for adequate preventive maintenance has grown tremendously. Equipment which in normal times was idle from 12 to 16 hours out of every day is now being operated at maximum output the full 24 hours, 7 days per week. The possibility of failures due to wear are, therefore, increased proportionally. Preventive maintenance detects and eliminates the causes of such failures before they can occur.

It is easy to neglect the maintenance of industrial electronic control equipment because it is so ruggedly constructed, conservatively rated and has so few moving parts to break or get out of adjustment. This does not alter the fact that vibration loosens connections and breaks wires, tubes fail, relay contacts require periodic cleaning and adjustment, and that dust and dirt reduce the effectiveness of the optical systems of photoelectric devices.

It is not the intention of this article to give specific instructions for the maintenance of any particular electronic control but rather to discuss the fundamental principles upon which good maintenance is based. Trouble-shooting techniques in so far as they can be applied to electronic control equipment in general, will be included.

Basically, the procedure for maintaining electronic equipment in good working order is no different from the procedure used to keep a piece of mechanical or electrical machinery working. A careful, periodic inspection should be made for surface defects. If any are found, they should be corrected immediately. This may mean a minor repair or adjustment, or the complete replacement of one or more parts, depending on the nature of the defect. The equipment should be cleaned thoroughly and a final test made under actual operating conditions to check the effectiveness of the work done.

Maintenance would be greatly simplified if it were not for the great variety of electronic devices used in industry. For instance, there are electronic welding controls, photoelectric safety devices for punch-presses and other dangerous machinery, high-power r-f oscillators and their associated power supply units for electrostatic and electromagnetic induction heating, vast sound distribution systems by which paging announcements and music are carried to all parts of factories and various electronic intrusion alarms to mention only a few.

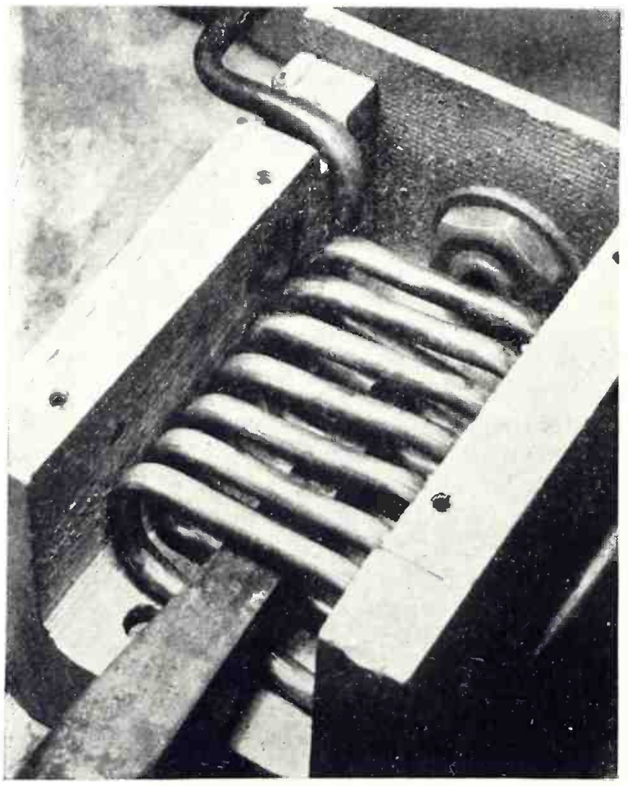
Electronic equipment has also been devised for inspection work. X-rays are now being used to check castings, cathode-ray oscilloscopes, vacuum tube voltmeters, sound-level meters and variable frequency audio and radio signal generators are just a few additional applications of electronic methods for test and inspection work.

There are, of course, many other electronic devices which could be mentioned. However, since this is a discussion of maintenance methods, these few shall suffice to illustrate the variety that must be serviced.

Considering this variety of electronic devices, it is fortunate that there are certain component parts which, with but few exceptions, are common to all types of equipment. These basic parts are six in number, units of resistance, capacity and inductance (transformers and reactors), various types of electron tubes and electromagnetic relays plus the network of wires which connect the various parts together. The optical systems of photoelectric devices were purposely omitted from the above list, since they are used in only one type of control and are more a special accessory than a basic component of many different types of controls.

Anything that affects the basic components must of necessity affect the operation of the device as a whole. Whether or not the effects are serious depends on the nature of the trouble. It is not necessary to test each part individually during the regular periodic inspection of the equipment. The

Fig. 1. Special induction heating coil.



very fact that it is working is proof that nothing serious has happened. Therefore, it is only necessary to look for loose connections, dirty relay and switch contacts, broken wire strands, poor insulation and partial cracks. While this type of inspection materially shortens the routine, the inspection must be nonetheless rigid. The success or failure of the entire program of preventive maintenance rests on the care exercised in locating these few simple defects.

Broken wires mean an open circuit and must be replaced when discovered. Wires having broken strands will break completely in time and should be replaced when discovered. Loose connections introduce undesirable resistance, are the cause of much intermittent operation, and may result in false test-instrument readings. They are most often caused by excessive vibration or constant handling.

Vibration also tends to loosen the mounting bolts which hold such heavy parts as transformers, reactors and filter condensers in place. These must be checked regularly. If frequent tightening is found necessary, the panel should be shock mounted to reduce the vibration.

Plugs, receptacles and cables which must be handled often, those used on test and inspection devices in particular, must be checked carefully for broken wire strands, frayed insulation, corroded shield and ground connections (due to electrolysis), loose contacts in the receptacles and bent plug pins. Wire insulation should also be checked for the effects of corrosive vapors.

Indicating meters should be inspected at periodic intervals and any abnormal readings investigated immediately. Encourage machine operators to report any irregularities in the performance of their machines and associated controls.

Equipment must be kept clean, as accumulations of dust, dirt, and grease not only reduce operating efficiency, introduce leakage between circuits and cause undesirable resistance between switch and relay contacts, but make a thorough visual inspection difficult and in general gives an unsatisfactory impression.

Cleaning of the machinery can be carried on at the same time the check for surface defects is made. A good grade of lintless cloth should be used. The material that machinists call "waste" is not suitable for this job and it is important to realize that lens tissue should be used to clean optical systems.

Insulators in high-voltage (10,000 volts and up) power supplies must be kept clean or flash-overs will occur. They must be washed periodically. This, of course, should be done with the equipment entirely shut down.

Relay contacts require special attention. The need to clean them regularily arises from the constant formation of grease films from the surrounding atmosphere, and natural films resulting from the chemical combination of the contact material with oxygen in the air. There are several ways of removing these films.

Some recommend that the contacts be wiped with a clean piece of good quality bond paper. Others object to the use of paper and recommend chamois dipped in carbon tetrachloride. There's no doubt that this is a good cleaning fluid, but there is danger of a corrosive action due to free chlorine in the solution; a half-and-half solution of alcohol and ether is also recommended.

Burned and pitted contacts are evidence of excessive arcing. In dressing the contacts to correct this trouble, great care must be exercised to maintain the original contact shape. If the contact shape is altered, the current density per unit of contact surface is changed. When the current density per unit of contact area rises above the safe limit, pitting and burning are accelerated. Thus the object of servicing the relay is defeated.

After the contacts have been dressed, the relay will have to be readjusted in order to maintain the pull-up and drop-out current values within the limits of the device. It is recommended that the manufacturer's specifications be followed closely.

Some arcing at the contacts is bound to occur and is desirable to the extent that it helps retard the formation of grease films. Excessive arcing, however, cannot be tolerated. To reduce excessive arcing (after the contacts have been cleaned and dressed and the relay properly adjusted), connect a condenser, in series with a resistor, across the contacts. The resistor value should be *at least* one ohm per volt of power supply. Thus, if the voltage across the contacts is 50 volts, the resistor value should not be less than 50 ohms. This limits the flow of current *from the condenser* to a safe value (1 ampere) when the contacts close and short-circuit the condenser.

The relay should be wiped free from dust and dirt and tested under actual operating conditions to check the effectiveness of the work that has been done.

Electron tubes are the heart of most industrial electronic control equipment, with a type for every class of service. A broad classification of the types in general use include the following:

1. Common radio receiver tubes

2. Phototubes (both high vacuum and gas filled)
3. Cathode-ray tubes
4. Thyratrons
5. Ignitrons
6. Hot-cathode (thermionic) mercury-vapor rectifiers
7. High-power, forced-air draft and water-cooled triode oscillators for induction heating equipment.

As a result of normal use, cathode emission falls off, making eventual replacement necessary. More frequent replacements will have to be made, however, if the tubes are overloaded, operated with excessive filament voltage or outside the intended temperature limits. Today, as never before, these effects should be avoided.

Receiver type tubes require little special attention unless it is to shock mount them to eliminate vibration. Furthermore, they may be checked for emission, leakage and shorted element in any standard commercial tube tester. The other tube types listed cannot be so checked.

Phototubes gradually lose their emission and if a large number of them are used in any one plant, it is advantageous to have some means of checking them. The requirements for this testing equipment include a variable light source, a polarizing voltage and a vacuum tube voltmeter. All these components can be built into a single instrument so that the phototube can be plugged into a socket, the illumination adjusted to the *minimum* amount permitted in actual service and the output of the cell read on a meter in the plate circuit of the v.t.v.m.

Thyratrons are a special type of rectifier tube which operate on the principle that when the plate voltage exceeds a certain critical value, the tube begins to conduct. Once conducting, the grid has lost control until the plate voltage is removed. It is evident, therefore, that here again a special test jig is necessary to check these tubes. The characteristics to be determined are the total space current (emission) and the plate voltage necessary to "fire" the tube with a given value of grid bias. Such a test device must include in its plate circuit sufficient resistance to limit the plate current to a safe value; for when the tube conducts, it becomes a short-circuit.

Cathode-ray tubes, ignitron rectifiers and the high-power oscillator tubes will have to be checked in the equipment in which they are normally used. Tube defects will show up in faulty operation and abnormal readings on the associated indicating meters. Such a test procedure is effective, however, only if the equipment, excluding the tube, is normal.

Before new thermionic (hot-cathode) mercury-vapor tubes can be put in service or stored, they must be pre-heated to vaporize all the mercury thus driving it off of the elements and into the bottom of the tube. No plate voltage is applied during this pre-heating period. The average preheat time is 15 to 20 minutes, although in some cases it may be advisable to preheat for as long as one hour. If the tubes are kept in storage for a period longer than 3 months, they should be pre-heated at regular intervals. Furthermore, they must be stored and operated in a vertical position.

Application of plate voltage to a thermionic mercury-vapor rectifier before it has reached normal operating temperature will damage the tube. Positive ion bombardment of the cathode before the space cloud has a chance to build up, will in time completely destroy the cathode. It is imperative, therefore, that the plate voltage time delay mechanism function properly and be adjusted for the correct delay interval.

A periodic inspection of water cooling systems must be made for the purpose of detecting and removing scale formations. Chemically pure (distilled) water as the cooling agent will retard scale formation. If scale does form, and is promptly detected, it can be removed by flushing the system with a solvent such as "Oakite."

It is also essential that water temperature be held within the specified limits. In general, the temperature of the water leaving the tube should not be more than 10 or 15 degrees higher than the water entering the tube. Over-cooling of mercury-vapor tubes should be avoided.

If fans are used to supplement the normal cooling methods, place them so the air blast will be distributed over the entire tube, not concentrated on one spot.

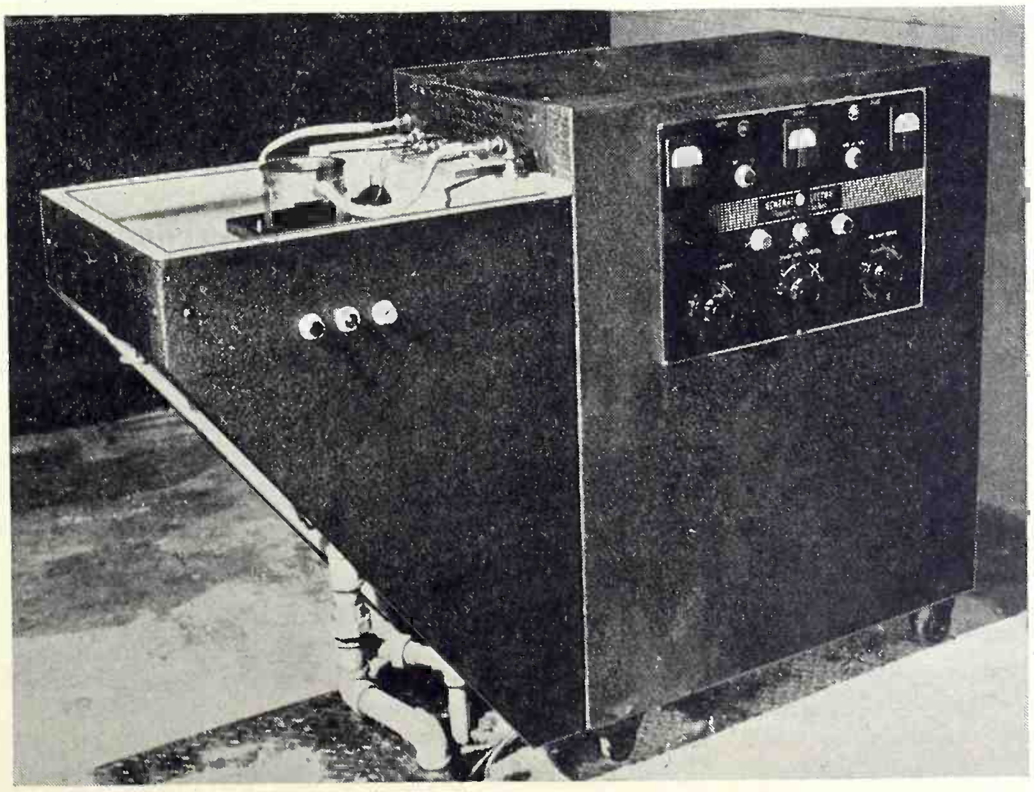
Additional hours of service from tungsten-filament tubes may be gained by operating them at slightly reduced filament voltage. It has been shown that a filament voltage reduction of only 5% *doubles* the life of tubes of this type. Another factor which will give extra tube life is a reduction of filament voltage to 80% of normal during standbys of less than 2 hours rather than cutting it off altogether. Every time a tube is turned on and off, the filament is weakened as it passes through the wide change in temperature.

Accurate records showing the hours of service for each type tube, other than receiving types, are extremely valuable. They not only make it possible to predict with good accuracy the amount of service to be expected from any particular tube type, but form the basis from which a comparison may be made between tubes of different manufacture. The records should show the following: (1) Type number, serial number and manufacturer; (2) date received; (3) date in service; (4) date tested; (5) date out of service and reason. Additional information, useful but not essential, is a list of the normal operating voltages, currents and temperature.

From the foregoing, it can be seen

(*Continued on page* 39)

Fig. 2. An industrial electronic heating unit which requires intelligent maintenance.



ELECTRON OPTICS

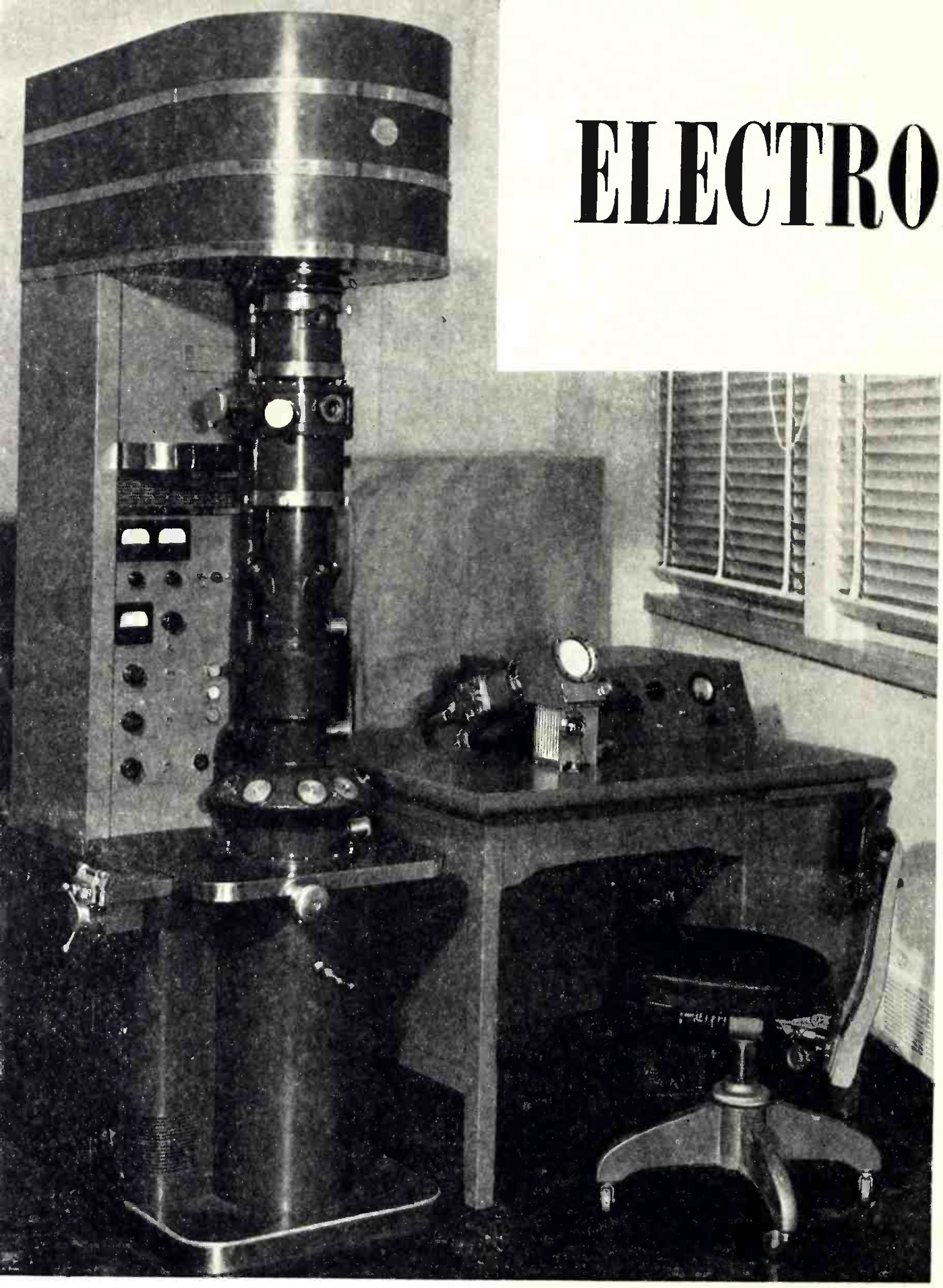


Fig. 1. Commercial electron microscopes which use principles of electron optics.

By D. FIDELMAN

Fundamental mathematical relations of electron optics applied to commercial units using electron focussing.

ALTHOUGH electron optics is a relatively new science, in the twenty years of its existence it has been of great importance in providing the solutions to a number of problems involving the motion of electrons in electric and magnetic fields. Such problems are constantly arising in all fields of radio and electronics—the cathode ray tube, electron multipliers, and vacuum tube design are just a few of those which have been encountered and solved by the application of electron optical principles.

The fundamental theory of electron optics is based on Hamilton's Principle of Least Action which existed more than sixty years before the discovery that the motion of a charged particle in a field of potential, V, becomes identical with the path of a light ray in an optical medium of index of refraction n, when n is set equal to $\sqrt{V}$. For instance, in Fig. 3 it can be seen how an electron beam would be refracted when going from a medium of lower to a medium of higher potential, just as a light ray is refracted when going from a less dense to a more dense medium. The main point of difference between the two cases is that in optics there is almost always a distinct surface at which there is an abrupt change in the index of refraction, while in electron optics the potential changes gradually.

Many years later, in about 1930, it was shown that electrons on passing through an aperture in a charged conductor received rather sharp deflections in the distorted electrostatic field. By properly choosing the geometry of slits and circular holes in charged plates and cylinders, the interaction between the distorted field and the incident electrons simulates the interaction between an optical lens and incident light rays. Fig. 4 shows the focussing action of a typical electron lens compared with that of the equivalent optical lens. Many different types of electron lenses were investigated in the early days of electron optics, but those included in this article are of the more recent design.

In a similar manner magnetic fields can also be made to focus a beam of electrons, but in the case of a magnetic lens the focussing action depends upon the velocity of the incident electrons as well as on the strength of the field, while in the electrostatic case it depends only on the field. A particle with charge, e, moving perpendicularly to a magnetic field, H, with a velocity, v, will have acting on it a force

$$F = Hev$$

at right angles to the plane formed by the direction of motion of the particle and the direction of the magnetic field, and will therefore move in a circle whose radius, R, is determined by the fact that the magnetic force must equal the centrifugal force, or

$$Hev = m v^2/R$$

If an electron is moving in a uniform magnetic field at an oblique angle to the direction of the field, the component of its velocity perpendicular to the field causes a circular motion while the parallel component is unaffected, and the resultant path is a spiral—all electrons having the same velocity parallel to the field returning to the axis at the same point, regardless of the value of the perpendicular component.

This is, however, different from the focussing action of the short magnetic field. The electron, upon entering a short non-uniform magnetic field, is first deflected sidewise by the force due to the radial component of the magnetic field, and then moves in a helical path with slightly varying radius, the inward motion being caused by the force due to the axial magnetic field and the lateral velocity. This lateral velocity decreases when the electron leaves the coil, because then the radial component is reversed and the axial speed of the electron has been maintained. The rotation has ceased when the electron has completely left the magnetic field and therefore the electron passes through the axis, for if it maintained its rotatory motion after leaving the coil it would pass the axis without intersecting it. The focal length of such a magnetic field used as an electron lens is given by the relation:

$$f = \frac{4\,m^2\,v^2}{e^2 \int_{-\infty}^{\infty} H_z^2\,dz}$$

In general, electromagnets are preferred to permanent magnets in electron optical practice because the focal length of the lens can be changed merely by varying the current through the coils.

The action of both the electrostatic and magnetic electron lenses can be expressed in a single set of equations which are derived from Maxwell's equations of electromagnetic theory. By considering the motion of an electron in an electromagnetic field which is symmetrical about a fixed axis, as all spherical lenses are, the equation of motion of the electron is found to be:

$$\frac{d^2z}{dt^2} = \frac{e}{m}\frac{\partial}{\partial z}\left(V - \frac{e}{2m}A^2\right)$$

where:
- r = the distance of the particle from the axis
- V = the electric potential
- A = the magnetic vector potential of the field
- z = the distance along the axis
- e = the charge of the electron
- m = the mass of the electron

In the theory of light it is customary to consider only the so-called paraxial rays, that is, those which do not move at too great an angle to the axis, in determining the image-forming properties of a lens system. Therefore, following this same procedure for the electron lens, the path of a paraxial beam of electrons has been found to be given by the differential equation:

$$\frac{d^2r}{dt^2} + \frac{V_o'}{2V_o}\frac{dr}{dt} + \frac{1}{4V_o}\left(V_o'' - \frac{e}{2m}H_o^2\right)r = 0$$

where V_0 and H_0 are the electric and magnetic field distribution along the axis of the system, and the primes represent their successive derivatives with respect to z.

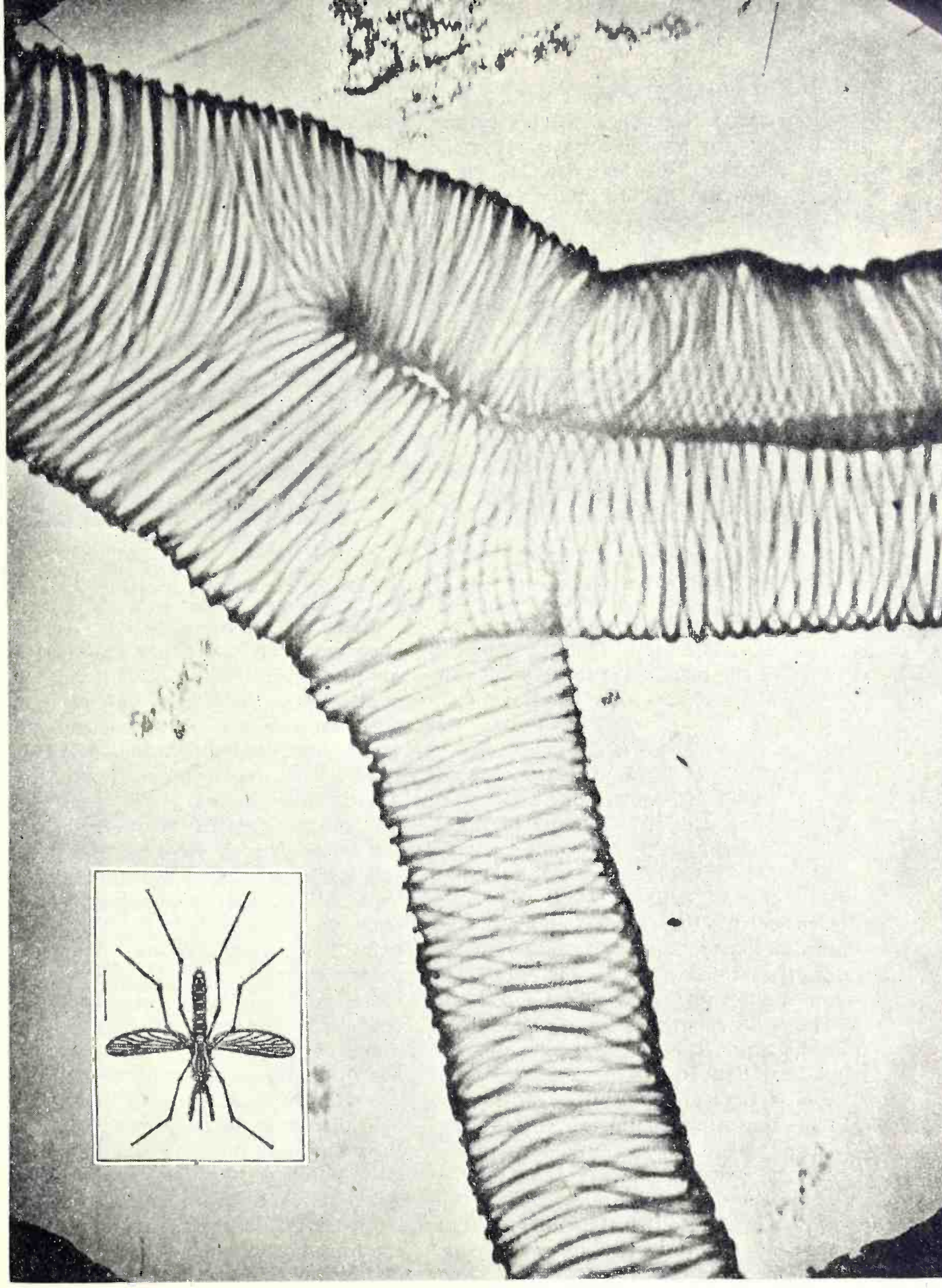


Fig. 2. Windpipe of a mosquito larva as seen under the electron microscope.

This is the fundamental equation of electron optics, and from it the characteristics of any symmetrical electric or magnetic electron lens can be derived. In the case of the purely electrostatic lens $H = O$, while in the case of the magnetic lens $V' = V'' = O$ and $V =$ const. representing the accelerating voltage which determines the velocity of the electrons.

Once it had been shown that it was possible to construct lenses capable of focussing beams of electrons and forming electron images, these lenses were soon combined to form microscopes in which electrons were used to form a magnified image of an object just as light rays do in the ordinary optical microscope. Such a procedure, although of great scientific interest, would be of no great practical value were it not for two very important facts:

1. The smallest sized object that can be seen through a microscope is determined by the resolving power of the microscope, that is, the closest distance between two points at which they can still be seen as distinct points instead of a single blur. The most important factor limiting the resolving power of the optical microscope is the wave-length of the light by which the object is viewed. The limit of resolution of the most powerful optical microscope, using ultra-violet light and observing the image photographically, is approximately 1000 Angstroms.
2. It has been demonstrated by phy-

sicists that all particles exhibit certain wave-like properties, the electron, for instance, has associated with it a wave-length which is much smaller than that of visible light. The wave-length of the electron is readily calculable, and obeys the relation:

$$\lambda = \sqrt{\frac{150}{V}}\ A^\circ$$

where V is the voltage through which the electron is accelerated. Thus, the wave-length of a 50-kilovolt electron would be 0.055 A°, or 10^{-5} times smaller than that of light.

Considering these two factors, it immediately becomes apparent why the electron microscope has become such an important research instrument. The wave-length of the electron is so small that it is of minor importance compared to the other factors which limit the resolving power. With electron lenses in their present state of development the best theoretical resolving power of the electron microscope should be of the order of 1 A°, which is about 1000 times better than that of the best optical microscope, but in actual practice it has been found that the best resolution that could possibly be expected would be about 10 A°. At the present time this limit has not yet been attained, but electron microscopes have been built with resolutions of 20 A°.

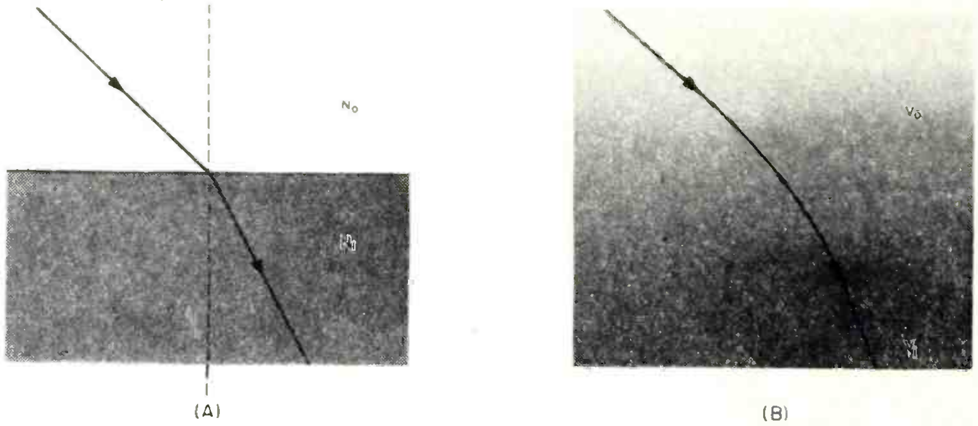
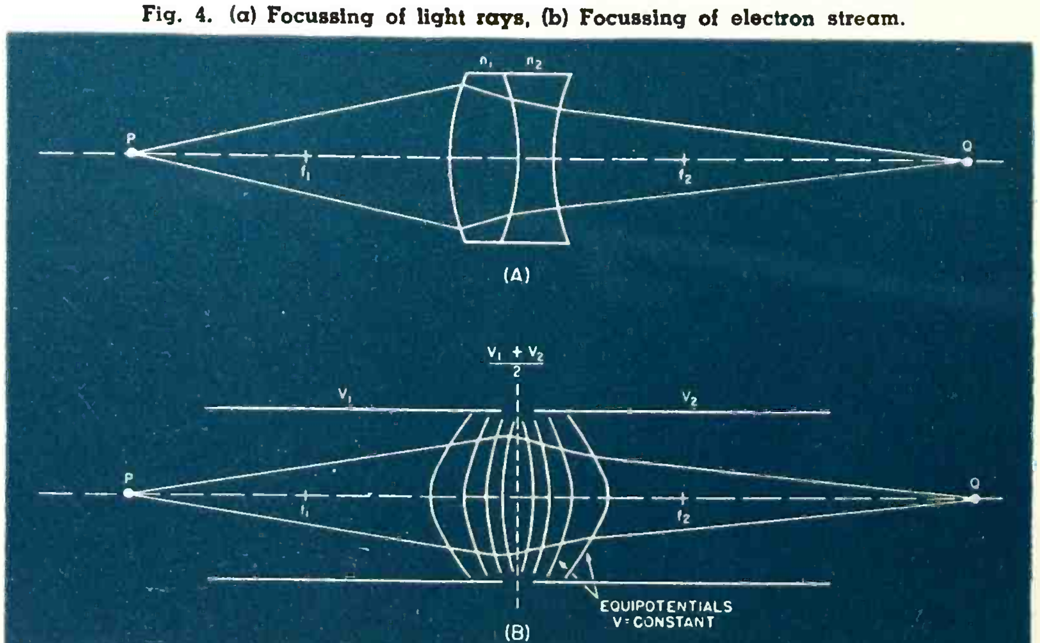


Fig. 3. (a) Refraction of light ray, (b) Refraction of electron stream.

Electron microscopes can be constructed to utilize either electrostatic or magnetic lenses. Until very recently, however, the emphasis has been on the use of magnetic lenses when high magnifications were desired. The electrons originate in a cold-cathode discharge tube and are accelerated through a small hole in the anode, which is at ground potential while the cathode is negative at a potential which accelerates the electrons to a final velocity of anywhere from 10 to 100 kilovolts. The beam passes through the anode and is focussed on the object by the condenser lens. The image is formed on the fluorescent screen by the two lenses, the first and second objectives, which are usually constructed with the iron pole pieces of the coils projecting into the vacuum in order to make the magnetic fields as strong as possible. The image on the fluorescent screen can be observed or photographed through the observation window, or can be photographed directly from within the vacuum by means of a special type of camera which provides for several separate exposures without disturbing the vacuum and allows visual focussing of the image before each exposure. Focal lengths of 0.5 cm. can be obtained with magnetic lenses, so that in a two-stage instrument with a distance of 60 cm. between the object and the fluorescent screen magnifications of over 12,000 diameters can be obtained, and the image can be further magnified optically or photographically to about 100,000 diameters. Magnetic electron microscopes are now being manufactured on a commercial scale, and photographs of two instruments of this type are reproduced in Fig. 1.

Fig. 4. (a) Focussing of light rays, (b) Focussing of electron stream.



A similar system can be constructed using electrostatic lenses exclusively instead of magnetic lenses. One of the main advantages of such a system is the elimination of the closely regulated power supply, which in the magnetic instrument must remain within tolerances of the order of 0.01 per cent. However, extreme care must be taken to prevent external magnetic fields from affecting the image, and to accomplish this the entire instrument must be shielded by mu-metal. The most convenient lenses to use are of the unipotential type, with the middle electrode of each lens at cathode potential to eliminate the need for more than one power supply. The mechanism of image formation is exactly the same as in the magnetic electron microscope, and any number of stages of magnification may be used. An electrostatic electron microscope using three stages of magnification and having a resolving power of 200 Angstroms is now being manufactured commercially.

Other types of electron microscopes have also been constructed for various purposes—such as for the observation of thermionic emission of electrons from hot cathodes, or for the examination of metallic surfaces by self-illumination, but the high-voltage transmission type compound microscope described above is by far the most important type of electron microscope that has yet been built. Because of its high resolving power and magnification, which is so much greater than that of any light microscope, it has made objects visible that could never be seen by any other means, and has found innumerable applications in such fields as medicine, biology, colloidal chemistry, and metallurgy. An indication of the potentialities of the electron microscope can be obtained from the electron micrographs reproduced in Figs. 2, 5, 6 and 7. Fig. 2 shows the windpipe of a mosquito larva—the smallest structural details visible are considerably less than one-half millionth of an inch in size. Figs. 6 and 7 show two micrographs of the tobacco mosaic virus, and in Fig. 5 is reproduced the first photograph ever taken of the influenza virus.

Many of the electronic instruments in widespread use have been developed by the direct application of electron optical principles. Probably the best-known of these is the electron gun, which has made possible the development of the cathode ray tube, the Kinescope, and the Iconoscope. Reference to Fig. 8 will make clear the electron optical behavior of the electron gun. The electrons are emitted by the cathode and focussed into a small spot, or "cross-over," by the immersion lens formed by the grid and the first anode; the grid, in addition, serves to control the electron density of the beam, and hence the brightness of the spot. The second lens, formed by the first and second anodes, focuses the images of the cross-over to form the bright spot on a fluorescent screen.

The cathode ray tube and the Kinescope consist essentially of an electron gun followed by horizontal and vertical deflecting fields by means of which the pattern is formed on the fluorescent screen. These deflecting fields may be either electrostatic, magnetic, or a combination of both. In the Iconoscope a photosensitive mosaic takes the place of the fluorescent screen, and the electron beam is scanned across the mosaic by the deflecting fields. Although the three tubes are used for different purposes, their electron optical systems are identical.

A more striking example, from the electron optical viewpoint, is the "image dissector," a television pickup used mainly in the televising of motion picture films. The scene which is to be transmitted is focussed optically onto a translucent cathode which is coated with photosensitive material so that from each spot on the cathode surface is emitted a quantity of electrons proportional to the amount of light falling on the surface at that point. These electrons are attracted by the anode, which is at a positive potential with respect to the cathode, and by means of the magnetic lens the electron image is focussed on the anode so that all the electrons emitted from a single point on the cathode converge to a single point in the anode plane. The anode contains an aperture behind which a collector electrode is placed in such a manner that all the electrons which happen to be focussed on the aperture pass through the anode and strike the collector. Thus a current is produced through the load resistor which is proportional to the number of electrons focussed on the aperture, and therefore proportional to the intensity of the light at

(*Continued on page* 44)

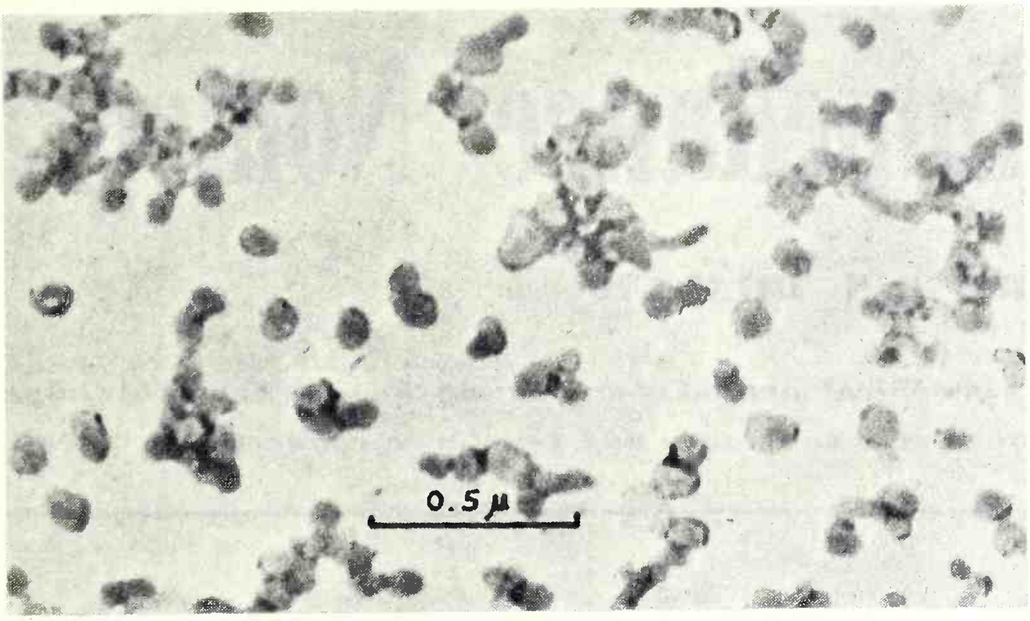


Fig. 5. First photograph of the influenza virus with scale of one inch to one-half micron.

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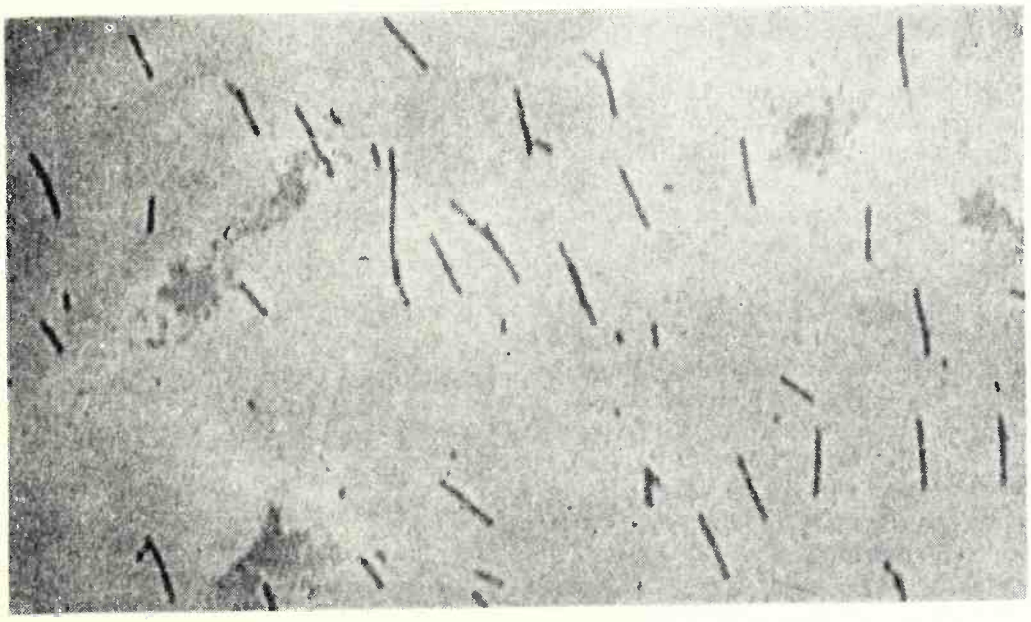

Fig. 6. Photograph of tobacco mosaic virus obtained with an electron microscope. The slide was placed in an evacuated chamber of the microscope and pierced by high velocity electrons.

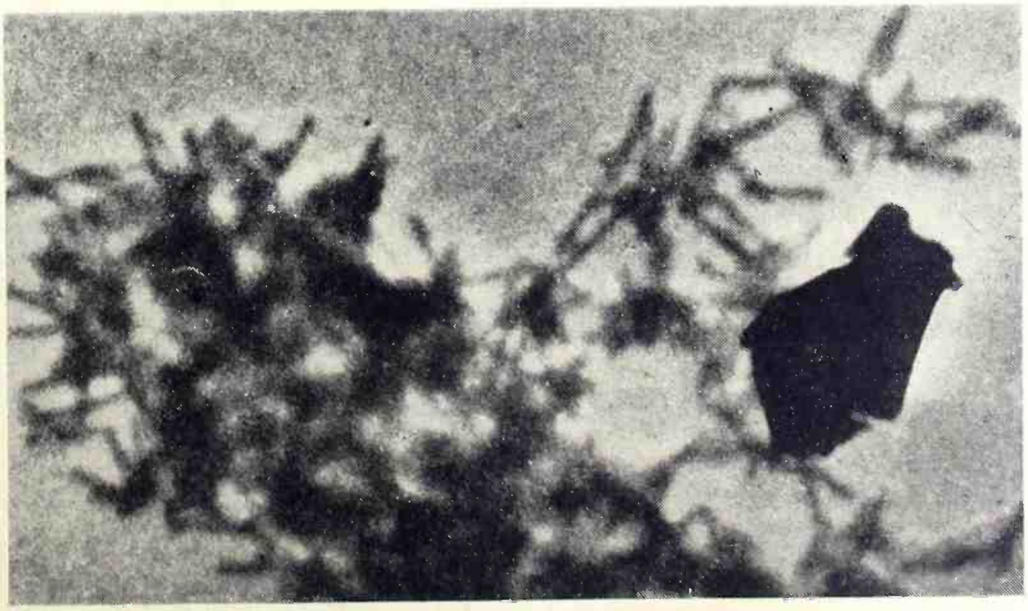

Fig. 7. Highly magnified electron photomicrograph of tobacco virus attacked by antibodies.

Impedance Nomogram

By B. S. BRANCH
Engineer

A graphical method of evaluating the series complex impedance of a resistance and reactance connected in parallel.

THE problem of calculating the equivalent impedance of a resistance and a reactance in parallel is frequently encountered in communication network design. The use of a polyphase or vector slide rule has simplified to a minor extent the necessary calculations required to give the final numerical answer. These calculations, involving complex numbers, must give two quantities in order to specify the answer. The magnitude of the impedance as well as the angle of the impedance must be obtained to determine completely the impedance of the parallel combination. The accompanying chart on the next page provides a means of obtaining the magnitude and phase angle of the parallel circuit. The theory involved in this calculation, using complex numbers, is outlined below.

First consider the shunt reactance to be an inductive reactance. The expression for the impedance will be given by Z as:

$$\frac{1}{Z} = \frac{1}{R} + \frac{1}{jX} \quad \text{(1)}$$

Then solving for Z

$$Z = \frac{jRX}{R + jX} \quad \text{(2)}$$

and rationalizing the fraction gives:

$$Z = \frac{RX^2}{R^2 + X^2} + j\frac{R^2X}{R^2 + X^2} \quad \text{(3)}$$

Then:

$$Z = |Z| \underline{/+\theta} \quad \text{(4)}$$

Where:

$$|Z| = \frac{R}{\sqrt{1 + \left(\frac{R}{X}\right)^2}} \quad \text{(5)}$$

and

$$\theta = \tan^{-1}\left(\frac{R}{X}\right) \quad \text{(6)}$$

Now consider the shunt reactance to be a capacitive reactance and the expression for the impedance will be given by:

$$\frac{1}{Z} = \frac{1}{R} + \frac{1}{-jX} \quad \text{(7)}$$

By solving for Z:

$$Z = \frac{-jRX}{R - jX} \quad \text{(8)}$$

and rationalizing the fraction, gives Z in the complex form:

$$Z = \frac{RX^2}{R^2 + X^2} - \frac{jR^2X}{R^2 + X^2} \quad \text{(9)}$$

Then

$$Z = |Z| \underline{/-\theta} \quad \text{(10)}$$

Where:

$$|Z| = \frac{R}{\sqrt{1 + \left(\frac{R^2}{X}\right)}} \quad \text{(11)}$$

and

$$\theta = \tan^{-1}\left(\frac{R}{X}\right) \quad \text{(12)}$$

This analysis shows that the angle of the impedance is positive when the shunting reactance is inductive and negative when the shunting reactance is capacitive.

The theory of constructing the three parallel line nomogram is based upon the procedure outlined on page 12 of the December issue of Radionics in an article by S. Klapman entitled "Nomogram Construction." From this article, "The general construction of a nomogram, as presented is based upon the fundamental necessary and sufficient condition for three points (x_1, y_1) (x_2, y_2) and (x_3, y_3) to lie on a straight line as shown by the determinant:"

$$\begin{vmatrix} x_1 & y_1 & 1 \\ x_2 & y_2 & 1 \\ x_3 & y_3 & 1 \end{vmatrix} = 0 \quad \text{(13)}$$

If the scales are vertical and parallel, let, $x_1 = -1$, $x_2 = 0$ and $x_3 = +1$ and y_1 y_2, and y_3 will become functions of the variables. This is expressed algebraically as:

$$\left.\begin{aligned} y_1 &= f_1(u) \\ y_2 &= -\tfrac{1}{2} f_2(v) \\ y_3 &= f_3(w) \end{aligned}\right\} \quad \text{(14)}$$

The determinant becomes:

$$\begin{vmatrix} -1 & y_1 & 1 \\ 0 & y_2 & 1 \\ 1 & y_3 & 1 \end{vmatrix} = 0 \quad \text{(15)}$$

or:

$$y_1 - 2y_2 + y_3 = 0 \quad \text{(16)}$$

To obtain a relation between X, R, and R/X in the determinantal form, consider:

$$\cot\text{an}\,\theta = \frac{R}{X} = K \quad \text{(17)}$$

or:

$$\frac{R}{X} = K \quad \text{(18)}$$

Then:

$$-\log R + \log X + \log K = 0$$

or:

$$\begin{vmatrix} -1 & -\log R & 1 \\ 0 & -\tfrac{1}{2}\log X & 1 \\ 1 & \log K & 1 \end{vmatrix} \quad \text{(19)}$$

The determinant indicates that the first vertical line will have a scale marked proportionally to $-\log R$ and the second line will have a scale of $-\frac{1}{2}\log X$ while the third will be scaled proportionally to log K. Notice that the scales of the first two lines are in the inverse order, that is, the numbers decrease along the upward direction and the scale along the third lines increases in the upward direction. Also, the scales of R and K are geometrically twice as long as that of X. By connecting any three points on the three parallel lines with a straightedge, the three points are related in accordance with equation (17). Thus, the nomogram must be constructed as indicated by (19).

With the aid of the accompanying nomogram, equations (5), (6), (11) and (12) are solved graphically.

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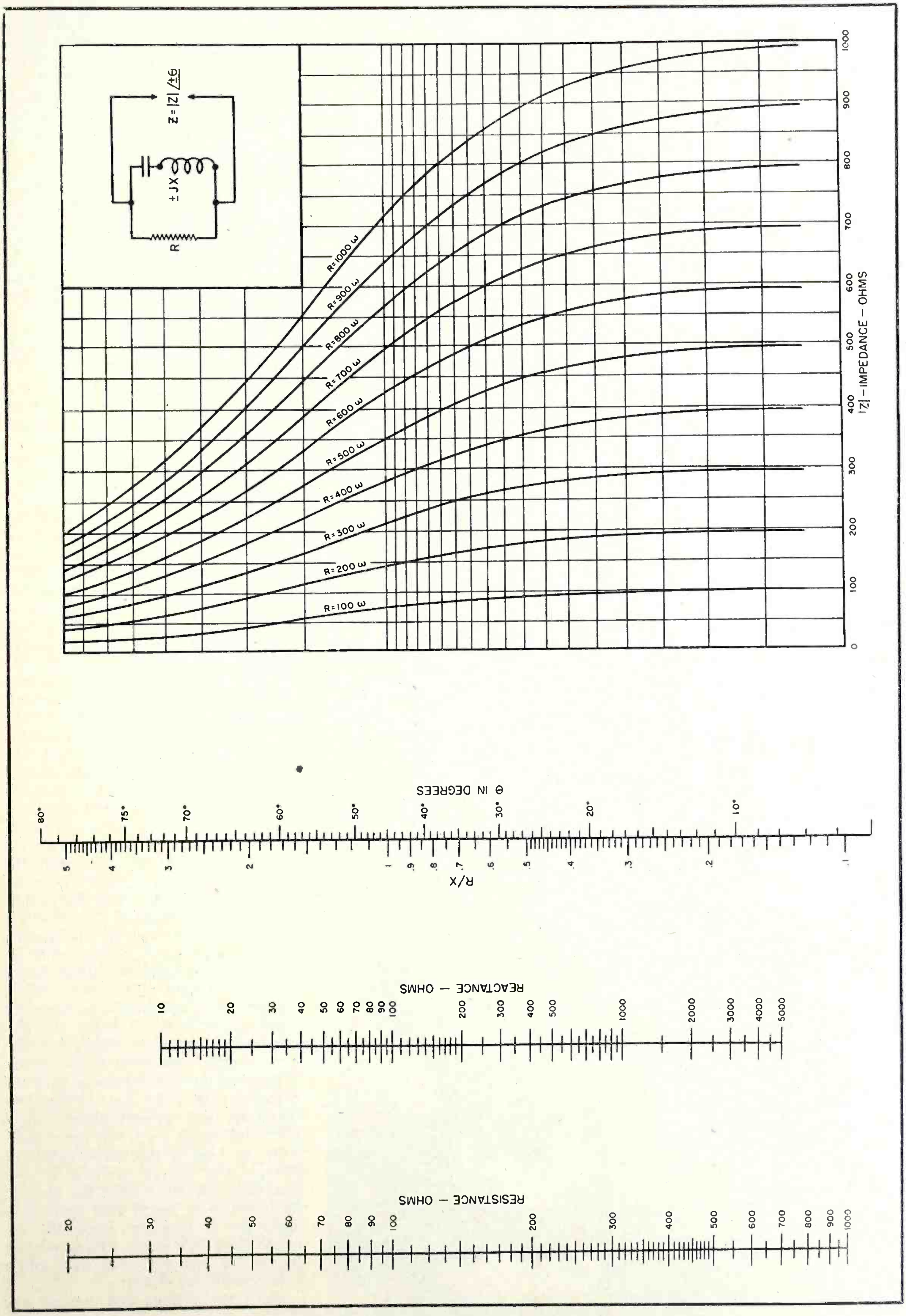


CHART FOR OBTAINING IMPEDANCE OF RESISTANCE AND REACTANCE IN PARALLEL

R-F FEEDERS

By R. A. WHITEMAN
Technical Editor, RADIO NEWS

An analysis of the function and operation of transmission lines at high frequencies with matching networks.

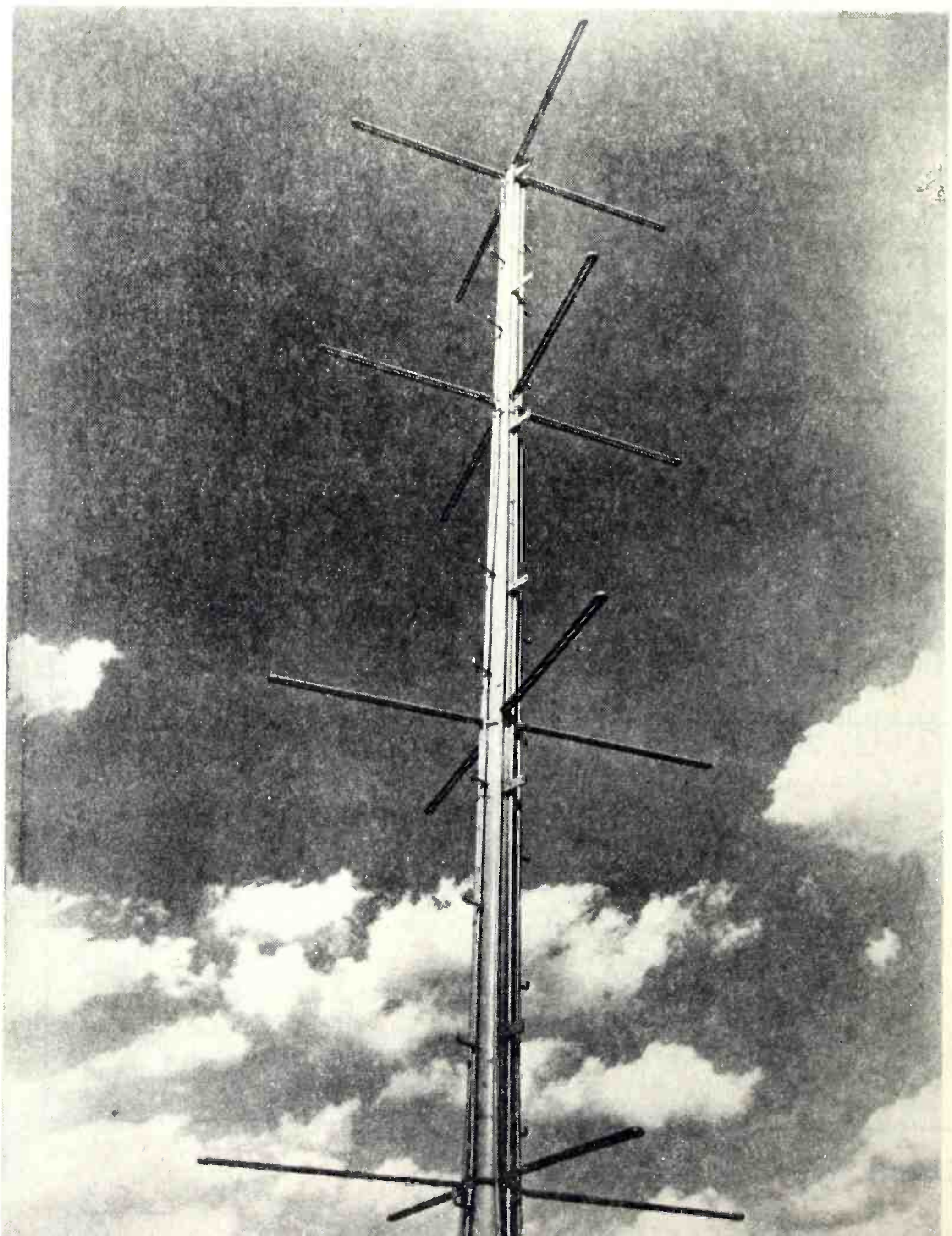
ONE of the most important engineering problems in the design of radio transmitters is that of transmitting, in an efficient manner, the r-f power output of a transmitter to the antenna.

The general layout of the equipment, which solves the problem, consists of a high-frequency feeder terminated at each end by appropriate matching networks. This article presents a practical analysis for the design of r-f feeders and associated matching networks.

In order to visualize the fundamental operation of r-f feeders, consider the simple arrangement of two parallel wires having a resistance per unit of length which is negligible as compared to the corresponding inductive reactance; likewise, a negligible leakage as compared with the corresponding capacitive reactance. This assumption holds true in the average r-f feeder and the conclusions obtained in an analysis using this assumption will be sufficiently accurate for practical design procedures. It is possible to systematize this analysis by considering five special conditions of operation, namely:

1. A feeder, an odd number of quarter-wave lengths long, with its receiving end open-circuited.
2. A feeder, an odd number of quarter-wave lengths long, with its receiving end short-circuited.
3. A feeder, an even number of quarter-wave lengths long, with its receiving end open-circuited.
4. A feeder, an even number of quarter-wave lengths long, with its receiving end short-circuited.
5. A feeder of any length terminated by a load impedance which absorbs all energy transmitted to the receiving end.

High frequency coaxial feeders for an antenna array.



In the analysis which follows, in all of the diagrams of networks and feeders, the input or sending end shall be considered as located at the left of the drawings, while the output or receiving end shall be located at the right.

Referring to Fig. 2A, consider the condition outlined in point 1, above. In this diagram the feeder is assumed to be three-fourths of a wave length long which will serve to illustrate the conditions existing when the geometrical length is any odd number of quarter-wave lengths. By applying the Law of the Conservation of Energy, it is possible to show, without the aid of mathematical formulas, that the voltage and current waves are 90 degrees out of phase and the power factor of the feeder is zero. It is also possible to arrive at these conclusions by realizing that the energy traveling down the line or feeder cannot be dissipated at the open-circuited receiving end but must remain within the system or be radiated. Of course, a small portion of the energy is radiated from the open-circuited receiving end, as well as, from the entire feeder, but this radiation is extremely small compared with the total energy assumed to be in the line. Since the energy traveling down the line must remain within the system, it is reflected from the receiving end into the line. This means that the reflected energy at the receiving end must travel back to the sending end, thus periodically aiding and interfering with the incident energy along the entire length of the line. When this action is interpreted in terms of electric and magnetic fields, the picture of the stationary waves becomes quite simple. Since the receiving end is open-circuited, it is obvious that the current at this point must be zero and therefore, the resultant magnetic field will likewise be zero. In accordance with the Law of the Conservation of Energy, the energy arriving at the receiving end, must be in the electric field and as a result will produce a difference of potential across the receiving end terminals. The power delivered to the receiving end under these conditions is zero.

Since the voltage and current are

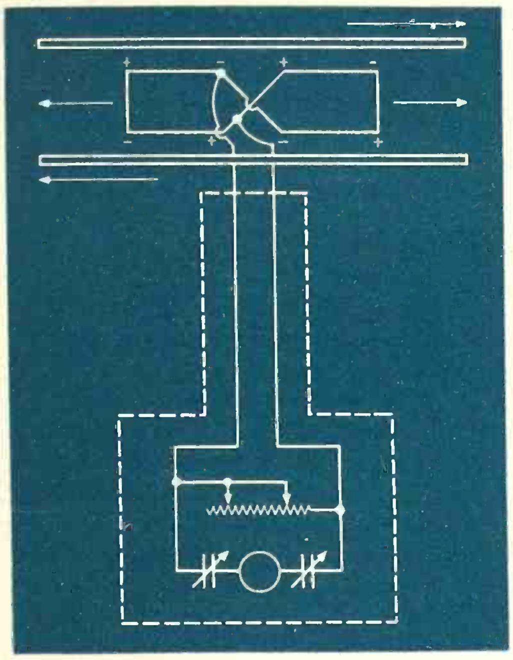


Fig. 1. Tuned r-f meter for feeder measurement.

sinusoidal functions, they must be 90 degrees out of phase. If the current is considered to be a sine-wave function and zero at the receiving end, the voltage must be a cosine-wave and a maximum at the same point. This is illustrated graphically in Fig. 2, where the solid line represents the current wave and the dashed line represents the voltage wave. These curves were drawn using the receiving end of the feeder as the starting point for laying out the corresponding sine and cosine waves. Since this feeder is an odd number of quarter-wave lengths long, it is evident that the sending-end current will be a maximum and the sending-end voltage a minimum, or zero. The input impedance of this feeder, in accordance with Ohm's Law, is given by:

$$Z = \frac{E}{I} \quad \text{..........................(1)}$$

Where:
$E = 0$ voltage
$I =$ Maximum current

This means that the input impedance will be zero and the feeder will act similar to a series resonant circuit. From this analysis, the following generalization may be made.

a. An open circuited r-f feeder, having a geometrical length equal to an odd number of quarter-wave lengths, will have a zero input impedance and will resemble a series resonant circuit.

A similar analysis may now be applied to condition 2 outlined above, where the feeder is short circuited. This arrangement is shown in Fig. 2B and by considering the difference of potential across the short-circuited terminals as equal to zero and the power factor also equal to zero, the current must be a maximum. By drawing the corresponding sine and cosine waves, the sending-end voltage must be a maximum and the sending-end current a minimum, or zero. The corresponding curves of voltage and current are also shown in Fig. 2B. The input impedance in this case, according to Ohm's Law, becomes infinity. This circuit, therefore, performs in a manner similar to a parallel resonant circuit, and as a result the second general statement may be made.

b. A short-circuited feeder having a geometrical length equal to an odd number of quarter-wave lengths has an infinite input impedance and resembles a parallel resonant circuit.

This same analysis may now be applied to high-frequency feeders that are an even number of quarter-wave lengths long, as shown in Figs. 2C and 2D. Representing the typical feeder as being one wave length long and open-circuited at the receiving end, the current and voltage will be 90 degrees out of phase as shown in Fig. 2C. The current at the receiving end must be zero and the voltage a maximum, which means that the current and voltage at the sending end, must be of a similar magnitude. The input impedance of this feeder, in accordance with Ohm's Law, is infinite and the line is similar to a parallel resonant circuit. This case may be summarized by a third general statement.

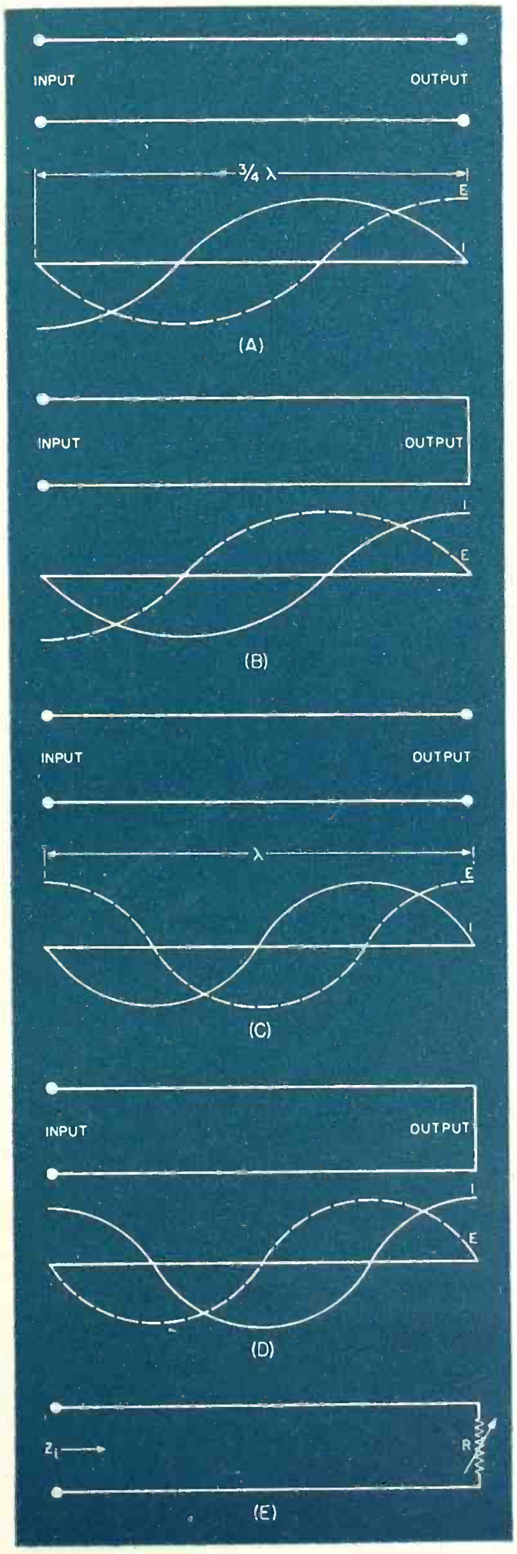
c. An open-circuited feeder having a geometrical length equal to an even number of quarter-wave lengths will have an input impedance of infinity and will resemble a parallel resonant circuit.

By referring to Fig. 2D, it is evident that the voltage must be zero at the short-circuited receiving end with the current a maximum value and the power factor equal to zero. By drawing the corresponding voltage and current waves as cosine and sine functions, the sending-end voltage will be found to be zero and the current will be a maximum. The input impedance at the sending end of this feeder must be zero and the line will act in a manner similar to a series resonant circuit. This leads to the fourth general statement.

d. A short-circuited feeder having a geometrical length equal to an even number of quarter-wave lengths will have an input impedance equal to zero and will resemble a series resonant circuit.

From the four preceding conditions, it is important to note that the input impedance changes from zero to infinity as the receiving end impedance is changed from infinity to zero. It is evident that if a resistive load is connected across the receiving end terminals of a feeder of any length, it is possible to adjust the magnitude of this resistance so that the input impedance to the feeder is numerically equal to the load resistance. Under these conditions the power factor of the line and load is equal to unity and the voltage and current throughout the line are in phase. All of the energy transmitted along the feeder is, therefore, absorbed by the load and none is reflected. This arrangement provides a special condition and this input impedance of the feeder is defined as the characteristic impedance of the line. If the load resistance is slightly different from the value defined as the characteristic impedance,

Fig. 2. Voltage and current curves on r-f feeders. (A) Open-circuited ¾ λ line; (B) Short-circuited ¾ λ line; (C) Open-circuited 1 λ line; (D) Short-circuited λ line; (E) Line with a resistive load.



all of the energy supplied to the line will not be absorbed by the load, but a portion of the incident energy will be reflected. If the line is being used

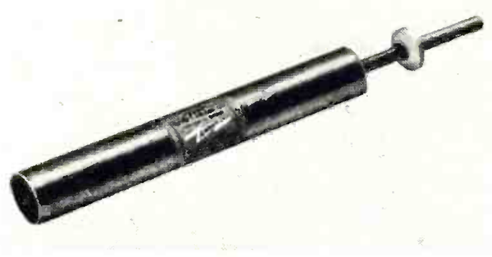


Fig. 3. Coaxial line with insulator.

for the purpose of supplying r-f power, the ideal conditions would be that of total absorption and zero reflection at the receiving end. In practice, this is not physically possible, but a reflection of approximately 5% of the incident voltage is considered to be satisfactory. It appears from this analysis that there are a number of different applications of r-f feeders other than that of transmitting maximum r-f power. The properties of resonant circuits which have been mentioned are used in replacing coil and condenser tank circuits with short-circuited lines an odd number of quarter-wave lengths long. This application is a special case of the more general classification listed as #5 in this article.

The foregoing qualitative discussion may be verified analytically by using the impedance formula for the dissipationless r-f feeder. The formula is expressed as:

$$Z_i = Z_o \frac{Z_r \cos \beta l + j\, Z_o \sin \beta l}{Z_o \cos \beta l + j\, Z_r \sin \beta l} \quad \text{......(2)}$$

Where:

Z_o = characteristic impedance
Z_r = receiving-end impedance
β = phase constant
l = length of line
$j = \sqrt{-1}$

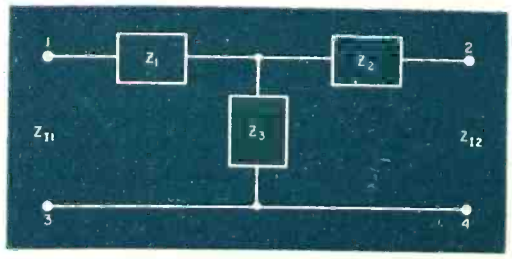
As an illustrative example, apply equation (2) to condition #1 above. The values of the quantities in the formula become:

$Z_r = \infty$

$\beta l = \frac{\pi}{4}$ · an odd number.

Since Z_r appears in the numerator of (2), divide the numerator and denominator by Z_r which gives the relation:

Fig. 4. Basic T matching network.



$$Z_i = Z_o \frac{\cos \beta l + j\frac{Z_o}{Z_r} \sin \beta l}{\frac{Z_o}{Z_r} \cos \beta l + j \sin \beta l} \quad \text{..........(3)}$$

and then:

$$Z_i = Z_o \frac{0 + j0}{0 + j1} \quad \text{..................(4)}$$

$$Z_i = 0$$

This justifies statement *a* analytically and a similar procedure may be used to justify the remaining statements.

If the short-circuited or open-circuited lines are not an exact multiple of a quarter-wave length, the input impedance will be either inductive or capacitive. Again with (2), consider the length of the line slightly more than a quarter of a wavelength with the receiving-end open-circuited. The quantities in the formula become:

$Z_r = \infty$

$\beta l = \frac{\pi}{4} +$

and the input impedance from (3) is:

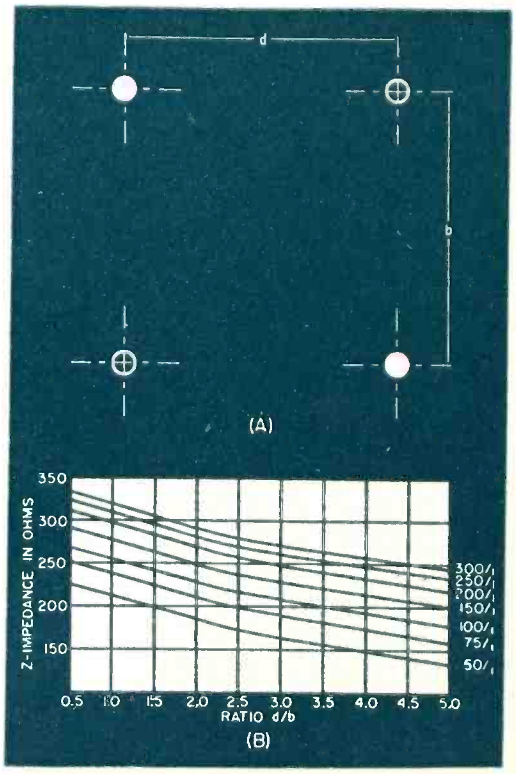


Fig. 5. (A) Geometrical arrangement of a four wire feeder; (B) Impedance in ohms of four wire line.

$$Z_i = Z_o \frac{-A + j0}{0 + jB} \quad \text{................(5)}$$

or:

$$Z_i = j \frac{AZ_o}{B} \quad \text{......................(6)}$$

Equation (6) shows that the input impedance is an inductive reactance and is quantitatively related to the geometrical length. If, however, the length were slightly less than a quarter-wave the input impedance would be:

$$Z_i = Z_o \frac{A + j0}{0 + jB} \quad \text{....................(7)}$$

or:

$$Z_i = -j \frac{AZ_o}{B} \quad \text{......................(8)}$$

Equation (8) shows that the input impedance would be a capacitive reactance and equal in magnitude to that given by formula (6).

The practical application of using r-f feeders as inductances or capacitances will be included in the latter portions of this article.

The use of the high-frequency feeder as a means of transferring r-f power to a load, such as an antenna, has been outlined in condition #5 above. To determine the percentage of the incident voltage or current which is reflected at a slightly mismatched receiving end, a method of measuring the relative magnitude of the maximum and minimum current is necessary. The ratio of these two numerical quantities is defined as the standing-wave ratio and is generally expressed as a number greater than unity. If this ratio is represented as *S*, the coefficient of reflection for the current or voltage wave is

$$k = \frac{S - 1}{S + 1} \quad \text{......................(9)}$$

and that for energy is:

$$k^2 = \left(\frac{S - 1}{S + 1}\right)^2 \quad \text{..................(10)}$$

A very accurate procedure for measuring *S* includes an arrangement such as that shown in Fig. 1, which is designed to absorb r-f energy based upon electromagnetic induction. This is accomplished by using two pickup coils connected in parallel, the output of which is connected through a screened line to a thermogalvanometer. The scale reading of the galvanometer will be proportional to the inducing magnetic field and therefore to the current in the r-f feeder. If some reflection exists at the receiving end, there will be a traveling wave as well as a stationary wave and *S* will be greater than unity. If, however, there is no reflection, as for ideal conditions, the traveling wave will exist alone and *S* will equal unity. By adjusting the matching networks at the terminations of the line, the numerical value of *S* may be reduced to a satisfactory minimum of 1.05.

Of the various possible types of feeders that may be used the coaxial line, the two-wire and four-wire line are the most practical. Coaxial lines are constructed in the rigid as well as the semi-flexible form for transmitting purposes and have the chief advantage of low attenuation and negligible radiation loss. The internal construction of the coaxial line is shown in Fig. 6 and the characteristic impedance is:

$$Z_o = 138 \frac{\log_{10} \frac{a}{b}}{\sqrt{1 + \frac{(\epsilon - 1)\, t}{d}}} \quad \ldots\ldots (11)$$

Where:

- a = radius of outer conductor
- b = radius of inner conductor
- ϵ = dielectric constant of insulating material
- t = thickness of dielectric insulator
- d = distance between dielectric insulators

When constructing or purchasing this type of line, it is important to realize that the maximum potential gradient between the inner conductor and the outer conductor occurs at the surface of the inner conductor. This is due to the air layer between the insulators and the outer conductor, since the air layer has a lower dielectric constant than the insulation material. This means that the insulators must fit very tightly against the inner conductor in order to minimize the potential gradient at the inner conductor surface.

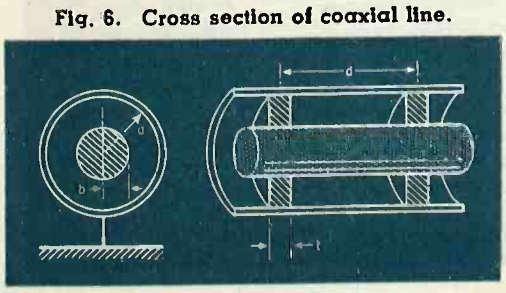
The two-wire line, as an r-f feeder, is extremely useful but has a few undesirable characteristics which must be avoided when possible. The relatively high characteristic impedance for this type of line is illustrated in Fig. 7 which necessitates proper matching with the load impedance.

The two-wire line should be carefully checked for balanced r-f currents in order to reduce radiation and losses. Frequently there are stationary waves partially displaced along each line due to unbalanced reflection at the supporting insulators and not due to a mismatched load.

A more practical layout for higher powers is that of a four-wire r-f feeder with the conductors arranged to form a rectangle. The conductors, located at the ends of the diagonal, are connected together thereby giving a lower characteristic impedance and a lower line voltage for a given power.

Smaller sized wires may be used in order to handle the r-f power. This is exemplified by a four-wire feeder using No. 6 gauge wire to carry 100 kw. Fig. 5 provides graphs for evaluating the characteristic impedance of a four-

Fig. 6. Cross section of coaxial line.



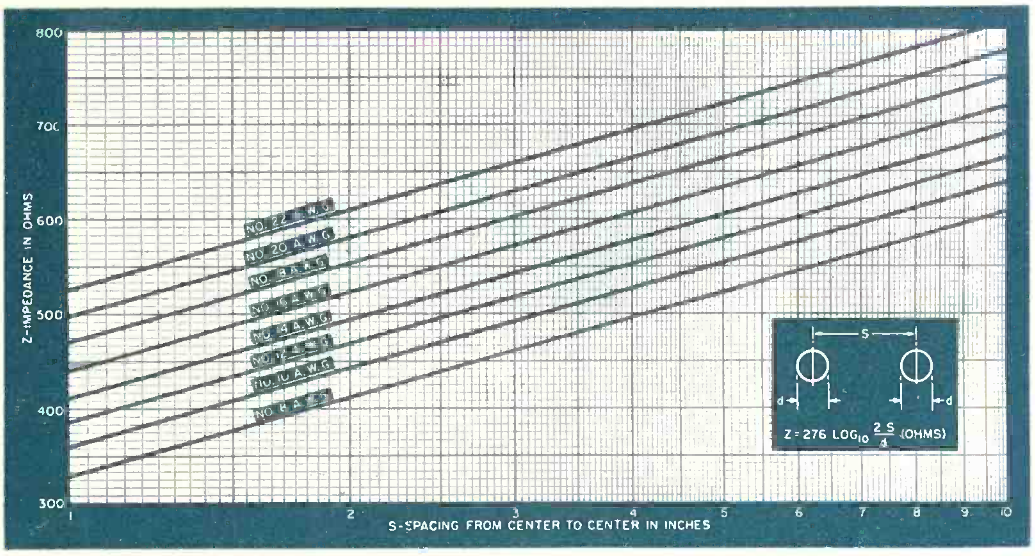


Fig. 7. Characteristic impedance of two-wire line as a function of spacing.

wire line for different spacings.

In order to match the impedance of the antenna to the line, several types of networks are available. Realizing that these circuits must be four-terminal networks with an input and an output, one basic requirement must be satisfied if lumped parameters are used. Since the r-f power at one frequency or a narrow band of frequencies is transferred to the antenna for radiation purposes, all harmonics of this frequency should be suppressed. The matching network under these conditions should contain a shunt capacitive reactance to by-pass the harmonic frequencies.

The three-element coupling or matching network is one of the most valuable types of network used. The elements may be arranged for a Π or a T network with three variables controlling the three quantities, input resistance and reactance and the phase shift through the network. The phase shift is important for maintaining the proper phase relationship of the antenna currents in a directional-antenna array as outlined in the article entitled "Antenna Performance" by John Barron in the March issue of Radio-Electronic Engineering.

The equations for the design of a general T network as shown in Fig. 4 are:

$$Z_1 = \frac{Z_{I1} \cosh \theta - \sqrt{Z_{I1} Z_{I2}}}{\sinh \theta} \quad \ldots\ldots (12)$$

$$Z_2 = \frac{Z_{I2} \cosh \theta - \sqrt{Z_{I1} Z_{I2}}}{\sinh \theta} \quad \ldots\ldots (13)$$

$$Z_3 = \frac{\sqrt{Z_{I1} Z_{I2}}}{\sinh \theta} \quad \ldots\ldots (14)$$

Where:

- Z_{I1} = image impedance across terminals 1 and 2
- Z_{I2} = image impedance across terminals 3 and 4
- θ = image transfer constant = $\alpha + j\beta$
- α = attenuation constant in db.
- β = phase shift in radians.

It is possible to simplify the general formulas so that they apply to a more special case, that is, for a network where:

$$Z_{I1} = R_1$$
$$Z_{I2} = R_2$$
$$\theta = j\beta$$

Equations (12), (13) and (14) reduce to:

$$Z_1 = -j \frac{R_1 \cos \beta - \sqrt{R_1 R_2}}{\sin \beta} \quad \ldots\ldots (15)$$

$$Z_2 = -j \frac{R_2 \cos \beta - \sqrt{R_1 R_2}}{\sin \beta} \quad \ldots\ldots (16)$$

$$Z_3 = -j \frac{\sqrt{R_1 R_2}}{\sin \beta} \quad \ldots\ldots (17)$$

The three quantities R_1, R_2, and β are independent and by selecting various values β it is possible to obtain a variety of T matching networks all of which match R_2 to R_1 with different values of Z_1, Z_2, and Z_3. There is a special simplified procedure for designing matching networks for a single antenna load. The phase angle of the antenna current is selected as 90 degrees and equations (15), (16) and (17) become:

$$Z_1 = j\sqrt{R_1 R_2} \quad \ldots\ldots (18)$$

$$Z_2 = j\sqrt{R_1 R_2} \quad \ldots\ldots (19)$$

$$Z_3 = -j\sqrt{R_1 R_2} \quad \ldots\ldots (20)$$

The fact that Z_1 and Z_2 are inductances of equal reactance and Z_3 is a capacitive reactance equal in magnitude to Z greatly simplifies the selection of component parts for the matching networks.

Instead of assigning a numerical value to β, it is possible to assign a value to Z_1, Z_2, or Z_3 and compute the resulting value of β that must be used. Since the antenna impedance gener-

(*Continued on page 41*)

Cathode-Ray Television Tubes

By HARRY D. HOOTON
Engineer, Philco Television Corp.

The structure and operation of cathode-ray tubes which form an essential part of modern television systems.

ELECTRONIC television had made rapid advancement up to the time of our entry into the war. Today, as in the case of other activities not essential to the prosecution of the war, television progress, as such, has been halted for the duration. Most of the television station licensees are broadcasting video programs only for the minimum number of hours per week necessary to retain their station licenses. However, research and development in closely allied fields, accelerated by war-time necessity, are doing much to assure television a prominent place in the scheme of things after the cessation of hostilities. The cathode-ray tube, once the most expensive part in the television receiver, is no longer a laboratory product; it is being turned out by mass production methods and in enormous quantities, almost as easily as were the ordinary glass and metal receiving tubes of a few years ago. Many new uses for television and television techniques will be found, probably as a direct result of the war.

Basically, the cathode-ray tube is quite simple, consisting of three essential parts: an electron gun for producing a narrow beam of rapidly moving electrons, known as "cathode rays"; a fluorescent screen which produces a luminous spot as a result of the cathode ray bombardment; and some means of deflecting or moving the luminous spot to any desired position on the screen. The drawing, Fig. 3, shows the general arrangement of the electrodes in both the magnetic-deflection, electrostatic-focus and electrostatic-deflection, electrostatic-focus types. It will be noticed that electrodes K, G, H, F and A constitute the electron gun or electron-optical system by means of which the electrons, emitted by the thermionic cathode, are concentrated into an intense, narrow beam. The gun is located in the narrow neck of the pear-shaped main body of the tube envelope, directly opposite the slightly curved broad end, upon the inside surface of which is placed the fluorescent material.

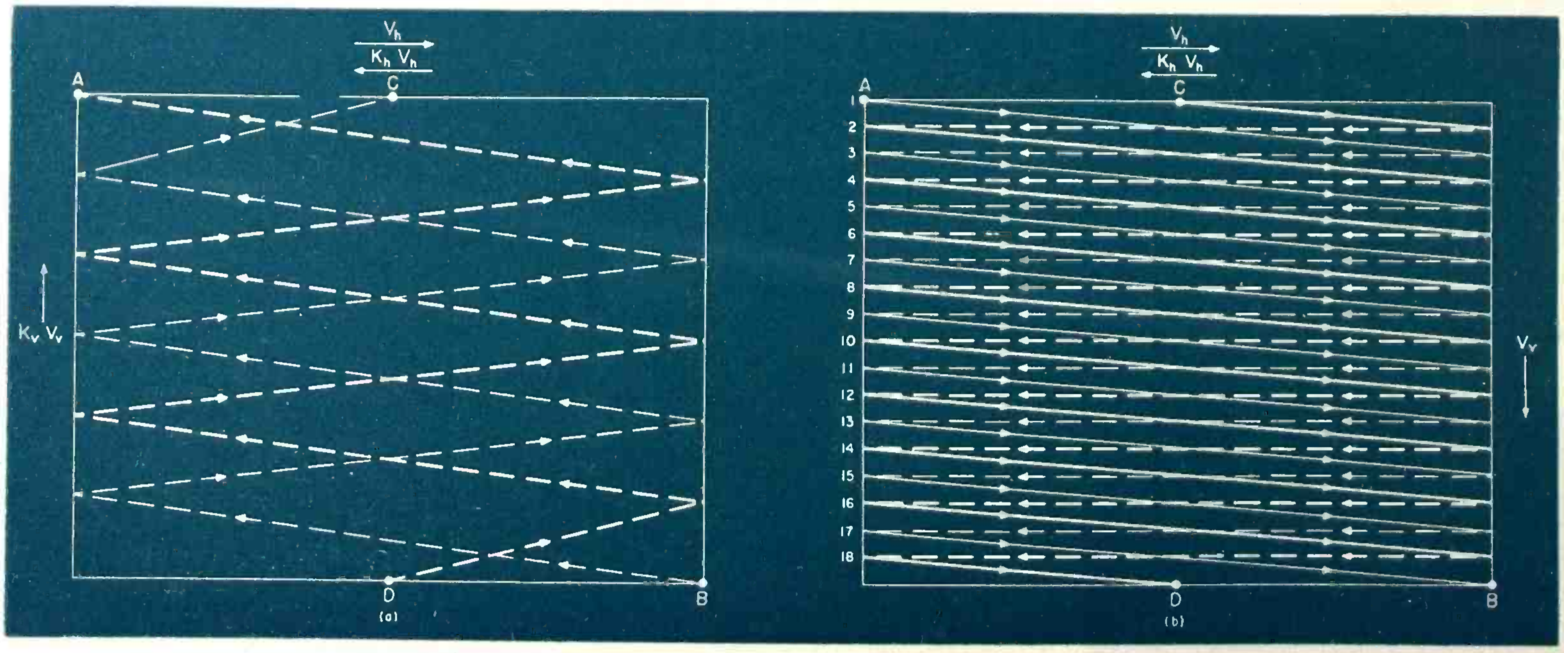
The fluorescent material, of which the screen is composed, glows under the intense electron bombardment and the spot is visible to the eye as a bright point of light. If the intensity of the beam is varied, the amount of light emitted at the spot will also vary. In actual practice the current in the beam and therefore, the amount of visible light emitted is varied by applying a potential to the control grid of the electron gun.

By means of a set of electromagnetic deflection coils or a set of electrostatic deflection plates (Fig. 3B), the spot may be moved to any desired position on the screen. In a modern television system the spot is caused to sweep across the screen in a series of straight, parallel lines, which are required for the scanning pattern, by means of suitably varying currents or potentials applied to the deflection electrodes. The electron beam is caused to sweep out the scanning pattern at such a tremendous rate that, due to the persistence of vision, the pattern appears to be stationary. If the screen is examined closely, however, the finely grained lines can be seen but, like the motion picture screen, at a short distance away the video screen appears to be uniformly luminous.

As the cathode-ray tube is the heart of the television system, so is the electron gun the heart of the cathode-ray tube. Two types of gun structures are generally employed, the magnetic focusing type, which has not been used to any great extent in this country, but is rapidly becoming more popular because of its ruggedness and structural simplicity, and the electrostatic focusing type.

A typical gun structure is illustrated

Fig. 1. Television scanning method in general use at present time. (A) Return path of scanning beam. (B) Pattern for interlaced scanning.



in Fig. 2. The particular structure shown in the drawing is that of the RCA-1850 camera tube (Iconoscope); the guns used in the viewing tubes are similar in structure except that these are generally designed for higher operating potentials. At the extreme left is the cathode, which is a cylindrical nickel sleeve approximately 0.120 inch in diameter and 0.5 inch long, with a close-fitting nickel cap. The emitting coating, which is usually about 60 per cent barium carbonate ($BaCO_3$) and 40 per cent strontium carbonate ($SrCO_3$) suspended in amyl acetate with a small amount of nitrocellulose as binder, is sprayed on this cap. Inside the nickel sleeve is the heater, which consists of several inches of tungsten wire, about 0.010 inch in diameter, wound in the form of a double spiral so as to neutralize its magnetic field. Previous to insertion in the nickel sleeve, the heater is first cleaned and dipped into a suspension of aluminum oxide (Al_2O_3) in amyl acetate with a small percentage of nitrocellulose as a binder. After firing in hydrogen or vacuum at a temperature of approximately 2000° Angstrom for several minutes, the aluminum oxide forms into a uniform and fairly solid insulating layer about 0.020 inch in thickness. The coated heater is then inserted into the cathode sleeve, the insulating material providing a fairly good thermal connection and electrical insulation. The leakage resistance between the heater and cathode elements in a well-designed cathode-ray tube is of the order of about 10 megohms. A cathode and heater assembly as described, is capable of safely emitting electrons to the extent of about 1 milliampere of current per square millimeter of surface area.

Directly to the right of the cathode surface is the control electrode or "grid," which is also a nickel sleeve with a disk parallel to the flat emitting surface of the cathode. An aperture in the center of the disk is coaxial with the cathode sleeve. The disk is placed so as to allow a portion of the cylinder known as the "grid skirt" to extend beyond it. This construction is very important from the standpoint of the control characteristic. In operation, the grid is usually at somewhat lower potential than the cathode and in this manner limits and controls the intensity of the beam. If a sufficiently negative potential is applied to the grid, the beam can be completely cut off.

In both Figs. 2 and 3, an accelerating electrode or "screen grid" is shown. This element is not always necessary or included in cathode-ray tube design. The principal function of the screen grid is to make the total current drawn from the cathode almost

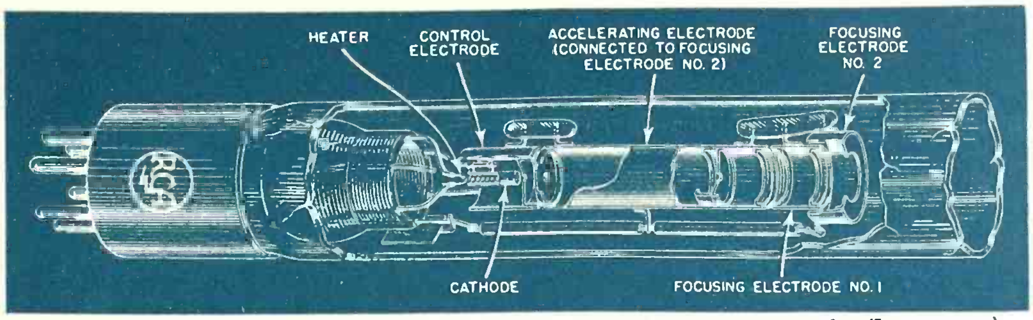


Fig. 2. Structure of the electron-gun used in the cathode-ray camera tube (Iconoscope).

independent of the first anode voltage. As shown in Fig. 2, the screen grid usually consists of a disk, having an aperture, placed close to the control grid, and it is usually operated at a potential lower than that of the first anode. Ordinarily, the screen grid of the television cathode-ray tube draws no current.

To the right of the control grid and insulated from it, is the focusing electrode or first anode. This electrode is usually in the form of a cylindrical sleeve and contains several apertures spaced at intervals on the axis of the system. These apertures serve to confine the beam further. The first anode is maintained at a high positive potential, in the case of the Iconoscope at about 200 volts and in the image-reproducing tubes from 400 to 1400 volts, with respect to the cathode.

Next in order is the high-voltage electrode or second anode. In Figs. 2 and 3, this electrode is shown in the form of a cylinder shorter and larger in diameter than any of the other cylindrical elements comprising the gun. This structure is not always used; in fact, it is more or less standard practice, in the image-reproducing tubes, for the second anode to take the form of a conducting coating on the inside of the glass envelope surrounding the gun. The second anode is placed so that its edge just overlaps the edge of the first anode. The final electron-accelerating potential is applied between the cathode and the second anode. Briefly, the purpose of the two anodes is: first, to stop the beam, which is chiefly the function of the first anode and is similar to the action of an optical stop in a lens; and, second, together with the second anode, to create an axially symmetric electrostatic field or an electron lens which starts the initially divergent electrons of the beam toward the axis. The luminous spot on the screen can be brought to a focus by an adjustment of the voltage on the first anode. So far as the focusing action of the second electron lens is concerned, the important factors are: first, the ratio of the diameters of the two cylindrical electrodes and, second, the ratio of the potentials applied to these electrodes, with respect to the cathode. Generally, the voltage applied to the first anode for optimum focus conditions will be about 20 to 25 per cent of that applied to the second anode. The absolute values of the first and second anode voltages vary, depending upon the design of the tube. The second anode voltage of the RCA-1847, which is an Iconoscope designed for radio amateurs' use, is only 600; on the other hand, the RCA-1850 Iconoscope, which is designed for the direct pick-up camera, has a second anode potential rating of 1200 volts. The first anode voltage, for best focus of the beam, is about 250 to 400 volts. The second anode voltage in Kinescopes (image-reproducing tubes) is much higher than that of the Iconoscope and ranges all the way from 1500 volts for the RCA-3AP4/906-P4, which is a 3-inch picture tube, to 7000 volts for the RCA-12AP4/1803-P4, which is a 12-inch picture tube.

The electron beam from a properly designed and constructed gun in either the camera or picture tube will, if left undisturbed, strike the surface of the mosaic or fluorescent screen near its center. In order to produce practical scanning, some means must be provided for moving the beam continuously across the screen independently in two directions at right angles to each other.

This deflection of the scanning beam can be accomplished in either of two ways: first, by passing the electron beam between two parallel flat plates, as shown in Fig. 3B, to which a source of potential has been connected, the electrons in the beam being attracted toward the positive plate and repelled by the negative plate; second, the beam may be deflected by setting up a magnetic field at right angles to the direction of deflection. In the electrostatic deflection method, the direction of deflection will be parallel with the electrostatic lines of force established between the two plates and the deflection of the electron beam from its normal position is:

$$y = \frac{E_d e h L}{v^2 m d} = \frac{E_d h L}{2E_a d},$$

where:

E_d = the voltage impressed between the deflecting plates,
e = the charge of an electron in e.s.u.
h = the length of the deflecting plates,
L = the distance from the center of the deflecting plates to the screen,

v = the electron velocity in cm/sec
m = the mass of the electron,
d = the separation of the deflecting plates,
E_a = the potential of the second anode relative to the cathode.

E_d and E_a are in the same units as h, L, d and y.

The deflection of the electron beam produced by a magnetic field will be at right angles to that field and is generally given by the expression:

$$y = \frac{0.297\ L_sB}{\sqrt{E_a}},$$

where:

L = the distance in centimeters between the screen and the point where electrons enter the field,
s = the distance in centimeters over which the deflecting field acts,
B = the flux density in gauss,
E_a = the second anode voltage.

The two expressions show that, for electrostatic deflection, the beam displacement is directly proportional to the deflecting voltage and inversely proportional to the second anode potential. For magnetic deflection, the beam displacement is proportional to field strength, which is in turn proportional to the coil current.

In general cathode-ray tubes that are designed for electrostatic deflection are also electrostatic focusing; tubes that use magnetic deflection generally use magnetic focusing. The principal advantage of magnetic focusing is, of course, in the simplification of the electron gun design. Other advantages are the lower cost and general ruggedness of the assembly. The advantage of the electrostatic method of focusing and deflection is that it requires little or no current and therefore draws a negligible amount of power from the source. The associated circuits are much simpler and inductance troubles are avoided.

A television image is "scanned" in almost the same manner as that in which a reader scans a page of printed material. The eye begins at the upper left corner of the page and slowly traverses the first printed line until the extreme right edge of the page is reached. At this point the eye quickly reverses its motion and returns to the left edge of the page and the beginning of the second line. The slower left-to-right motion is again resumed and each line is scanned in its turn until the page is completed.

In a modern television system, a scanning technique known as "interlacing" is employed in order to reduce flicker in the reproduced image. In this method the image is scanned in two or more groups of lines. Fig. 1b shows the scanning system now in general use in both this country and in Europe. The electron beam traverses the picture area in two series of lines, alternately, passing downward from point A to point B as indicated by the light solid line, following the back and forth motions as indicated by the arrows. After point B is reached, the beam then follows the return path, as shown in Fig. 1a, to point C. From point C the beam follows the path of the heavy solid lines to point D. From point D the beam returns to point A where the motion repeats itself.

The scanning spot is active in reproducing the picture while traveling from left to right over the lines shown solid and inactive when traveling from right to left and from bottom to top, over the lines shown dashed. In television textbooks, the total number of back and forth motions made in sweeping out both series of lines is usually indicated by the symbol n; the total number of active lines is usually designated as n_a. Obviously, the number of inactive lines will be $n - n_a$, and these are the lines made by the spot while traveling from the bottom to the top of the picture area. In a modern 525 line image, n_a may have a tentative value of, say, 485, which would give 40 inactive lines. The general formula for the number of active lines is:

$$n_a = \frac{n}{1 + \frac{1}{K_v}}$$

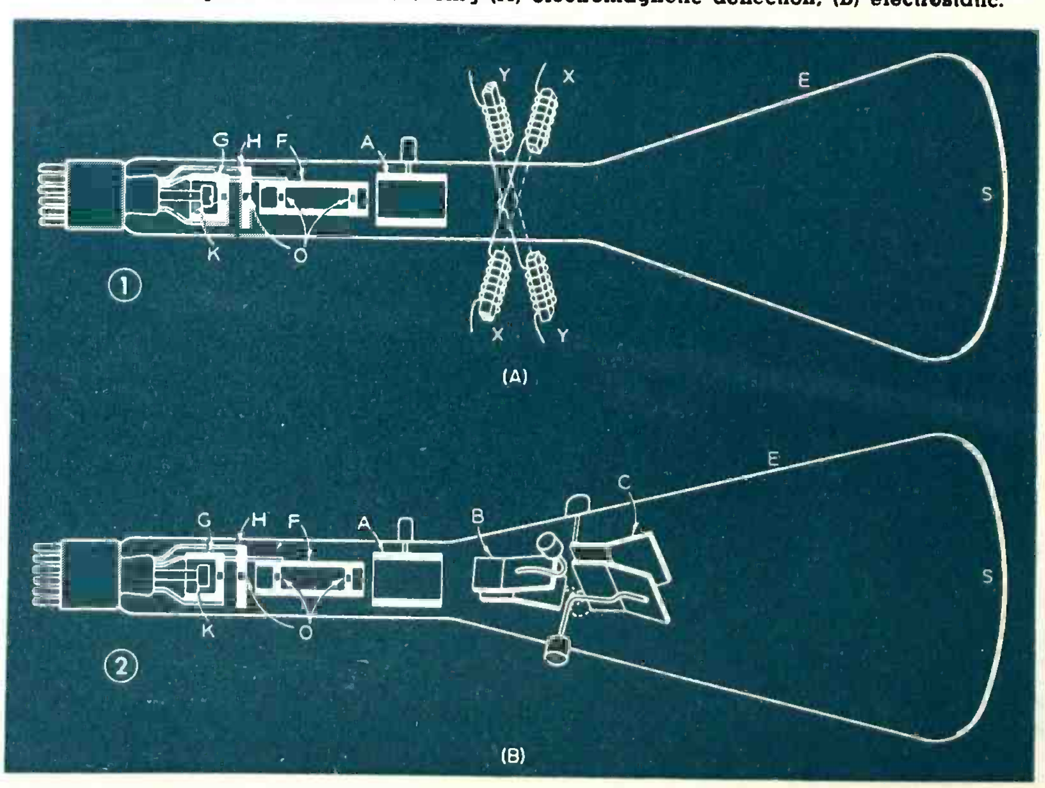
where K_v is the vertical retrace ratio, that is, the ratio between the upward scanning velocity and the downward scanning velocity.

The spot is caused to traverse the picture area by imparting to the electron beam vertical and horizontal motions, as stated above. Using standard textbook symbols, the speed at which the spot is displaced horizontally, left to right, is designated as V_h and the speed at which it is simultaneously displaced vertically downward as V_v. The two forces acting simultaneously and at right angles on the beam cause the spot to be moved slightly downward and to the right until the right-hand edge of the scanning area is reached. The motion of the spot is then rapidly reversed and it is returned to the left at a much faster speed, K_hV_h, forming the horizontal retrace motion to the left-hand edge of the picture area. During the successive back and forth motions of the beam, the downward motion has remained at a constant velocity until the spot reaches the bottom of the picture area. At this point the downward motion is reversed and the spot moves upward at a faster velocity, K_vV_v, until it again reaches the top of the pattern. The horizontal velocities, V_h and K_hV_h, are maintained during the upward motion of the spot, resulting in a number of back and forth motions of the beam. In actual practice about 8 to 10 per cent of a vertical period is devoted to return time, so that 8 to 10 per cent of the 262½ horizontal lines will be sloped in the opposite direction on the screen. Since these lines serve no useful purpose and would actually cause an interfering pattern on the screen, it is during this period that a negative voltage impulse, called the "blanking pedestal," is injected on the Kinescope gun control grid, biasing off the electron beam so that the return traces do not show.

After completing the first field scan, the spot returns to the top, and as will be noticed in Fig. 1a, is only one-half a line away from the upper left-hand side of the picture area. The spot is exactly on the same level with the

(*Continued on page* 47)

Fig. 3. Two types of electron focusing (A) electromagnetic deflection, (B) electrostatic.



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Typical in precision measuring of R. F. Inductors to rigid war production tolerances, the "Dynamic Inspection Analyzer" is representative of the ingenuity of Guthman "INDUCTRONIC" research. Employing a highly stabilized circuit of our own design this 24-frequency inspection device, used in the manufacture of an Ant. R. F. and Osc. assembly, can analyze the individual coils for band coverage, inductance, and Q. at their operating frequencies. Uniformity of electrical characteristics in the manufacture of Guthman super-improved coils makes...

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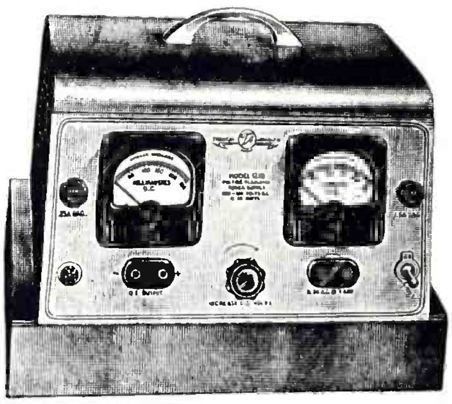
NEW PRODUCTS

POWER SUPPLY

Model 1218 Voltage-Regulated Power Supply is now available for general use in experimental development laboratories. D.C. loads up to 40 watts at 200 to 400 volts, with a voltage variation of less than 1% from zero to full load can be furnished.

A single operating control allows the d.c. output voltage to be set at a desired value, at which point it will remain regardless of the load variation. Current may be drawn up to 100 milliamperes at 400 volts, increasing to 200 milliamperes at 200 volts. Voltage regulation is assured by means of an electronic circuit using standard tubes.

The built-in voltmeter and milli-



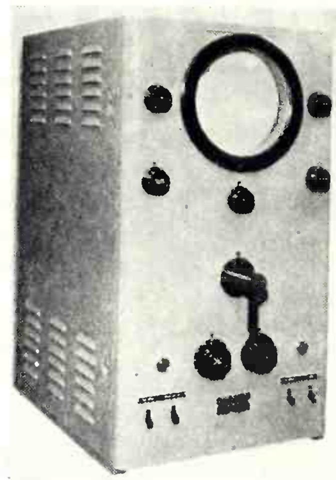
ameter permit direct reading of the output delivered at the safety jack located on the front panel. A second output jack, particularly valuable for experimental work, supplies 4 amperes a.c. at 6.3 volts (unregulated). Both the d.c. output and a.c. input are fused for protection.

For more detailed information regarding this power supply, Bulletin B-1218, Dept. RE-4 may be obtained from *Technical Apparatus Company, 1171 Tremont Street, Boston 20, Massachusetts.*

INSULATION TESTER

A new electronic winding-insulation tester for production line testing of faulty insulation and winding dissymmetries in motors, generators, coils and transformers has been announced by General Electric Company. Employing the priniciple of balance and comparison, the instrument simultaneously tests, turn-to-turn, coil-to-coil and coil to ground insulation. It simulates qualitatively such procedures as resistance, impedance-balance, turn-balance, and complete high-potential tests with one voltage application.

The new instrument is particularly



desirable for testing the completed windings of three-phase, low-voltage rotating machines, although it is also capable of testing the windings of single-phase, two-phase and d.c. motors and transformers whose insulation is not designed to withstand more than 10 kv.

When the tester is used to test a three-phase motor, the three instrument leads are connected directly to the three motor leads. After the electronic circuit in the tester is energized, any two phases of the motor (1-3, 2-3, 1-2) can be tested quickly by means of a four-position, hand-operated selector switch on the front of the meter. Short-circuits or grounds in any part of the winding are indicated on the oscilloscope by two waves dissimilar in shape and amplitude.

Single-phase motors are tested similarly, and d.c. motors by the bar-to-bar comparison methods. In both cases the divergence between the two waves on the oscilloscope indicates the presence of faults.

The tester consists of a repeating-type, surge-voltage generator, a cathode-ray oscilloscope, and a synchronously driven switching equipment, all housed in one steel cabinet, especially designed for bench mounting. The oscilloscope is mounted at eye-level, where it can be seen easily.

The insulation tester is available from *General Electric Company, Dept. RE-4, Special Products Division, Schenectady, New York.*

MICROHMMETER

A new self-contained microhmmeter Type G-710 has been announced by Tech Laboratories of Jersey City, New Jersey.

This instrument represents a new electronic development which is an a.c. bridge of great flexibility. Due to the sensitivity and large output of this instrument, it is possible to use this circuit for many purposes requiring recording or controlling apparatus such as temperature control, moisture control and pressure control.

The Type G-710 is a completely a.c. operated instrument capable of measuring from .0001 ohm to one megohm. Readings are taken from a decade and a meter is used as a null indicator.

One new feature of this microhmmeter is the fact that the same voltage, a few tenths of a milliwatt, is required for the measurement of all resistance whether low or high.

Pure resistance is measured directly in ohms and impedances may be measured by comparison with changes as low as .01% indicated. Contact resistance in relays, switches, joints and bondings may be measured without changing the actual conditions of the contact.

No terminals are required when the instrument is used as a Kelvin bridge. Low resistance measurements, such as those of a meter armature, small coils and fine filaments may be made without heating effect.

Further information regarding the microhmmeter may be secured by writing direct to the manufacturer, *Tech Laboratories, 7 Lincoln Street, Jersey City 7, New Jersey. Dept. RE-4.*

FATIGUE TESTER

A new addition to the line of vibration fatigue testing machines made by the All American Tool and Manufacturing Co., features automatic cycling. This new unit, designated as Model 10V, handles parts or assemblies up to 10 pounds in weight. The mounting table has an area of 8" x 8" and has drilled and tapped holes for attaching the work which is to be testing. The table is mounted on an X-frame, thus minimizing the stresses on the eccentric and connecting rod. The vibration mechanism runs in an oil bath.

Vibration, in simple harmonic motion, is produced vertically. Acceler-

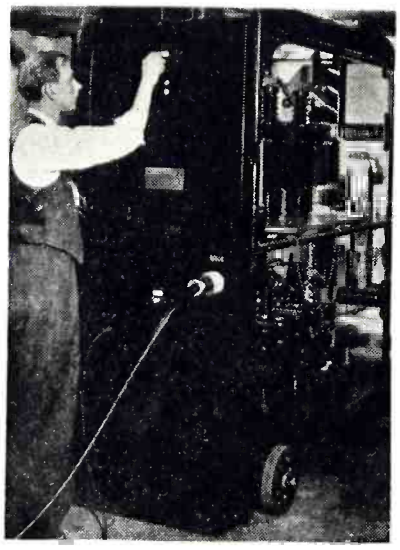
(*Continued on page* 38)

Industrial Review

X-Ray Aid Ballistics

X-RAY "pictures," or radiographs, taken in a millionth of a second by a 300,000 volt Westinghouse X-ray machine make possible studies of the action of bullets in motion within gun barrels and when they hit targets of armor plate or other materials.

The Army has two of these machines at Frankford Arsenal in Philadelphia, two at the Ballistics Research Laboratories of the Army Ordnance Proving Grounds in Aberdeen, Md.



Two mobile units are placed side by side, so that two pictures of a single bullet can be taken at different stages of its flight.

Each unit is mounted on wheels, weighs 1500 lbs., measures 8 feet long, 7 feet high and 3 feet wide. Projecting from the front of the carriage is the ultra high speed tube 24 inches long. The first experimental tube which made possible ultra high speed X-rays was developed in the *Westinghouse Lamp Laboratories at Bloomfield, N. J.*

* * *

Handy Stock Record

A STOCK record in folder form has been issued by Manufacturers Screw Products, manufacturers of fastening devices with the "STRONGHOLD" trademark. It is a periodical record of "in-stock" Aviation and commercial fasteners of every type and description, and keeps buyers abreast of the firm's stock conditions. Millions of regular and special items are listed in the record—including Screws, Washers, Rivets, Studs, Nuts, Bolts, Aluminum Washers, Drilled Screws and countless similar items. Fasteners in steel, brass, stainless steel and aluminum are represented.

Copies of this record are available upon application to *Manufacturers Screw Products, 216 W. Hubbard Street, Chicago 10, Illinois. Dept. RE-4.*

* * *

Chromium Development

TRIVALENT chromium, a long sought goal of scientists in the field of electroplating, has now become an established fact. The new process and its radically different salt, on which patents are now pending, promises to revolutionize a manufacturing process in which basic improvement has long been static.

The Warner Process, with its new "Skalite" chromium salt, provides substantially greater plating efficiency. Procedure for both hard and decorative chromium has been simplified. Plant investment is immeasurably less; the need for special chrome plating equipment has been eliminated. The Warner method is simple and automatic, and differs little from the process used in copper plating.

Time, electrical energy and salts required are only 20% of that required for the old process. Due to the bath's non-gassing characteristics and increased throwing power, there is no longer need for special contour anodes

on intricate objects. The bath is also non-corrosive. Chromium plating by this process is more uniform, thicker, denser and more resistant to the action of salt water.

Constant testing of the bath by trained chemists is no longer necessary. Because workers experienced in plating ordinary metals can also handle this new chromium, labor costs may be cut substantially. The new "Skalite" bath being non-poisonous, chromium plating is removed from the hazardous occupation classification, with attendant savings in liability insurance.

According to the developers of this new process, *Warner Laboratories, 360 North Michigan Ave., Chicago 11, Illinois,* definite promise of being able to plate with chromium anodes and thereby control the crystal structure is indicated as a possible development. Information will be forwarded interested readers by writing Dept. RE-4 at the above address.

* * *

New Magnetic Alloy

THE properties and characteristics of new permanent magnet alloys which increase the sensitivity of small panel type instruments beyond the possibilities of the chrome and tungsten alloy steels previously used for permanent magnets, was the subject of a paper delivered by M. S. Wilson and J. M. Whittenton, engineers in the Electrical Instrument Section of General Electric's West Lynn Works, at the AIEE winter technical meeting January 24 to 28 in New York City.

The paper, "Influence of Improved Magnetic Alloys on Design Trends of Electrical Instruments," takes the position that the design trend of electrical indicating instruments has been greatly influenced by the use of permanent magnet alloys which have been developed during recent years. Engineers Wilson and Whittenton state that for given sensitivities, instruments have been made available which are more sturdy and reliable, and that instruments of higher sensitivity have been made possible by the use of the newer alloys. Also, relatively higher coercive force and high residual materials are now available that are readily machined and use a minimum of critical materials. All of these are factors which are of particular importance designs for wartime application.

For the past 15 to 20 years, cobalt steel permanent magnets have been used in instruments, providing a means of producing higher sensitivities. This material has been used in forged and cast forms and is most attractive from the standpoint of high coercive force of about 210 with total energy of 900,000. However, its inherent high cost limits its use primarily to the higher sensitivity instruments where the chrome and tungsten steels are unsatisfactory.

Also discussed in the paper are the great advances which have been made recently in strength of permanent magnet materials by the development of the aluminum-nickel-cobalt iron (alnico) alloy.

(*Continued on page 45*)

One of the world's masterpieces in marble — "The Kiss", by the celebrated French sculptor, Auguste Rodin (1840-1917), creator of the famed and familiar "The Thinker".

NEWS BRIEFS

GENERAL MANAGER

Bendix Radio Division of Bendix Aviation Corporation has just announced the appointment of a new General Manager, who will succeed Mr. Hugh Benet who has been manager since 1939. Mr. W. P. Hilliard, Chairman of Panel Number 10, Radio Range, Detection and Recognition of the RTPB, is the company's choice for this position.

Mr. Hilliard has been director of sales and engineering of the Radio

Mr. W. P. Hilliard

Division since its inception in 1936. Prior to that time, Mr. Hilliard was connected with his own company in Chicago, which was purchased by Bendix in 1936 and became part of the corporation's Radio Division.

Mr. Benet will assume other responsibilities of a special assignment nature. During the period of his service, the personnel increased from 600 to the present complement of 7800 workers and the output increased more than a hundred-fold. More than 20 large companies have been trained by the division as subcontractors in the production of Bendix devices.

REORGANIZATION

The Universal Microphone Company, Ltd., which has been known by this name since 1928, will hereafter be known as The Universal Microphone Company. The stockholders and board of directors of the corporation elected to dissolve the corporation and filed certificate to that effect with the California Secretary of State and the Los Angeles County Clerk.

James L. Fouch and Cecil L. Sly, president and vice-president of the former corporation and its principal stockholders, have organized a partnership and have taken over the assets and liabilities of Universal Microphone Co., Ltd.

The partnership will continue to conduct the business of the former corporation. The new officers are James L. Fouch, president; Cecil L. Sly, vice-president and treasurer; and Durwood D. Allen, secretary.

GE REPORTS ACTIVITIES

A quarterly report to the stockholders of the General Electric Company, entitled *University of War*, presents an interesting picture of the type of training program the company is carrying on for the uniformed services.

The scope of this training program, carried on simultaneously with an extensive employee training program, is vast and provides part of the answer to the effective maintenance of our electrical equipment being used on the battle fronts.

Men who are to man the various pieces of complex modern equipment are brought to the General Electric plants and given a factory training for the repairing, and replacing of vital components.

The story is well told and to those interested in obtaining a copy of this booklet, it will be forwarded upon request by General Electric Company, Public Relations Department, Schenectady, New York. Specify booklet GEC-145.

ASA COMMITTEES REPORT

The five committees of the American Standards Committee whose work has been concerned with war standards have completed work on 13 war standards, with 12 others nearing completion, according to a report released by Mr. P. G. Agnew, secretary of the association.

Eleven regular standards, recommended by the Electrical Standards Committee, were approved by the Association during the year, in addition to the 13 war standards.

Under consideration at the present time are the standards on Protection Against Lightning, Rotation, Connections, and Terminal Markings for Electrical Apparatus, Insulated Wires and Cables, Radio, Industrial Control Apparatus, Insulators for Electric Power Lines, and Mercury Arc Rectifiers.

A complete report may be obtained from the American Standards Association, 29 West 39th St., New York 18, New York.

NEW APPOINTMENT

J. Kelly Johnson has been recently appointed Executive Engineer of all engineering activities at the Hammarlund Manufacturing Company, Inc., 460 West 34th Street, New York. Mr. Johnson's appointment is effective as of February 1, 1944.

Mr. Johnson's experience in the engineering field has been varied, ranging from teaching experience at Columbia University to practical development work in several well-known companies in Chicago and New York.

Prior to his acceptance of the position at Hammarlund, Mr. Johnson served as chief of the Production Section, Electronic Division, Office of Procurement and Material, for the Navy Department.

In his new position as executive engineer, Mr. Johnson will be in charge of all engineering activities and will direct the extensive engineering expansion program for Hammarlund.

TELEVISION BROADCASTERS

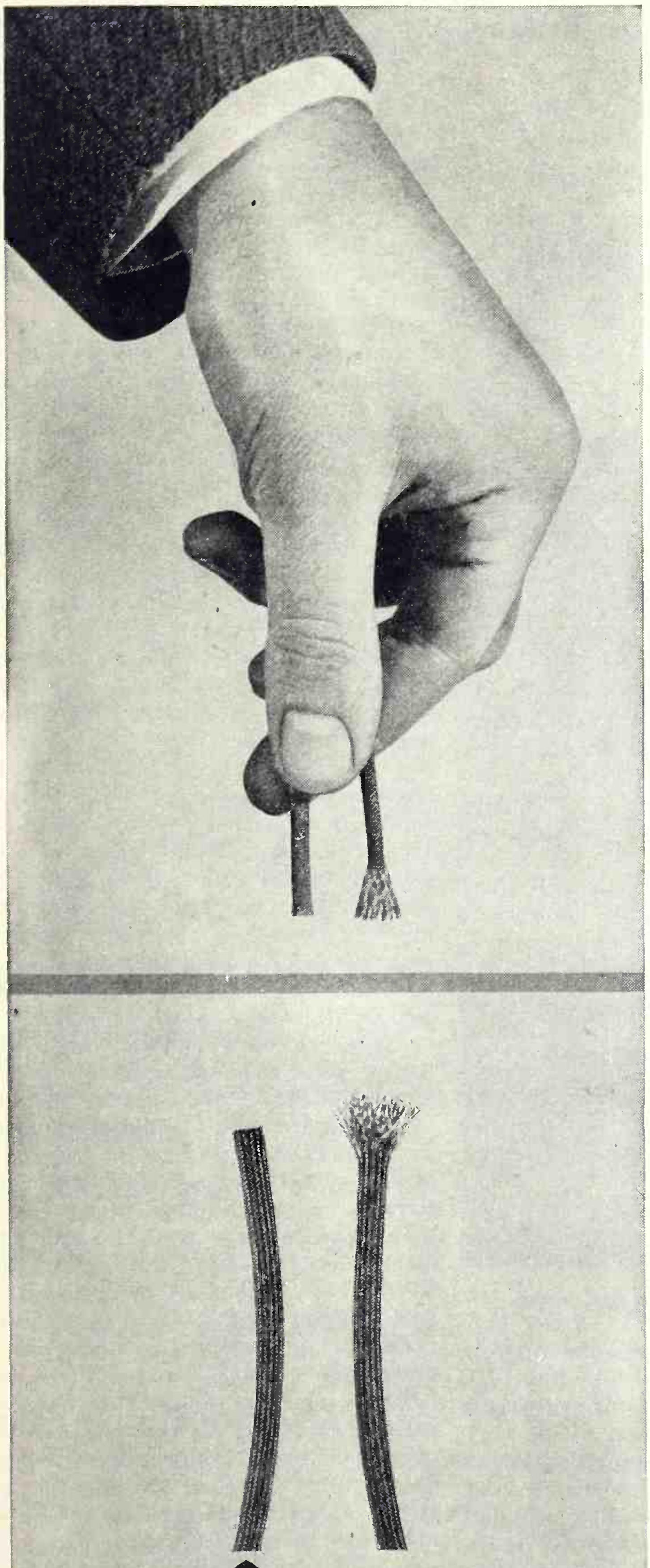
The newly organized Television Broadcasters Association, recently incorporated in Wilmington, Delaware, has announced the officers and directors of the Association. The organization meeting was held in Chicago and was attended by representatives of the leading television companies.

Mr. Allen B. DuMont of the Allen B. DuMont Laboratories, Inc., was elected president of the new organization, while Lewis Allen Weiss of the Don Lee Network will serve as vice-president. The directors elected include, F. J. Bingley, Philco, Inc.; Robert L. Gibson, General Electric Company; O. B. Hanson, National Broadcasting Company; C. W. Mason, Earle C. Anthony, Inc.; E. A. Hayes, Hughes Tool Co.; Worthington Miner, Columbia Broadcasting System; Paul Raibourn, Television Productions, Inc.; Lewis Allen Weiss, Don Lee Network; and Allen B. DuMont.

At the first directors' meeting, it was voted that the Association would become a contributing member of the Radio Technical Planning Board.

The following committees were appointed: Post-war Planning Committee, Paul Raibourn, Chairman, the function of this committee is to study the problems and potentialities of commercialized television not only in terms of telecasting, manufacture of sets, but also as a possible source of employment for many workers; Program Committee, Worthington Miner, Chairman, will serve as a clearing house for the exchange of information

(*Continued on page* 40)



THIS—NOT THIS

SNUB TEST

Proves non-fray feature of new BH Fiberglas Sleeving

NEW, BH Extra Flexible Fiberglas Sleeving *will not fray,* even under severe conditions. You can prove this *right at your desk*. It's easy as snubbing out a cigarette. Here's how:

Write us for a sample of BH Extra Flexible Fiberglas Sleeving equal in size to the saturated sleeving you use now.

Hold short pieces of both BH Fiberglas Sleeving and the usual saturated sleeving between your thumb and index finger, and snub the ends of both sleevings against your desk, similar to the way you would snub out a cigarette. Do this five to ten times, pressing hard.

BH Flexible Fiberglas Sleeving will spread slightly under this pressure, may fuzz a little, but *will not fray*. The usual saturated sleeving will break down at the edges and separate.

Continued snubbing will not noticeably affect the BH Extra Flexible Fiberglas Sleeving, whereas the saturated sleeving will readily unravel and become progressively worse.

NON-FRAYING • FLEXIBLE • HEAT-RESISTANT
NON-INFLAMMABLE • WATER-RESISTANT
NON-CRYSTALLIZING at LOW TEMPERATURES

The new BH Extra Flexible Fiberglas Sleeving is woven from the choicest continuous-filament Fiberglas yarns. It possesses high dielectric strength, is water-resistant and, like all BH Sleeving and Tubing—is non-inflammable.

All sizes from No. 20 to $\frac{5}{8}''$, inclusive, are available. Write for samples of this radically new and different sleeving today—in the sizes you desire. Seeing is believing! Bentley, Harris Manufacturing Co., Dept. R, Conshohocken, Pa.

BH PRODUCTS

NON-BURNING IMPREGNATED MAGNETO TUBING • NON-BURNING FLEXIBLE VARNISHED TUBING • SATURATED AND NON-SATURATED SLEEVING

BENTLEY, HARRIS MANUFACTURING CO.
Conshohocken, Penna.

CALENDAR of Coming Events

APRIL

19-22—**National Electrical Wholesalers Association,** Stevens Hotel, Chicago, Illinois.

APRIL

25-26-27—Technical Conference.

The Society of Motion Picture Engineers, Hotel Pennsylvania, New York. Julius Haber, Pub., Chairman.

27-29—**American Physical Society,** Pittsburgh, Pa.

MAY

12-13—**Acoustical Society of America,** New York.

* * * *

MONTHLY MEETINGS

Association of Electronic Parts & Equipment Mfrs. L. G. Groebe, Secy., 77 W. Washington St., Chicago, Illinois.

2nd Thursday each month.

* * * *

Sales Managers Club. Hotel New Yorker, New York. Walter Jablon, Secy., Hammarlund Mfg. Co.

Lunch meeting on the 4th Wednesday each month.

* * * *

The Representatives. R. Edward Stemm, Secy. Chicagoland **Chapter,** Chicago, Illinois.

Luncheon meeting 1st Monday each month.

* * * *

I. R. E., Chicago Section. William O. Swineyard, Secy., 325 W. Huron Street, Chicago, Illinois.

Meeting April 21, 1944, Central Y.M.C.A., 19 South LaSalle St., Chicago, Illinois. 6:45 P.M., Glen Ramsey, Mgr., E. W. Lincoln, Engineer, Rectifier Division, Fansteel Metallurgical Corp., speaks on *Characteristics and Applications of Selenium Rectifiers.*

7:55 P. M.

Bell Telephone Demonstrators, Bell Telephone Engineer, Illinois Bell Telephone Co., Chicago, will present *The Automatic Telephone, A Play and Demonstration of Equipment,* also *The Lake Bluff Ship-Shore Radio-Telephone Installation.*

Phosphors For Tubes

(Continued from page 12)

their excess energy, $B_1 - A^+$, as a quantum of light. This action is delayed in time and is called phosphorescence.

It would require about 10,000,000 of these diagrams, presented simultaneous 3-dimensional motion pictures, to portray the actions taking place in one tiny phosphor crystal only 1/4000 inch in diameter.

Some of the electronic application of phosphors are:

1. *Fluorescent Lighting.* The use of phosphors in fluorescent lighting has been indicated in figure 4. Low velocity (about 100 volt) electrons are alternately emitted from the hot cathodes in each end of the tubular lamp. The lamp has a slight amount of mercury vapour which upon electron bombardment emits ultraviolet quanta of $\lambda = 2537$ Angstroms. These ultraviolet quanta, in turn, strike the billions of phosphor crystals in the tube coating. The phosphor crystals, finally, transform the invisible 2537 Angstroms radiation into visible light (4000 to 7000 Ang.).

In a three-foot long, one-inch diameter, 40-watt fluorescent lamp there are approximately 10^{18} electrons pro-

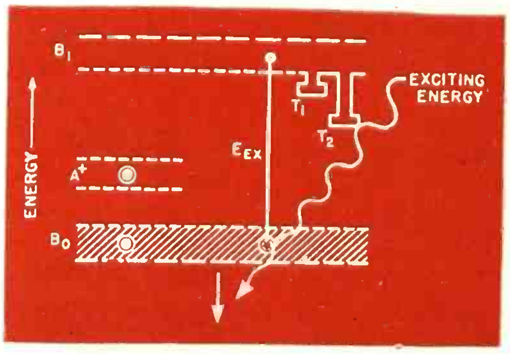


Fig. 8. Energy in phosphor crystal.

ducing about 10^{18} ultraviolet quanta, and 10^{18} quanta of visible light; all being emitted and transformed during each second of operation. This veritable "beehive" of ultramicroscopic activity produces 1200 lumens of cool, white light with an efficiency of about 5%. By comparison, a 40-watt incandescent lamp produces only 425 lumens with an efficiency of about 1.7%.

2. *Electronic Television.* The use of phosphors in producing visible moving television images, under excitation by a scanning beam of electrons, has been mentioned in connection with Figs. 1 and 5. In this use, high-velocity (5000 to 50,000-volt) cathode rays impinge directly on a thin coating of phosphor crystals which transform the electron energy into visible light.

During each second of average television Kinescope operation, at 6,000 volts and 50 microamperes, about 10^{14} primary electrons strike the phosphor crystals which emit 10^{14} secondary electrons plus about 3×10^{16} quanta of visible light. This corresponds to about 10 lumens, or 20 foot-lamberts from an 8" x 10" image.

3. *"Magic Eye" Tuning Indicators.* A very thin phosphor coating in the cup-like metal anode in the top of a tuning indicator tube, such as the one pictured in figure 13, is excited to luminescence by a spray of low-velocity (about 100 to 300-volt) electrons from a cathode in the center of the "cup." Degree of tuning is instantaneously indicated as a variable electrostatic shadow cast by a grid post located proximate to the cathode.

The luminescent efficiency of this device is low, due to the low electron velocities, but its technical advantages in affording inexpensive, practically inertialess monitoring of tuning, signal strength, and end points (in chemical titrimetry) have made it a widespread feature of many modern circuit designs.

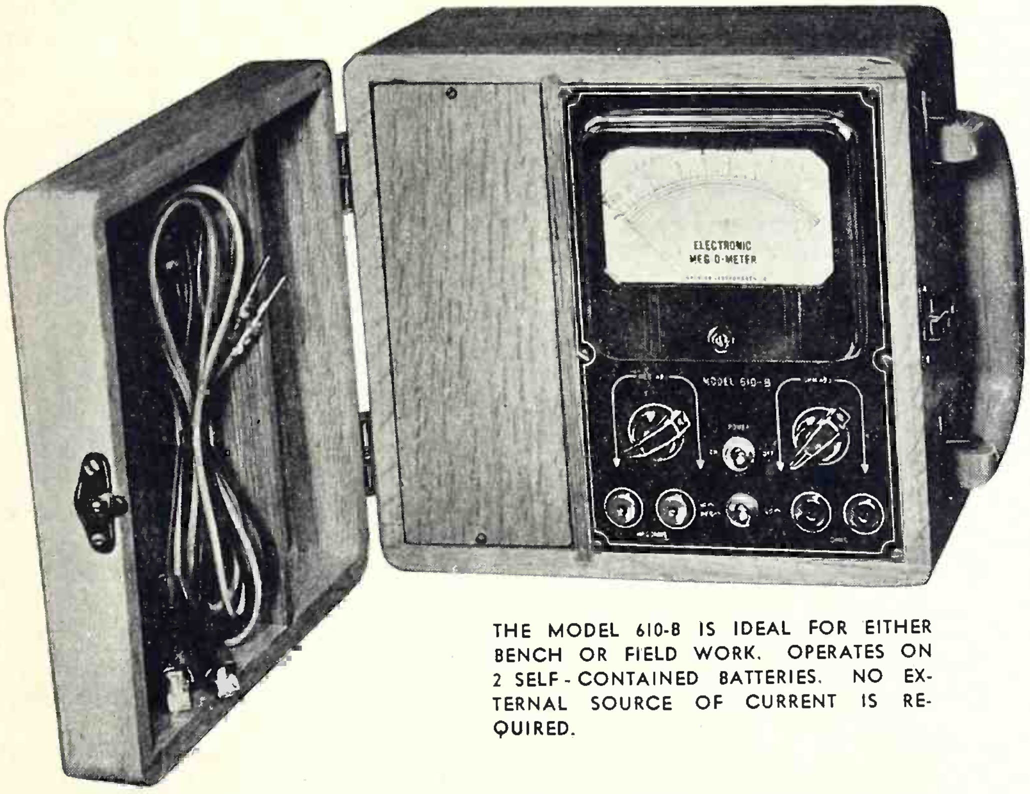
4. *Electron Microscopes.* These more recent members of the electronic family, such as the one shown in Fig. 15, fire a beam of very high-velocity (20,000 to 200,000-volt) electrons through thin specimens whose enormously magnified electronic images may finally be made visible by a phosphor screen. Magnifications up to 100,000 diameters are made possible by electron microscopes which have afforded a hitherto unattainable insight into the realm of the infinitesimal.

In considering future phosphor uses, it is worth noting that the contrast ratio, i.e. ratio of light to dark, attainable with phosphors is greater than the contrast attained with pigments viewed under white light. This is true because phosphors are excited by invisible radiations so the non-luminous backgrounds upon which phosphors may be placed are truly black, i.e., they emit no light. The contrast ratios attainable by this means are over 1000 to 1. With ordinary pigments, however, even the best blacks reflect about 4% of the incident light and hence restrict contrast to about 25 to 1. The much greater contrast obtainable with phosphors heightens the stereoscopic sense of depth perception and affords a striking artistic and decorative medium.

There are, and will be, other useful electronic devices employing phosphors. Wherever it is necessary to convert electricity into light, with high efficiency plus controllable color and controllable duration of light emission, phosphor crystals fulfill the role of the legendary genie of the lamp in being "at your service."

The Model 610-B

MEG-O-METER



THE MODEL 610-B IS IDEAL FOR EITHER BENCH OR FIELD WORK. OPERATES ON 2 SELF-CONTAINED BATTERIES. NO EXTERNAL SOURCE OF CURRENT IS REQUIRED.

A New, Battery-operated

INSULATION TESTER!!

Instantaneously measures the exact leakage of all insulation from zero up to

200 MEGOHMS

At a Test Potential of

500 VOLTS D. C.

Supplied by built-in battery and vibrator power supply.

3 RANGES:
0 — 20,000 OHMS.
0 — 2 MEGOHMS.
0 — 200 MEGOHMS.

ADDED FEATURE: The MODEL 610-B has been designed to function with a high degree of accuracy both as a resistance measuring instrument and as an insulation tester. In addition to the 0 to 200 Megohm Range which is used for insulation testing, two additional lower resistance ranges are provided. The two lower Resistance Ranges are 0 to 20,000 Ohms and 0 to 2 Megohms. Thus the MODEL 610-B may be used to accurately measure all resistances from 0 to 200 Megohms.

Specifications

***NO HAND CRANKING—** The 500 VOLT POTENTIAL is made instantly available by simply throwing a front panel toggle switch.

***DIRECT READING—** All calibrations printed in large easy-to-read type enabling exact determination of leakages from 0 to 200 Megohms. In addition, the Megohm scale is also sub-divided into BAD (0 to 1 Megohm) DOUBTFUL (1 to 3 Megohms) GOOD (3 to 200 Megohms) sections. The BAD Section which indicates the danger point is printed in red.

*The instrument is housed in a heavy-duty Oak portable cabinet.

*Meter movement—a 4½" 0 to 200 Microampere sensitive meter guarantees extremely accurate readings on all ranges.

Model 610-B comes housed in a beautiful, hand-rubbed Oak cabinet complete with cover, self-contained batteries, test leads and instructions. Size 9½" x 8½" x 6". Shipping weight, 16 pounds.

Price **$62.50**

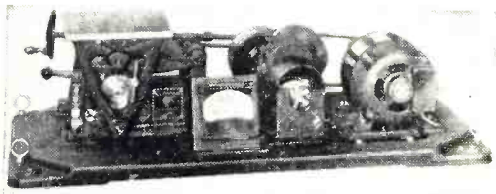
Important: We also make the Model 610-E Meg-O-Meter which operates on 110 Volt 60 Cycle A.C. The Model 610-E is especially recommended for production testing where product must meet specified insulation requirements. Model 610-E provides exactly same services as the Model 610-B except that it operates on 110 Volt A.C. current instead of batteries. Price of Model 610-E complete is **$52.50**

SUPERIOR INSTRUMENTS CO., Dept. R. N., 227 Fulton St., New York 7, N. Y.

New Products

(*Continued from page* 30)

ation, or rate of change of velocity, is controlled automatically by a device which changes the frequency from 10 cycles per second to 55 cycles per second and back to 10 cps. continuously and uniformly. The complete cycle requires one minute. Frequencies are recorded on a sensitive electric tachometer.



The unit is powered by ½ hp., 110 volt, 60 cycles, a.c. split phase motor. The tester simulated vibration fatigue which may be encountered under actual operating conditions.

This testing machine is fully described in Bulletin 210, Dept. RE-4, *All American Tool and Mfg. Company, 1014 Fullerton Avenue, Chicago, 14, Illinois.*

SYNCHRONOUS MOTORS

The Leich Synchronous Motor is designed to meet the demand of manufacturers of control, timing, and recording devices who require a compact, sturdy and accurate synchronous motor.

The rotating element of the motor operates at a fixed speed which is determined by the frequency of the alternating current energizing the motor. With most power systems operating at a fixed frequency, it is possible to operate dependent on exact timing for proper functioning by means of these motors.

Standard output shaft speeds of 1-4-15 and 60 r.p.m. can be furnished. By means of external movements, slow speeds of one revolution per hour, per twelve hours and per twenty-four hours can be obtained.

Special motors, designed to fill certain engineering requirements, may be furnished if ordered in sufficient numbers to make the necessary tooling worthwhile.

For further information, inquiries and engineering problems, inquiries should be addressed to *Leich Electric Company, Genoa, Illinois, Dept. RE-4.*

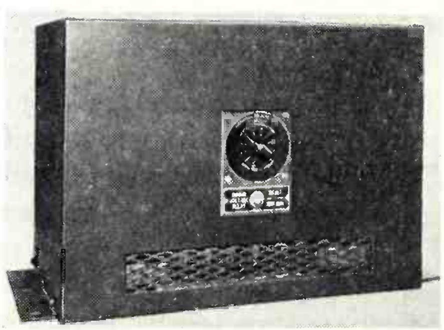
THYRATRON CONTROL

A new thyratron welding control for providing precise control of low-capacity spot welders has been announced by the Industrial Control Division of the General Electric Company. Coupled with a suitable welding transformer, this control can be used with either welding tongs or a small bench welder, and is particularly suitable for the spot-welding of vacuum tube parts.

Other applications for which the control, in combination with the proper welding transformer, is desirable include the welding of solid or stranded wires to terminals of copper, brass, bronze, steel, or ferrous alloys; joining two tinned-copper, steel, or alloy wires; and spot-welding thin pieces of various alloys.

Suitable for operation on either 230 or 460-volt, 60-cycle power supply, the new control is an adjustable, synchronous-precision, electronic type in which only three thyratron tubes perform all the functions. Two Type FG-172 tubes control the primary current of the welding transformer, and a single Type FG-97 tube controls the firing time. Since the tubes have the same current rating on either voltage, the transformer used on a 460-volt supply can be twice as large as that used on a 230-volt source, which will approximately double the secondary current. The control is rated 53 amperes rms (primary current of the welding transformer) on a duty cycle not exceeding ten per cent.

The new control is mounted in a compact, dead-front metal enclosure designed to permit the control to be attached either to the top of the assembly bench or underneath, by a simple reassembly of parts. A single calibrated time adjustment on the front of the panel provides either one-half cycle or any number of complete cycles from one to ten. The removable cover of the enclosure allows quick inspection and complete accessibility of all component parts.

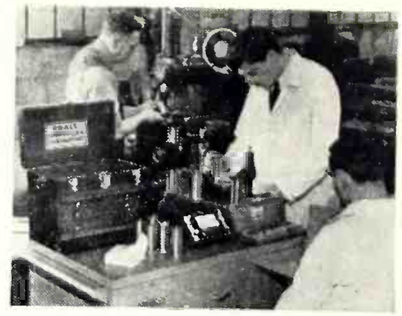


Additional information is contained in Bulletin GEA-4175, Dept. RE-4, available from the *General Electric Company, Schenectady, N. Y.*

INSPECTION UNIT

A complete inspection department, which may be brought to the point of work, is the product of the Continental Machines, Inc. Known as the DoALL Mobile Inspection unit, this laboratory on wheels contains all of the necessary instruments and gauges usually found in a plant inspection department.

Regular testing, or periodic sampling may be accomplished on this one instrument. The unit occupies an area of approximately 24" x 42" and can be brought to the machines which are producing the to-be-tested samples. The unit is all steel construction which assures sturdiness. Rubber tired, heavy duty caster wheels permit easy movement, while during the operation of the unit, the wheels can be locked for steadiness.



Every convenience is provided for the inspector to facilitate easy testing. A plug-in-box at the back of the unit permits an easily accessible outlet for attaching the fifty foot extension cord and automatic take-up reel.

A desk drawer and chair is furnished to permit the inspector to record the information and results that he obtains from his tests.

Many other features of this unit will be described by *Continental Machines, Inc., 1301 Washington Boulevard, South, Minneapolis, Minnesota,* upon request to Dept. RE-4.

CAPACITY METER

An interelectrode capacity meter, with a range of from .001 to 100 mmfds. has been announced by the Technical Apparatus Company of Boston.

Simplicity of operation permits unskilled personnel to use this meter as easily as an engineer, as readings are taken direct from the large dial and read in micro-microfarads. The tube to be measured is plugged into a wholly shielded measuring circuit incorporated in the instrument.

The connector base accepts adapters for tubes up to 8-pin and provides for connection of coaxial cables to any pair of elements whose capacity is to be measured. The "universal" shield furnished with the instrument accommodates tubes up to 2⅝" in diameter and 4¾" high. Standard RMA shields, as specified for various tube types may also be used. Special shields for unusual tube types may be furnished.

Special adapters for measurements other than for vacuum tubes are available.

The flexibility of this instrument coupled with the advantage of simplicity of operation makes this

(*Continued on page* 43)

Maintenance

(*Continued from page* 15)

that preventive maintenance is primarily constant attention to small details and in spite of the precautions taken, troubles do occur. When they do, swift and accurate trouble-shooting, together with the necessary adjustment, repair or replacement indicated, must follow as soon as possible.

When it comes to locating trouble in any electronic control device, there is no substitute for a thorough knowledge of how that device works. This, together with effect-to-cause reasoning and a few simple voltmeter or ohmmeter tests, is all that is necessary to locate a majority of the troubles that occur. Methods of using voltmeters and ohmmeters are well known by most maintenance technicians. Effect-to-cause reasoning is nothing more than a determination of the most logical cause for the observed effect. It is based on a knowledge of the purpose of each component part and what will happen if that part fails. If there aren't enough clues for effect-to-cause reasoning to be used effectively, the following procedure will produce results.

Power supplies should be checked first, as temporary or permanent overloads may have blown fuses or tripped circuit-breakers. If a power cord is used, make sure it is firmly inserted in the proper power outlet. Be certain also that all connections are tight and that there are no broken wires.

If the power supply is functioning, the trouble must be in the control itself. Here again the trouble may be blown fuses or open protective relays. Possible causes for these effects are dirty switch and relay contacts, loose connections, broken wires, defective tubes, open resistors or reactors, and shorted capacitors.

If further steps are necessary to locate the trouble, the manufacturer's service data, and the maintenance department's own notes regarding that particular control should be consulted. Herein lies the value of keeping records which show all important voltage, current, resistance and capacitance values.

Once the trouble has been found, the following steps are practically automatic. That is, the defect must either be repaired or replaced. If the trouble was found to be a maladjustment, it should be corrected.

Such details of maintenance may have been unimportant before the war, but they certainly are not at the present time. Our war effort can not afford the crippling delays caused by equipment failures that might have been prevented.

UHF Equipment

(Continued from page 8)

end and thus provides for tuning. The horn may be used either as a receiving or sending unit.

For rectangular wave guides the rectangular sections are flared forming a rectangular horn. If the flare angle is the same along the vertical and the horizontal axis, the radiation

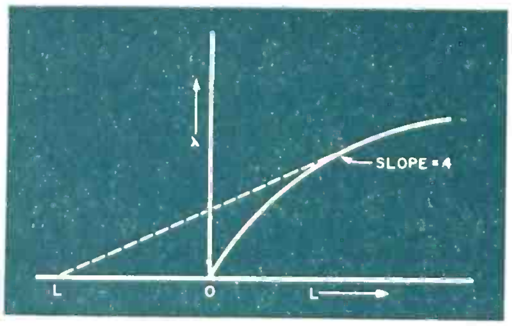


Fig. 11. Wavelength vs. line length.

pattern is essentially symmetrical about the axis of revolution. However, if the horn is flared only in one direction the electromagnetic radiation is narrow in the direction the aperture is narrow and wide at right angles to this direction. Such an assymmetrical radiation pattern is extremely useful in certain applications requiring a narrow beam along one axis and a wide beam along the other.

A predecessor to the horn radiator is the parabolic reflector. It was first put into commercial service in 1934 in the line-of-sight ultra-high-frequency communication link between St. Inglevert in France and Lymphne, England. A parabolic reflector is illustrated in Fig. 20. A half-wave antenna is placed at the focal point of a parabolic spun metal sheet which is large in comparison with the length of the antenna. The waves radiated from the antenna in the back direction are reflected from the parabolic metal sheet according to the simple laws of geometrical optics. The parabolic reflector is mounted so that it may be rotated in a horizontal plane, the angle of rotation being read on a protractor. The antenna is fed from the oscillator by means of a coaxial line. The connection is made through a T section, and a coaxial tuner, discussed previously in connection with wave guides, serves to match the antenna system to the coaxial line.

It is hoped that the preceding discussion may serve as a guide and aid in the construction of ultra-high-frequency apparatus.

Reference:

1. *Schulz, E. H., and Anderson, L. T., "Experiments in Electronic and Communication Engineering," Harper and Brothers, New York, 1943.*

2. *Sarbacher, R., and Edson, W., "Hyper and Ultra-High-Frequency Engineering," John Wiley and Sons, New York, 1943.*

Newsbriefs

(Continued from page 34)

on developments, while the Engineering Committee, with Mr. Jack Poppelle as chairman will assist in coordinating information regarding engineering improvements for post-war sets.

PANEL NO. 4 CHAIRMAN REPORTS

At a recent meeting of the I.R.E. held in New York, Mr. Howard S. Frazier, Chairman of Panel No. 4 on Standard Broadcasting gave a resumé of the work of this committee to date.

The main body of this RTPB group is divided into three sections, Allocation, Transmitters, and Receivers. Each group will perform certain functions under a central plan and report their findings to Mr. Frazier, Mr. Burgess Dempster, the vice-chairman, and the committee as a whole.

The Allocation Committee will review the FCC standard of good engineering practice and study the allocation problems involved in alleviating interference with existing stations and improving coverage in rural areas.

The Receiver Committee will consider standards and possible improvements for postwar standard broadcast receivers.

Like the receiver group, the Transmitter Committee will seek standardization and improvement in the transmitter field. Their work will be closely coordinated with that of the Receiver Committee in problems involving receivers and transmitters considered as a system.

F. M. Ryan, Vice-Chairman of R.T.P.B. Panel No. 2 on Frequency Allocation.

Under study are items dealing with FCC average sky wave curves, operation of compressor amplifiers, a review of present FCC rules regarding standard broadcast standards, with suggested revisions and additions.

The personnel of Panel No. 4, is made up of 63 members with distribution among the members, alternates and observers as follows: 25 broadcast operating engineers, 8 allocation consulting engineers, 14 transmitter design engineers and 12 receiver design engineers.

Dr. Ray H. Manson, Vice-Chairman of Panel No. 1, Sectrum Utilization.

NEW PLANT

Western Electric, for 75 years a manufacturer of communications equipment and now almost wholly engaged in war production, has leased Area 2 of the Eau Claire Ordnance Plant at Eau Claire, Wisconsin, formerly engaged in arms production.

Western Electric Company's war production responsibilities have grown beyond present manufacturing facilities, which include three main plants at Chicago, Ill., Kearny, N. J., and Baltimore, Md., and numerous distributing house shops located throughout the country.

Although the plant, which is located midway between Eau Claire and Chippewa Falls, is well suited for the type of work Western Electric will perform, some changes will have to be made to conform to Western Electric's processes. As soon as these have been completed, the Company expects to begin operations. Capacity manufacture will follow as rapidly as equipment can be obtained and personnel trained.

TUBE STANDARDIZATION

A subcommittee, known as the JAN-1, has been functioning as a department of the Joint Army and Navy Standards Committee, for the purpose of standardizing tubes for both army and navy equipment.

Four agencies of the War and Navy Departments are the active participants in this program, the Navy Bureau of Ships, the Signal Corps Aircraft Signal Agency, the Signal Corps Ground Signal Agency and the Signal Corps Standards Agency.

Contractors of either the Army or Navy may submit standardization procedures deemed necessary to increase production and inspection time. The subcommittee then makes the requisite tests and recommendations for standardization. This committee has achieved this standardization for a great number of often used tubes for navy and army electronic equipment.

Work is still continuing on other more complex and less used tubes in the hope that easy replacement of needed tubes may be made from joint tube inventories of the two Services, thus avoiding delay and overstocking of tubes.

This standardization procedure has resulted in an interesting quotation from a British Report on *Lessons in Signal Operation* from Burma, "American tubes are superior because they are sturdier, and standardized and interchangeable."

R-F Feeders

(*Continued from page* 25)

ally includes a reactance, Z_2 may include it and therefore Z_2 cannot be preassigned with any great degree of certainty. If Z_1 is made the independent quantity and assigned a value of zero, the T network becomes an L network with the equations (15), (16), and (17) reducing to:

$$\cos\beta = \sqrt{\frac{R_2}{R_1}} \quad \ldots\ldots (21)$$

$$Z_2 = -j\,\frac{R_2\cos\beta - \sqrt{R_1 R_2}}{\sin\beta} \quad \ldots\ldots (22)$$

$$Z_3 = -j\,\frac{\sqrt{R_1 R_2}}{\sin\beta} \quad \ldots\ldots (23)$$

The shunting element will be capacitive if β lies between zero and 180 degrees and inductive for values between 180 degrees and 360 degrees. Since the shunting element should be capacitive, the former range for β should be selected and Z_2 will generally be inductive. Equation (21) also indicates that R_2 should be less than R_1 in order to obtain a physically realizable L matching network. This fact limits the usefulness of the L type matching network.

The foregoing analysis has not included the effect of losses and the value of Q of the impedances upon the performance of the networks. It is necessary to maintain the losses at a low value while the Q must be high in order to allow for the application of the formulas in this article.

The tabulation and discussion of the properties of r-f feeders and associated networks are in convenient form in this article for future use and reference.

TECHNICAL BOOKS

"HEARING," by S. S. Stevens and H. Davis. Published by *John Wiley and Sons, Inc.*, 440 Fourth Avenue, New York, N. Y. 489 pages. Price $4.50.

This book is an authoritative account of the acoustical properties of the human ear, and includes experimental results relating to loudness, pitch and frequency sensitivity. These topics are analyzed in a manner which enables the results to be applied to architectural as well as electro acoustics. This treatment of the subject will be of particular interest to the acoustical engineer regardless of his specialized branch of science.

Such interesting topics as auditory masking are studied in detail with the aid of empirical charts and graphs which are of value to design engineers who are confronted with the problems of eliminating undesirable sounds and noises in industrial applications.

Not since Helmholtz wrote his treatise on human hearing in 1863 has such a comprehensive work on the subject of human hearing in terms of electrical phenomena appeared. Since that date great vistas of new technical knowledge have opened and the necessity for such a work as this one by Drs. Stevens and Davis was created.

Formulas for auditory phenomena in electrical terms make up an interesting section of the appendices. Tables and charts showing ratios in decibels as well as glossary of terms further enhances the value of this text. A most complete bibliography covering domestic as well as foreign writings on the subject of human hearing is included for further study on the subject.

"ULTRASONICS," by L. Bergman and translated by H. S. Hatfield. Published by *John Wiley and Sons, Inc.*, 440 Fourth Avenue, New York, N.Y. 264 pages. Price $4.00.

Ultrasonics applied to submarine detection was one of the most important applications for this science in World War I. Similar applications are being made in the present conflict, however by referring to an article on the subject of Ultrasonics in the February issue of this magazine, new and varied uses may be visualized, all of which are not related directly to pursuance of war.

Since this subject is again receiving considerable attention, it is well to be aware of the textual material that exists on the subject.

This book is divided into five main topics, each of which occupies one chapter in the book. The first part deals with the available methods for generating ultrasonic energy. These methods include mechanical, thermal, magnetostriction and piezoelectric generators. The piezoelectric method of generating ultrasonic energy is the most effective and convenient method developed thus far. The construction of typical crystal generators and their associated circuits are discussed in chapter 1.

The second part of this book presents the methods of detecting and measuring ultrasonic waves by mechanical, thermal, electrical and optical means. The electrical and optical methods, which are extremely sensitive, are very well explained with complete illustrative material. The placing of experimental methods, with the results obtained, in the primary position, with a discussion of the theory last, is a wise choice as the easy understanding of the matter assembled in this manner is facilitated.

The third and fourth chapters include various experimental methods of measuring the velocity of ultrasonic energy in liquids, gases and solids.

The fifth and final chapter is devoted entirely to the applications of ultrasonics. Various uses ranging from applications in television to chemical, thermal and biological effects are analyzed authoritatively and clearly with the aid of diagrams and photographs.

This book includes a comprehensive bibliography of over 450 references to articles dealing with the subject of ultrasonics. To persons interested in this subject this book offers a basic treatment of the subject as well as a complete and valuable bibliography for further study.

"TABLES OF FUNCTIONS WITH FORMULAE AND CURVES," by E. Jahnke and F. Emde. Published, 1943, by *Dover Publication*, 31 East 27th Street, New York. 303 pages. Price $3.50.

This volume contains a collection of tables, formulas and curves of a great many mathematical functions justifying its reputation as the world famous computing aid for workers in mathematics, physics and engineering. An outstanding feature of this book is the manner in which the graphs are drawn, a great many of which are plotted as contour surfaces representing the functions in three dimensions. This volume includes the original German text on the same page with the English translation.

Of the various mathematical functions tabulated, some are of particular interest to the radio engineer. A few of these important functions are the sine-integral, cosine-integral, exponential-integral, elliptic-integral and Bessel functions with real and complex arguments. These functions find application in the analysis and design of filters, thermionic tubes, high-frequency resistances, wave guides and FM side bands.

This book was first published in 1933 and a new edition appeared in 1938 with improvements and omissions of various parts of the 1933 edition. The 1943 edition is a reprint of the 1938 edition with the omitted portions from the 1933 edition included.

"PRESENT SAVINGS AND POST-WAR MARKETS" by Sumner H. Slichter. Published by *McGraw-Hill Company*, New York. 73 pages. Price $1.00.

In this book Prof. Slichter has presented a very real and urgent problem now facing the United States, that of inflation and the subsequent postwar depression.

Mr. Slichter is presenting facts, not opinions, regarding our present monetary structure. He has prepared a thoughtful analysis of the crisis we may have to face if the public indulges in a buying spree comparable to the one which plunged the country into the depression years.

Industry is accumulating vast liquid assets in the form of cash and bonds and it is evident that care in expending such vast sums must be taken to avoid the over expansion which seems likely in view of the competition which will develop for the new and rich consumer markets which will open up after the war.

This book deserves a place on the reading shelf of every thoughtful American who can remember October 1929.

"RADIO RECEIVER DESIGN," by Dr. K. R. Sturley. Published by *John Wiley and Sons, Inc.*, New York. 421 pages. Price $4.50.

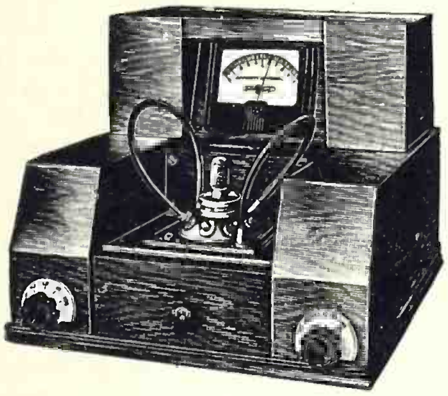
Dr. Sturley has made a real contribution to the art of receiver design in this book. In the past it has been necessary to consult many texts in order to secure a lucid explanation of the components of a radio receiver. But here between two covers, Dr. Sturley has gathered a wealth of material on the subject, which he presents in an easily understandable form.

Beginning with the aerial, the author traces the signal through the re-

(*Continued on page* 46)

New Products
(*Continued from page* 38)

capacity meter a worthwhile addition to the usual testing and inspection equipment to be found in most factories and laboratories. Large quantity testing may be handled quickly and



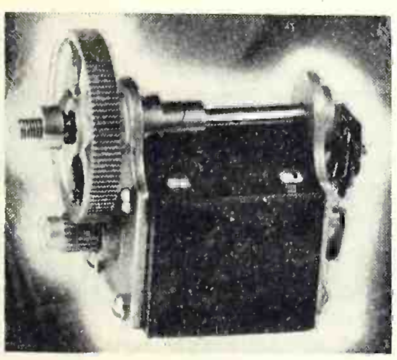
efficiently when this instrument is made part of the standard inspection equipment.

Interested persons should address inquiries to Dept. RE-4, *Technical Apparatus Company, 1171 Tremont Street, Boston 20, Massachusetts.*

HAND GENERATORS

One of the sturdy components being built into the Signal Corps' famous field telephones, the EE-8 and EE-8A, is a new lightweight generator made by Kellogg Switchboard and Supply Company of Chicago, Illinois.

Known as the GN-38-B, this generator is standard equipment for all of the field telephones for the Signal Corps. A redesign of the generator made possible the saving of critical materials and scarce labor.



While this component is being built for the armed services exclusively at the present time, post-war uses of field telephones of the type used by the Signal Corps may be made by the forestry services, aviation, construction projects where quickly installed temporary service is needed for rapid communication.

Inquiries regarding this generator should be addressed to *Dept. RE-4, Kellogg Switchboard and Supply Company, 6650 South Cicero Avenue, Chicago 38, Illinois.*

Personals

PAUL L. CHAMBERLAIN has been recently appointed Manager of Sales of the Transmitter Division of General Electric's Electronics Department. To this position Mr. Chamberlain brings a wealth of experience in the radio field. He has held many important sales positions with radio and electric companies. Until his recent promotion he was in charge of the Army Aircraft Section of the Government Division.

H. A. CROSSLAND'S new position with the General Electric Company's Electronics Department is that of Manager of Sales of the Receiver Division. Since 1942 Mr. Crossland has been at the Schenectady office in charge of military radio contracts. In his new post he will be responsible for all sales matters of the Receiver Division and will maintain offices both in Bridgeport and in Schenectady to be available for consultation.

PAUL W. POLK, vice-president of The Sheffield Company of Dayton, Ohio, has been granted a leave of absence from his firm to accept a commission in the Navy. He has already reported to duty. Mr. Polk served as manager of the field distribution and engineering department and was the acting supervisor of all the educational, distribution and field activities. He is an aviation enthusiast and holds a pilot's license.

HARRY S. ROSE, formerly the Chief Engineer of the Progressive Welder Company, Detroit, Michigan, has been placed in charge of all Service and Sales Engineering activities of the company. Mr. Rose was connected with the Chrysler Corporation in the capacity of tool engineer before joining the engineering staff of Progressive Welder in 1941. His work has been chiefly in the field of resistance welding.

G. J. STEGEMERTEN is on leave from the Westinghouse Electric and Manufacturing Company and is now serving as consultant to the Secretary of War. His work in this position will involve study of certain administrative functions in connection with the various arsenals and ordnance plants operated by the War Department. The position which he vacated at Westinghouse was that of Staff Supervisor of Industrial Methods.

F. W. CUFFE, a Commercial Engineer with General Electric Company for many years, died suddenly while on a business trip to Cleveland, Ohio. Mr. Cuffe was born in London in 1893 and came to this country where he became a citizen in 1930. Since that date he held posts in the Industrial Engineering Department.

Electron Optics

(Continued from page 19)

the corresponding point of the optical image on the cathode. By means of horizontal and vertical deflecting coils the image is moved across the anode plane so that a different part of the image falls on the aperture at each instant, to accomplish the scanning action necessary for television transmission.

The image dissector is generally used in conjunction with another electron optical device to increase its sensitivity, the secondary-emission electron multiplier, one form of which is shown in Fig. 8. It consists of two rows of plane electrodes in a tube, of which only the bottom row need be secondary emitters; and each electrode is made positive with respect to the preceding one. A transverse electrostatic field is maintained between the upper and lower sets of electrodes, and a magnetic field is established perpendicular to the axis of the tube and to the field between the two sets of electrodes. Electrons leaving A are caused by the combined electric and magnetic fields to move in such a path that they strike B, where a greater number of secondary electrons are released, which are in turn deflected so that they strike C, and the multiplication keeps up in this manner until the final output is collected at the last electrode. Multipliers of this type have been constructed using as many as twelve stages, and current amplifications of several million have been

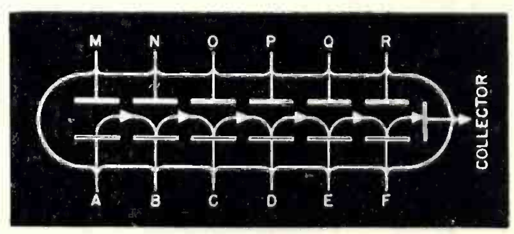


Fig. 8. A multiple plate electron multiplier.

obtained. It is interesting to note that although it had been recognized for some time that secondary emission could be used as a means for amplifying small electron currents, the earliest schemes for electron multiplication gave very poor results and the first efficient models were produced only after the development of electron optics had provided the basis for a suitable design.

The devices which have been described above are by no means all of the applications of electron optics.

It is to be hoped that as the application of electron optical reasoning becomes more familiar, it will become one of the more valuable techniques in the field of electronics.

Industrial Review

(*Continued from page* 32)

These magnets are characterized in electrical instrument design by their relatively large cross section and short length which produce a given flux across a given air gap ration. They are highly resistant to demagnetizing fields due to their high coercive force. Alnico materials have been widely used as instrument magnets and their manufacture may be carried out by either of two methods—the sintering process or casting. The first is usually employed to produce relatively small magnets sometimes found ideal for damping magnets and the like. The latter process is used for the production of the majority of alnico magnets.

The ideal magnet from the standpoint of the instrument designer would be one having high coercive force, residual induction and available energy, and which had good machining and fabricating qualities. An approach to this ideal has been made in the cobalt-molybdenum-iron alloys more commonly known as "comol." Comol, whose typical composition is 12 percent cobalt, 17 percent molybdenum, balance iron, contains a minimum of the critical metals; it can be easily cast, and when properly heat treated, can be readily drilled, milled and machined. As a result, accurate machining dimensions permit the degree of precision which is required to fully utilize this material in instrument magnets.

A coercive force of about 245 is obtained as compared with 210 for 36 percent cobalt with a residual induction of 10,300, higher than either 36 percent cobalt or alnico II, and a maximum energy value of 1,100,000 as compared with 930,000 for 36 percent cobalt and 1,650,000 for alnico II.

A magnet of the comol type containing appreciably lower percentage of the critical elements has been utilized in instrument application as the permanent magnet in a new "thin" line of direct current and radio frequency G-E small panel permanent magnet-moving coil type instruments.

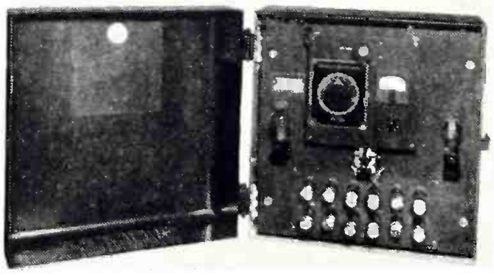
The General Electric Company of Schenectady, New York, is responsible for this development.

* * *

Electric Control

A NEW current-regulating compensator for resistance welding machines has been announced by the electronic control section of the General Electric Company. The new compensator is specifically designed to facilitate consistent welds by holding the rms, or true heating value, of the weld current constant for any heat-control setting, without requiring continual manual adjustment.

After the predetermined heat-control setting for a particular job has been made on the compensator, it requires no further adjustment. It will hold the welding current to a varia-



tion of plus or minus two per cent under the same conditions which would cause the unregulated welding current to vary plus or minus 20 per cent.

The compensator consists of an electronic control circuit which automatically retards or advances the firing point of the ignitron tubes used to control the welding current, thus holding the current constant regardless of line voltage changes or welding conditions. Housed in a sturdy steel enclosure, the compensator can be readily mounted on or near the welding machine. A desirable feature of the compensator is that it can be applied to most General Electric resistance welding controls which incorporate the phase-shift method of heat control.

This equipment is available from *General Electric Company, Electronic Control Department, Dept. RE-4, Schenectady, New York.*

* * *

RCA Electronic Oven

A NEW use for electronic heating has been found by RCA's Electronic Apparatus Section in the development of the electronic oven for high-speed molding of plastics. Heretofore many possible uses of plastics were impractical due to the time involved in curing and molding the preforms or "biscuits."

Savings in time and material have been effected because of the automatic feature of the oven. The preforms are placed in the oven, a starter switch is snapped and the molding process is under way. When the plastic has reached the desired temperature, the oven door opens automatically and the power is turned off. Overcuring and undercuring of plastics is eliminated in this manner.

The possibilities of this method in securing stronger plastic parts and the use of this material for new applications in post-war production is anticipated by the manufacturer, *Radio Corporation of America, RCA Victor Division, Camden, New Jersey.*

* * *

New Installation

OF INTEREST to radio engineers is a recent installation of Andrew Coaxial Cables in the Zenith FM station WWZR located on top of the Field Building in Chicago.

Feeding the four bays of the turnstile antenna are eight Andrew 1⅝ diameter coaxial cables. These lines, as well as the 4⅛ diameter cables feeding power from the transmitter, are used in a "back-to-back" connection to provide a balanced 140 ohm transmission line. All cables are equipped with Andrew gas tight terminals and the entire system is constantly maintained under gas pressure.

The Andrew Company of Chicago is a pioneer in the manufacture of a complete line of coaxial cables and all necessary accessories, including junction boxes.

Nomogram

(*Continued from page* 21)

As an example, consider an analysis of a simple equalizer consisting of a 450 ohm resistance shunted by a 0.5 mfd. condenser at a frequency of 1000 cycles per second. By substituting the frequency and capacitance values into the formula $\frac{1}{2}\pi$ fc this gives a reactance of 319 ohms. To apply the chart, place a straight-edge in such a manner as to line up the 450 ohm point on the R scale and the 319 ohm point on the X scale. The corresponding intersection on the R/X scale is found to be 1.41, and the angle of the impedance, read on the adjacent θ scale, is 54.5 degrees. A horizontal projection of the ordinate value of 1.41 on the graph to the curve corresponding to R equal to 450 ohms gives 260 ohms for the amplitude of the impedance as read on the abscissa, $|Z|$.

Since the reactance is capacitive the negative value of the phase angle is used, giving as the final result:

$$Z = 260\underline{/-54.5^\circ}$$

Technical Books

(*Continued from page* 42)

ceiver to the speaker in an orderly and thoroughgoing manner.

This text presents radio in a highly mathematical manner hence this book is not recommended for home study, but it will serve the engineer or radio man with a valuable reference manual for working formulas and other factual material so necessary in the design and construction of trouble-free radio receivers.

An extensive bibliography which accompanies each chapter, will provide the serious student with textual material for further study on any of the subjects discussed.

"MATHEMATICS OF RADIO COMMUNICATIONS" by Dr. T. J. Wang. Published by *D. Van Nostrand Company,* New York. 366 pages. Price $3.00.

Many a practical radio man and student radio technician has been waiting for a text of the nature of Dr. Wang's "Mathematics of Radio Communications."

Dr. Wang has assumed little previous experience with the mathematics encountered in radio work and it is in this quality of straightforward simplicity of presentation that the value of this book lies.

Suitable as a home-study text, this book might also be used to advantage in radio schools. The author has correlated the mathematical theories in his text with definite radio applications. Thus the student is aware at all times why he is studying the mathematics involved in instantaneous rate of change or the complex numbers vector. The radio application accompanies the problem in mathematics under discussion.

The text is complete enough to include some of the more advanced work including integration as summation, Fourier series, simultaneous linear equations and exponential functions. An advanced radio technician might well profit by a review of Dr. Wang's presentation of the higher mathematical subjects treated in this book.

"ELECTROMAGNETIC WAVES" by S. A. Schelkunoff. Published by *D. Van Nostrand Company, Inc., New York.* 530 pages. Price $7.50.

Dr. Schelkunoff's contributions to technical publications dealing with electromagnetic radiations exemplify the spirit of his entire book entitled "Electromagnetic Waves." As the title implies, the author analyzes the radiation and propogation of electromagnetic waves through various media and with different boundary conditions. The approach to these problems is surprisingly systematic in nature and is based upon a few important mathematical procedures outlined in the first three chapters of the book. The first chapter presents a review of the most important parts of vector analysis with emphasis on the three important coordinate systems used throughout the book. They are the rectangular, cylindrical and spherical coordinate systems. A further extension of the required mathematical methods are made in the next two chapters using functions of a complex variable applied to discontinuous functions as the "unit step" and "unit impulse" functions. An interesting correlation between the current due to a unit impulse and Green's function is outlined in Chapter two.

The remainder of the book, following the first three chapters, is devoted to the properties of electromagnetic waves and their relation to circuits, transmission lines, wave guides and resonators. Of the various basic concepts introduced in this book, the impedance concept has received a great deal of attention and space, in fact, the last chapter is entitled "Impedance Concept."

Chapter four is a resumé of the fundamental equations of Maxwell, with the aid of the MKS system of units. These equations are also written in the complex form so that steady-state a-c conditions may be visualized for the electromagnetic waves in source free regions as well as in dielectrics and conductors.

Television Tubes

(Continued from page 28)

point where the first field scan began, as shown in the figure, and therefore lies above the first line in the first field by the thickness of one line. From this position the beam can now sweep out the additional 262½ lines in reaching the bottom of the area and returning to the top. At the conclusion of the second field scan, 525 lines (a whole number) will have been swept out and the spot has returned to its original starting position. The third field, which the spot is now preparing to scan, will fall directly in the same position as the first field.

It is necessary that the amplitude of each vertical motion be held constant; otherwise, the interlaced relationship in this method of scanning will not be preserved. It is also very important that the timing of the beginning of each field be accurate. If at the beginning of a field, the spot is not on the same level with, and exactly one-half line distant from, the beginning of the previous field, the lines of one field will tend to overlap the lines of the preceding field. In television parlance this defect is known as "pairing" of the fields. The result is a reduction in the detail of the reproduced picture in the vertical dimension.

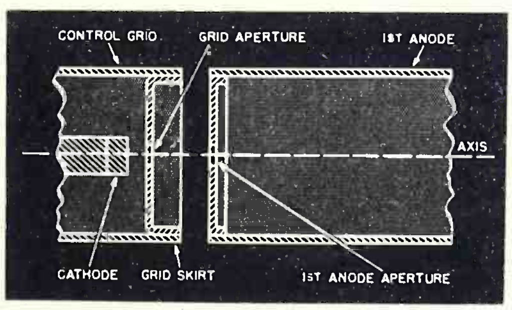


Fig. 3. Simple three-element lens.

The exploring spots at both the transmitting and receiving ends must sweep out a similar pattern. Not only must the two scanning patterns have the same number of lines and aspect ratio (ratio of width to height), but also the spot at the receiver must be so synchronized with that at the transmitter that at every instant the two spots will be at the same relative positions on their respective patterns. Thus, if the brightness of the spot at the receiving end is controlled by the amplitude of the video signal, a reproduction of the image being transmitted will be formed on the viewing screen. In a practical television system the amplitude variations in the video signal, caused by the scanning beam sweeping across the light and dark areas of the subject, are applied to the control grid of the electron gun. Also transmitted as a part of the video signal are the "horizontal" and "vertical" synchronizing impulses which are applied to the horizontal and vertical deflecting elements respectively. The purpose of these impulses is to maintain the exploring spot at the receiver in exact synchronization with that at the transmitter.

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