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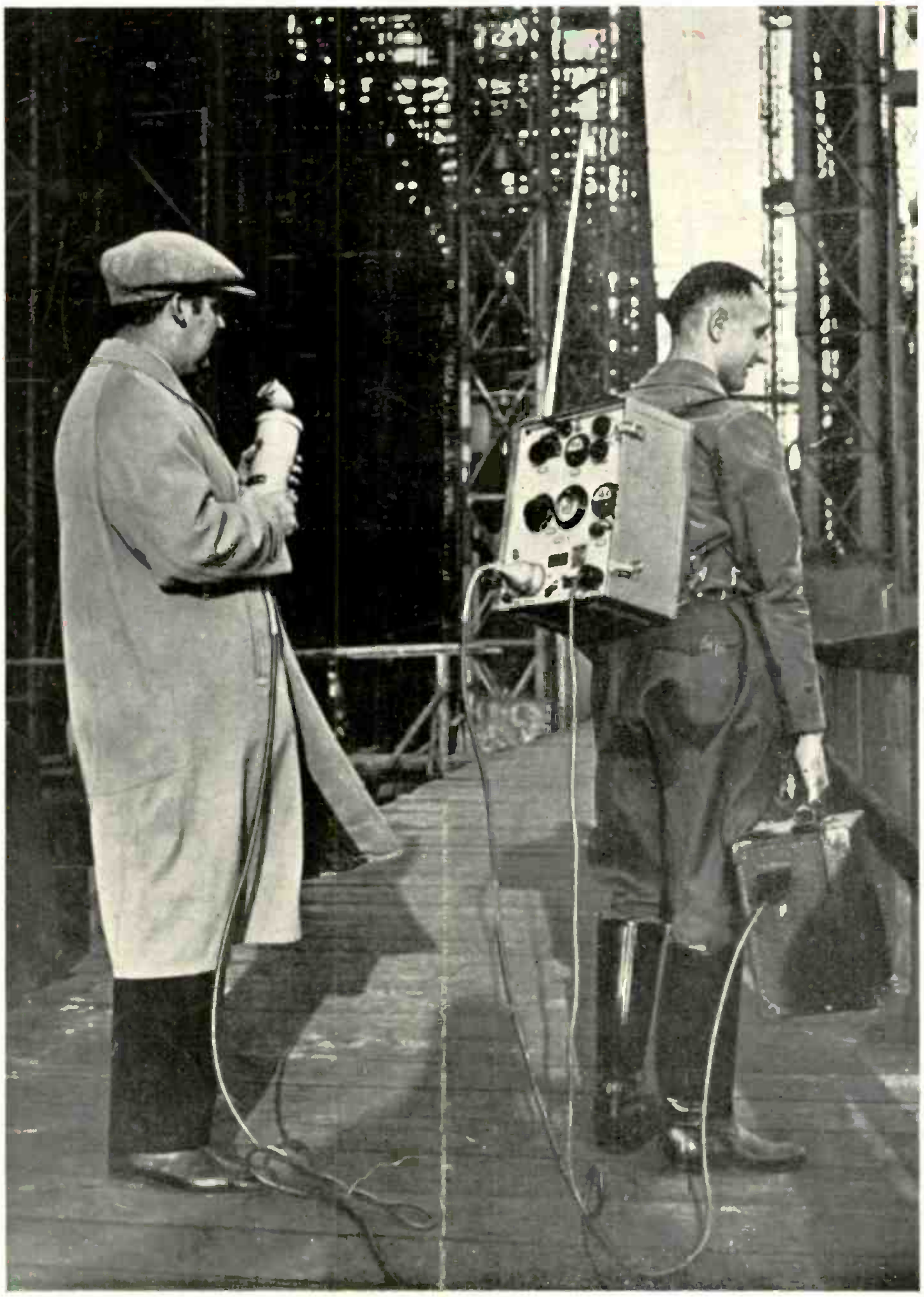

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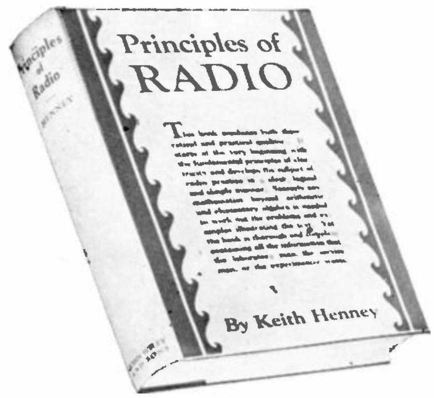

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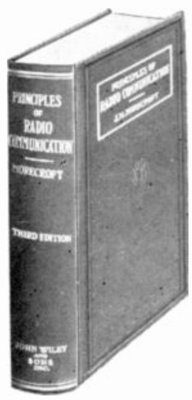

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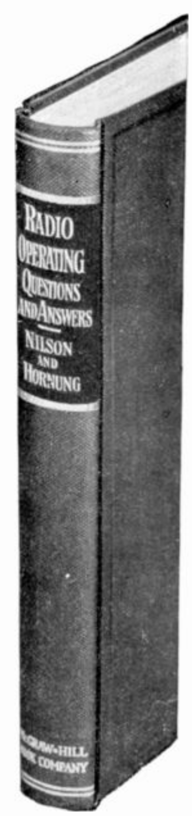

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DURING the past year, in talking with various radio operators, this subject has come up frequently: Why can't and shouldn't the commercial radio operators have an organization something like the amateur operators have in their American Radio Relay League, and a publication in which they can have published descriptions of various pieces of equipment which they have built and kinks about various improvements they have made and are using. The organization could be called the American Society of Radio Engineers or some such suitable name. I believe the membership fee should be a subscription price to COMMERCIAL RADIO plus say fifty cents for a membership button. I believe that an organization of this kind would be genuinely appreciated and supported by commercial operators. At least I have heard many of them express a desire for just such an organization. To start such an organization I would suggest that you print a notice in COMMERCIAL RADIO and then start a magazine department for the organization.

ROY H. MCCONNELL,
Chief Engineer KGFW

COMMERCIAL RADIO

(FORMERLY "C-Q")

The Only Magazine in America Devoted Entirely to the Commercial Radio Man

Contents for May, 1935

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The Photo-Electric Effect

By BERNARD EPHRAIM, E. E.

An Advanced Study Based on The Quantum Theory.

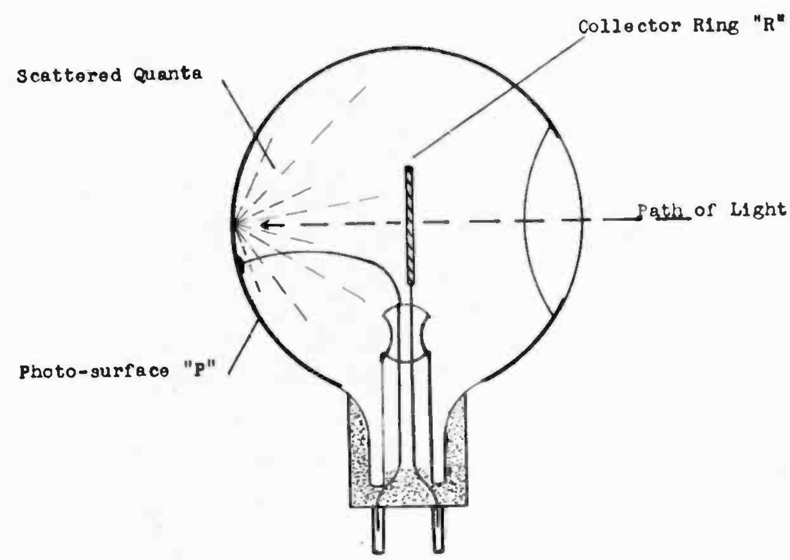
THE reception given to the quantum theory as a means of explaining certain electronic phenomena has led to its general acceptance by many investigators in the field of electronics and atomistics. The quantum theoretical formulation of the photo-electric effect was developed by Albert Einstein, the noted physicist, whose researches in the field of atoms, molecules and quanta represent one of the most outstanding developments of this age. The exposition of the quantum theory in its many ramifications is too vast to be recited here. The possibilities of treating such a subject specifically without too many generalities may be satisfied by selecting only the more qualitative and quantitative data. With these premises, it is possible to explain the existence of certain effects, that is, effects dealing with the modern physical concept of matter, electricity and energy. The physical developments underlying the photo-electric effect have been regarded by many as matters of conjecture due to the impossibility of reconciling conflicting theories which involve the phenomenon, light, and the interactions between light and electricity. No attempt of a reconciliation will be made here; however, the hypothesis of light-quanta together with the experimental facts gathered in the field of electronics described in the subsequent paragraphs explanations of the quantum theory as it pertains to the photo-electric effect.

Synopsis of the Quantum Theory

The quantum theory (the word "quantum" has evolved from the Latin word, quantis, which means "how much." A single unit of energy is termed as a quantum, the plural being quanta.) was introduced by Max Planck (1900), who hypothicated that radiated energy in the form of heat or light rays was made up of small units, each unit representing a certain amount of energy, any one of which unit may liberate its energy and produce an effect. Planck also states that small amounts of energy are interchanged by electronic transition when energy is being absorbed or emitted in an atomic system, and that these amounts are in definite quantities, each quantity representing an independent unit of fixed magnitude. It can be seen that such a theory does not assume that energy is of a continuous nature, this is true and has been confirmed by many investigators. Of late some modifications have been added to the original theory, and today we have what is known as quantum (wave) mechanics, describing the effects and behavior of quantum conditions. How the quantum theory is applied to the photo-electric effect follows.

Limitations of Physics as Regards Photo-Electricity

To give a categorical answer to the question: Is light undulatory or corpuscular, is one of the greatest handicaps physics must overcome. From every source of research comes this perplexing question, and it is of the opinion of some that science is confronted with an impasse, due primarily to the irreconciliation of a group of phenomena to a certain set of acceptable facts. According to experimental conclusions that have been gathered regarding the phenomenon, light, it might be acceptable to say that light must be undulatory. Yet, on the other hand the facts that have been established regarding the corpuscular theory are just as convincing as the evidence offered by the wave theory. The principle of both theories have been confirmed by observers and investigators. In passing, it may be conceded for the while that, the photo-electric effect *cannot* be explained on the basis of the wave theory of light as it is generally understood. This is because the effect has always been described as a function of the corpuscular theory or as now termed "quantum theory".



Quantum Theory Explanations

In order that the evolutionary principles of the quantum theoretical formulation be better understood, a brief resume of the more important research findings will first be cited.

EFFECTS OF RADIANT ENERGY: When a radiation of energy such as a light ray impinges upon a photo-sensitive surface, a part of that energy is absorbed by the surface itself, whereas, the major portion is reflected. That portion of the radiation which is absorbed is consumed by the metal, so as to disengage and eject electrons from its surface. The rays of light, just referred to, are those belonging to the visible spectrum. Some metals are photo-sensitive to radiations other than those belonging to the optical spectra, such are X-radiations; Gamma radiations; Ultra-violet and Infrared rays. Each photo-sensitive metal responds only to its characteristic stimuli, and will not emit photo-electrons above or below the region of selective absorption.

When taking into account the effects of radiant energy, the consideration of the following facts will prove invaluable: Light rays falling upon a photo-sensitive surface carry to that surface, energy and impulse. The energy which an electron may be liberated by a radiation of light is dependent upon the frequency of the radiation which has caused its ejection. This energy is dependent not on the energy of the light radiation but on its frequency or inverse wavelength. The energy given to the photo-electron is received from the light ray plus the energy of the electron emitted. The intensity of illumination determines the number of electrons emitted together with an added ratio-increase in the escape energy of each electron. The total energy of a photo-electron comes from degenerate electrons in the emitter plus the energy received from the light less the energy of escape.

Optical radiations of certain frequencies bring about changes in the energy of electrons being emitted. The amount of energy changes are proportional to the frequency which brought about such a change. Light rays in the lower end of the spectrum cause smaller amounts of electrons to be emitted, while radiations found in the higher spectrum cause a greater efflux of electrons to be liberated. These emissions are proportional to the frequency of light radiation inundating the surface of the photo-sensitive metal.

QUANTUM FORMULATION: From the effect regarding proportionality, previously stated, a "constant" may be determined by dividing the energy of the ejected electrons by the frequency of the radiation causing photo-electric emission. This constant, which is a ratio between energy and frequency, is applicable to all atomic phenomena. It was first discovered by Max Planck, and is known as the universal constant," denoted in all electronic formula by the letter, h, which is the magnitude of the quantum. The value of this physical constant is: (6.547 plus or minus 0.008) 10^{-27} erg seconds. The energy content in a radiation of light of frequency v, is expressed by the product of the radiated frequency v, into Plancks constant, h; that is to say, hv. The intensity of light is measured by the number of quanta hv present in the radiation. At this point it should be noted that it is the quantum which governs and controls all exchanges of energy. A simple rule to remember is: That during an energy transition of frequency v, cycles per second, there will be exchanged in like amount the quanta hv. The photo-electric effect is an excellent example to which this rule applies; remembering, *that the phenomenon of photo-electricity is regulated by the quantum, and without it it is inexplicable.*

Electrons and Atomistics

The Bohr atomic system postulates a scheme whereby atoms consist of a central positively charged nucleus called a proton, surrounded by electrons at planetary distances revolving around the nucleus in orbits according to the inverse-square law. This atomic system has been given the name of the nuclear atom. The charge retained in the nucleus of an atom is what designates its weight, while the attendant electrons revolving around the nucleus is that which determines the atomic number. Atomic numbers run from one to ninety-two, which are the ranges given to the elements of nature. The electron, being a constituent of every atomic system, has numerous characteristics, some of which pertain to the electron itself and others to its behavior. Of interest regarding the photo-electric phenomena, the electron becomes a matter of great importance, not so much as the electron being an entity or that regarding its environment in photo-sensitive metals, but as regards its relations or activity under certain stimuli, namely, light.

The two following statements concern electron mechanics; these will be coupled to the next subtopic. (1) that the energy needed for an electron to escape from its orbit is double the energy required for its circular revolution, and that the energy of possible escape from one orbit to another is proportional to the effective attractive charge in the nucleus of the atom and inversely as the electrons' distance is away from the central charge or proton. (2) that the kinetic energy of an electron is proportional to the square of its speed, algebraically written as $\frac{1}{2}mv^2$, where m is the moment of the momentum of the electron, and v its velocity.

"Bound" Electrons

Two classes of electrons are ascribed to electronic conduction in metals, these may be (1) bound electrons, which are constituent electrons of the atoms of the metal and, (2) free electrons, which are free attendant electrons in the interatomic spaces. A question may now be brought forth: Why is it that a photo-electron does not come from a bound electron in a photo-sensitive metal? The answer, taken from mechanics of quantum phenomena, may be formulated thusly: The, mass of a quantum in a light radiation has a considerabe amount of kinetic energy when taking into consideration that the speed of light rays is ten times greater than the migrating electrons in an x-ray tube; therefore, the v^2 factor in the equation $\frac{1}{2}mv^2$ for kinetic energy will be 100 times greater. It follows, then, that when a quantum collides with an atom, an electron should be displaced in its orbit and, during transition should emit an electro-magnetic wave. On the other hand, if the electron was completely removed from the atom, the result would be of ionization and the emission of a photo-electron. This last statement was at one time accepted as "the" explanation, however, lately has been regarded as being erroneous as pertains to emissivity in photo-sensitive metals. This, now, disembraces the theory of ionization by light-ray impacts due to the fact that light rays cannot free a bound electron, that is, an electron which is part of the atoms of the metal.

From the aforegoing, it is quite evident that a bound electron has a greater affinity to stay in its own orbit than to wander from it due to the great attractive power of the nucleus; furthermore, the energy required to free a bound electron is greater than the energy expended freeing a free electron. The probability that photo-electrons come from free electrons is much more of a possibility than a probability.

Free Electrons

The particular free electrons involved in the photo effect in metals are a group of electrons which are regarded from the point of view of natural mechanics as being degenerate. In addition to the large numbers of free degenerate electrons at room temperature there are also a few non-degenerate electrons. The electrons which escape in the photo effect are free electrons of both types. Most frequently, however, they are free degenerate electrons. As a photo-sensitive metal is heated up the proportion of electrons which are degenerate decreases and those which are normal free electrons increases, at first slowly, and then more rapidly as the temperature increases. When temperatures of white heat, such as 1500 degrees C, the proportion of normal electrons in metals becomes quite appreciative. The normal electrons have the temperature distribution of their surroundings. The degenerate electrons have other temperature distributions. It is only the normal electrons liberated photo-electrically that will have temperature distribution and will be temperature sensitive. Those at low temperatures, 99.9% or more of the photo-electrons are degenerate and temperature insensitive. At higher temperatures such as 1500 degrees C, there may be 20% of the temperature sensitive photo-electrons and 80% degenerate. Then 80% of the photo-electric effect will be temperature sensitive. The fact is that at high temperatures the photo-electric effects do show some temperature variation.

The energy of the escaping photo-electron consists of the energy of the degenerate electrons in the atom plus energy extracted from the light hv less the energy of escape. If the photo-electron is one of the temperature electrons, the energy which it has will be hv plus the energy of motion which it has due to its temperature less what is called the work function to escape. This function is best explained by the Einstein photo-electric equation which follows.

Einstein Formulation

Electrons leave an irradiated photo-metallic surface with a definite velocity. The velocity of these electrons may be determined by the application of the quantum relation for impact: A light-quanta hv liberates an attendant electron

(Continued on Page 22)

Wrinkle from KGCU

By JAMES E. GILFOY, Ch. Eng.

USERS of the Type FD1 Visual Frequency indicator manufactured by Doolittle & Falkner, Inc., Chicago, Ill., may be interested in the methods we used at KGCU, Mandan, N. Dak., to remove the effects of strong R. F. fields from affecting the accuracy and operation of our frequency monitor.

Ordinarily this instrument should be used at some distance from any strong R F field such as a 100 or 250 watt output stage or larger. In our case here it was much more convenient to mount the frequency check in our regular transmitter racks and that is where we ran into trouble. The frequency meter fluctuating on heavy modulation and the Thyratron persisting in rectifying even when the thermostat was open thus raising the heat in the frequency monitor oven was above normal. To correct these conditions we first placed two 1 mfd. condensers in series and then across the 110 volt 60 cycle line for the frequency monitor, right at the monitor. The center tap of these two condensers is then grounded to a good low resistance ground.

Since we use Class B. modulation here we then changed the power leads for the monitor to a pair of wires which did not carry load to the Class B. stage, thus getting away from change in voltage at the monitor.

Lastly, we disconnected the end of the grid leak that connects to the common filament and permanently connected it to the other filament terminal at the tube socket. This results in increasing the bias voltage by approximately half the filament voltage which greatly helps in curing the trouble.

As an added change we use now the new FG 81 Thyatron which is less affected by stray R F fields. Our trouble was completely cured from then on.

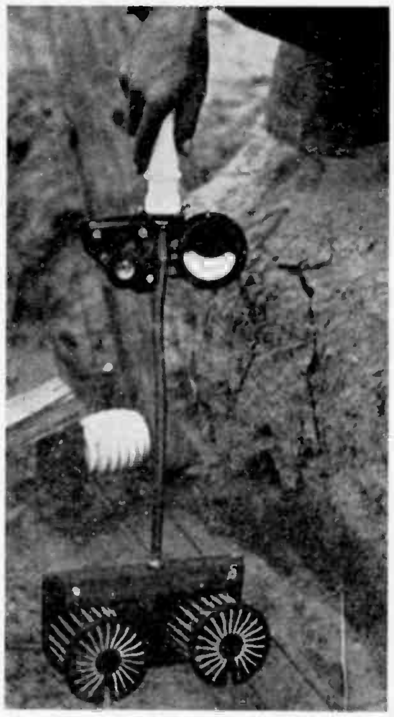
Book Review

SOS TO THE RESCUE, by Karl Baarslag. In this book Mr. Baarslag gives us the results of his many years of painstaking investigation and study on a subject that is close to the heart of every radio man. Sea-going radio operators should buy two copies, one for himself, and one to present to the captain of his ship. The one complete story of wireless; or as we now know it —radio at sea.

From the very beginning, Mr. Baarslag carries the reader through the early developments of wireless as a means of safety at sea, devoting a chapter each to the outstanding shipping disasters where wireless played an important part. Just a little different than anything we have ever read.

Mr. Baarslag naively states he will leave the romancing of the radio story to those who so cheerfully digress from the truth, and then by a painstaking collection of the actual facts presents to us in more lively and romantic fashion the complete story of distress at sea than we have ever read before.

A chapter is devoted to the "Republic" and Jack Binns (1909), the "Titanic" and Phillips (1912), the "Empress of Ireland" (1914), the "Antinoe" (1926), the "Vestris" (1928), right up to the



This instrument is being used around the conducting wires between the transmitter house and antenna tower. Europe shows us this one.

"Morro Castle" and other historic burnings of vessels at sea.

The story of the pioneer radio operators at sea, the story of girl marine operators, and other interesting tid-bits that will carry the reader through the last fifty pages of the book without wanting to be interrupted before finishing the volume. Every man who ever has, or will touch a marine radio key, as well as those who are at all interested in the romance of the sea will make it his business to read this book. Mr. Baarslag is also to be congratulated on his constructive style of writing this volume. Published by Oxford University Press, 310 pages. Price $2.50.

WORK

WORK is the station at York, Pa., and is using 1,000 watts, on 120 kc full time. At night the antenna is made directional so as to concentrate the signal AWAY from Akron, Ohio.

William N. Weaver is the Engineer in Charge, with Luther Mathoit in charge of the Control Room. Both of these engineers have been with WORK since its first day. William Frank Klugh, Jr., is the other engineer and he came to work at WORK in July 1934.

Most of the equipment used is of Powell make.

Weaver, the chief, is building a 500 watt ham station which he expects to have on the air in about three weeks. Will use, he says, voice on 20 meters and CW on 40 meters. The call W3AVO will be used. Mathoit will probaby come in for some operating, too. His call now is W3HF.

Interception of Publication

IN order that the public may be fully informed concerning the protection provided for private radio messages, the Commission suggests that each purchaser of a combination broadcast and shortwave receiver be furnished by the salesman with the excerpts from the Communications Act concerning the secrecy of radio messages and the penalty for violations. It is suggested that publishers of newspapers be very careful to observe the provisions of the Act.

It has also come to the attention of the Commission that newspapers have published information obtained from intercepting police messages, two-way conversations between ship and shore, etc. The publication of such information without permission is a violation of the Communications Act of 1934.

Reports reaching the Commission indicate that the public is increasingly intercepting police and other shortwave communications. Only in rare instances, it is believed, is this information abused. However, it was brought to the attention of the Commission that a young man in Baltimore intercepted a police call on a shortwave receiver in his home and notified law violaters that officers were coming to arrest them. The young man himself was taken into custody and found guilty in a police court for violating police regulations.

In view of the large number of combination broadcast and shortwave receiving sets in the hands of the public the Federal Communications Commission today issued a statement calling attention to provisions of the Communications Act of 1934, regarding the secrecy of certain radio messages and the heavy penalties provided for violations:

Section 605 of the Communications Act of 1934 provides as follows:

"No person receiving or assisting in receiving, or transmitting, or assisting in transmitting, any interstate or foreign communication by wire or radio shall divulge or publish the existence, contents, substance, purpose, effect or meaning thereof, except through authorized channels of transmission or reception, to any person other than the addressee, his agent, or attorney, or to a person employed or authorized to forward such communication to its destination, or to proper accounting or distributing officers of the various communicating centers over which the communication may be passed, or to the master of a ship under whom he is serving, or in response to a subpoena issued by a court of competent jurisdiction, or on demand of other lawful authority, and no person not being authorized by the sender shall intercept any communication and divulge or publish the existence, contents, substance, purport, effect, or meaning of such intercepted communication to any person; and no person not being entitled thereto shall receive or assist in receiving any interstate or foreign communication by wire or radio and use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto; and no person having received such intercepted communication or having become acquainted with the contents, substance, purport, effect or meaning of the same or any part thereof, knowing that such information was so obtained, shall divulge or publish the existence, contents, substance, purport, effect or meaning of the same or any part thereof, or use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto; Provided, That this section shall not apply to the receiving, divulging, publishing, or utilizing the contents of any radio communication broadcast, or transmitted by amateurs or others for the use of the general public, or relating to ships in distress."

Heavy penalties are provided in Section 501 of the same Act for violations of its provisions. That Section reads as follows:

"Any person who wilfully and knowingly does or causes or suffers to be done any act, matter or thing, in this Act prohibited or declared to be unlawful, or who wilfully and knowingly omits or fails to do any act, matter or thing in this Act required to be done, or wilfully and knowingly causes or suffers such omission or failure, shall, upon conviction thereof, be punished for such offense, for which no penalty (other than a forfeiture) is provided herein, by a fine of not more than $10,000 or by imprisonment for a term of not more than two years, or both."

Letter from Lee de Forrest Read at 1st Annual Pacific Branch V.W.O.A. Banquet

Mr. Tom Stefens, Gen. Supt.
Radio Marine Corporation,
16 First Street
San Francisco, California.

I deeply regret my inability to be with the Veteran Wireless Operators at our first Pacific Coast banquet. Whereas the etheric woods are filled with increasing numbers of hams and amateurs the roster of old veterans is inevitably diminishing. It is most fitting therefore that we hold these annual meetings for good fellowship, for renewing of old acquaintances, and to cherish recollections of those never returning days when wireless was young and daring and romantic, when were founded those fine traditions welding "Sparks" and seamanship, mingling the waves of the ether and those of the ocean, traditions which have made the wireless operator respected by his fellow officers and honored by passengers whose very lives are so often placed in his keeping. Today the rank and file of our brethren are faithfully following these traditions you long ago established. We may therefore pass along assured that the primitive fire of the crashing spark is still alive in the flood of silent electrons that throng the transmitter tube, and that although technical methods may alter and advance and engineering principles are changed—yet the spirit and principles which inspired our beginnings in wireless shall continue to guide our successors in the paths of duty and deserved promotion. Brother veterans I give you this toast, "WIRELESS FOREVER!"

(Signed) LEE DE FOREST

"PIPING" RADIO PROGRAMS TO A NATION

By GEORGE G. BREED

IN October, 1922, the American Telephone and Telegraph Company decided to give the stay-at-homes at New York and Princeton an eyewitness description from Station WEAF of the Chicago game at Stagg Field. It was the first experiment in pick-up from a distant point, and a novel feature in broadcasting.

The undertaking was an instant success and "sportscasting" became immensely popular. There were insistent demands for more. Foot ball fans were just becoming inter-sectionally conscious and wanted to hear those games out West or back East. So, having done it once, the telephone company soon found itself in the business of providing circuits to inter-connect broadcasting stations which are owned and operated by the Broadcasting Companies and others.

The telephone company had been making some experiments in piping a program from here to there. The quality of the music differed from the Quality of Mercy in that it was decidedly strained, being very much filtered by the radio equipments and circuits that were the best thing available when radio was new and all. But it sounded wonderful in the earphones. The family grew tolerant of the debris that Sonny called his "radio."

So the company undertook to carry programs from one place to another and to hook stations together. This was a logical development as there was already available an extensive nation-wide system of routes developed for long distance telephone service. The equipment was crude compared to that which carries today's chain programs, but the idea met with an immediate and hearty response. The fans had got past the thrill of hearing voices in the air. They already felt the need of being informed, educated and entertained. And if the program had to be brought hundreds of miles by wires it was all right by them.

Piece by piece the new devices were installed. Toll circuits were equipped, and circuits specially designed for broadcasting were constructed. Special staffs were drilled at the key points and a routine of lining up, testing and operating the system was developed. In an incredibly short space of time the service was on a standardized basis and working as smoothly as toll service. Today the wire facilities provided for the broadcasting companies are a virtually separate network from the telephone lines of the Bell System and are maintained, tested and operated by their own staff with their own equipment and testing apparatus. The layout is designed for the exclusive purpose of handling radio programs—from whatever point they may come and to whatever chain of stations the broadcasters may wish to send them.

A complete description of what happens to the broadcast programs from the time they enter the telephone wires until they are delivered to the transmitting radio station. The important part taken by the telephone circuit.

Needless to say, programs—or rather the events which produce programs—do not always occur at certain places at previously specified times, any more than murders, earthquakes or other events of general interest to the community at large. This necessitates extreme flexibility—a flexibility, in fact, just short of the impossible. The required layout might be compared to a water supply system in which provision has been made by which any one of fifty or more pumping stations can put water into the system by means of a few manifolds which can be operated on a few minutes' notice.

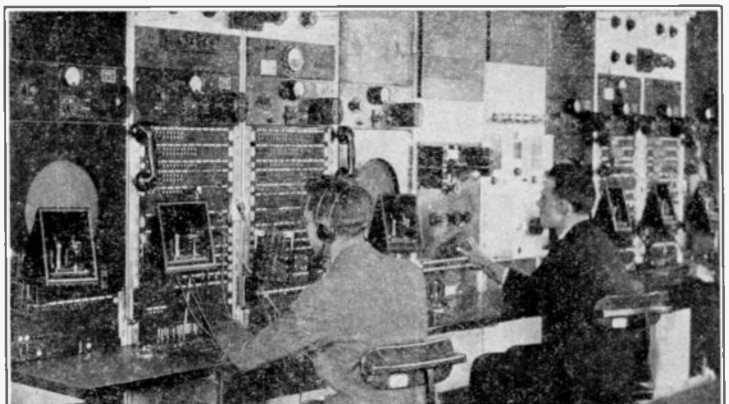
Again, the system must be an ingenious combination of central control and general decentralization. With wires stretching from coast to coast and from the Gulf up into Canada, over mountains and rivers, through deserts and forests, the network is exposed to a thousand accidents—the least of which may shut the program off from the nation. This means that each subdivision must be able to act quickly and with initiative, and yet the co-ordination between them and General Control must make it easy to mobilize every facility to handle an emergency.

There are other highly important requisites of the service. While the telephone company has developed circuits which are quite adequate for easy conversation across the continent, the task it has assumed for the broadcasting companies is "something else again." Circuits that are entirely satisfactory for conversational purposes are not suitable for transmitting hotcha singers, political orators and other colorful sound effects.

When you converse with your friend in Philadelphia or Seattle you do not miss some of the overtones that give his voice brilliance; at least the absence of them does not seriously affect the intelligibility. Nor is it necessary to a satisfactory exchange of ideas for you to alternately whisper and shout at each other. But it's different when you're listening to a symphony orchestra. The circuit must handle a much wider band of frequencies, or the music sounds thin. It must handle a much wider range of volume, from the delicate pianissimo of woodwinds to the thunder of the full orchestra—with no extraneous noises to mar the soft passages and no "blasting" effect when the brasses and kettle-drums let go.

Nor are these requirements of less importance in non-musical programs, where the sound effects—such as the slamming of a door or hoof-beats in a radio drama, or the roar of a crowd at a foot ball game—must be faithfully reproduced at the other end of the circuit.

With transmission over the distances involved in present broadcast chains, another factor has entered the problem. This is known as delay distortion, and is the distortion of the total sound due to the variation of the speed at which the different frequencies travel along a wire circuit. Not only do these electric im-



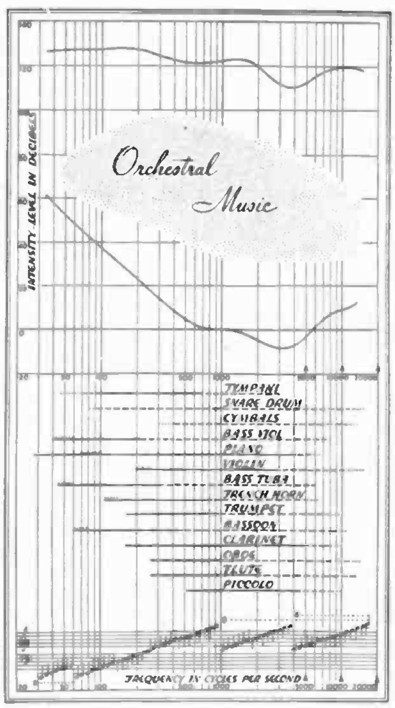
One section of the distributing center in New York for radio broadcast programs. Controlled and safe-guarded by telephone engineers, the wire network transports programs from such a center to radio stations from coast to coast.

Bell Telephone Laboratories

pulses travel at different speeds along different types of circuit—the speed varies from 10,000 to about 180,000 miles per second—but special equipment must be provided to offset the fact that the various frequencies travel at different speeds. For example, without such equipment, the note E below the bass clef might travel over a given circuit at about 30,000 miles per second while high C might zip along at over 100,000 miles per second. The failure of the frequencies to arrive simultaneously produces a blurred or fuzzy sound.

These esthetic considerations necessitate wires of larger gauge and special types of loading coils and repeaters. Moreover, the circuits must be shielded against the chance cross-talk, which might prove as irritating in the pianissimi of a nocturne as one of those walruses who go to a concert to have a good cough.

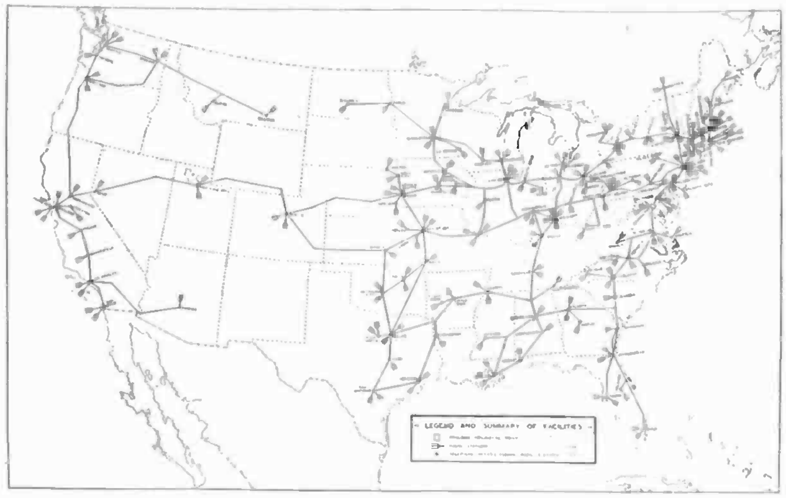
Another prime requisite of the network furnished to broadcasters is absolute dependability. The program must go through, and where every second has a definite value in money, it must go thru



In the lower part of the chart, the dashed and dotted lines indicate the pitch ranges of various sounds and instruments audible to 80% and 60% of the auditors, and the solid lines the ranges of the fundamentals of the instruments.

on schedule. So well has this requirement been met that radio listeners seldom hear any serious interruption of a chain program. And few listeners have any conception of what *that* means when a program is being piped to every corner of the country.

For it means not only a separate permanent network, but spare circuits that constitute a virtually duplicate network. It means special provision for picking up toll circuits, making them suitable for transmitting programs and patching them into a chain. It means an instantaneous and highly sensitive communication system along the network.



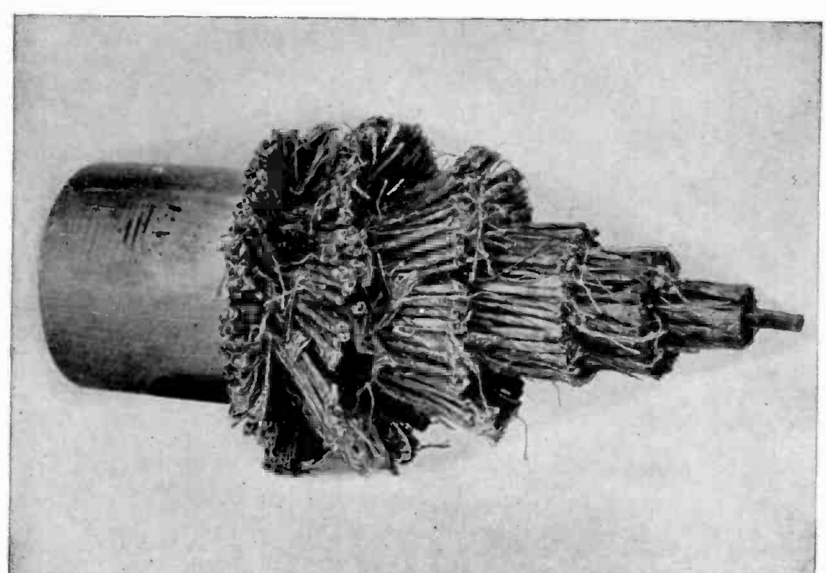
Special hook-up of stations in connection with country-wide celebrations of President Roosevelt's birthday, January 30, 1934

A few figures may suffice to give an idea of the magnitude of the physical plant devoted to this service.

The Long Lines department of the American Telephone and Telegraph Company, which operates the principal long-haul circuits of the Bell System, furnishes between 85 and 90 per cent. of the facilities provided by the telephone companies for program transmission. These Long Lines facilities comprise some 50,000 miles of aerial wire and 60,000 miles of wire in cables, a total of about 110,000 miles. About 58,000 miles of this is in full-time service and the balance is available for recurring programs, emergencies and special occasions. It might be added that 71,000 more miles of large-gauge wire have been placed in new toll cables for future use in broadcasting chains. Not one of these channels is used for "composited" telegraph and less than 10 per cent. of the potential "phantom" telephone circuits are utilized.

There are some 2,200 telephone repeaters employed. These are of special design, able to transmit a wider frequency band and a greater range of volume than the repeaters used on a regular message circuit. They reduce distortion thru the use of special transformers and contain more refined adjustment features provided by special equalizing equipment —necessary where programs are transmitted over great distances.

Other special apparatus includes equipment to interconnect sections of a network. For example, at 65 telephone offices throughout the country, equipment is installed to enable any program passing through that point to be distributed in various directions over separate routes to supply radio stations on such routes. At 262 telephone offices are installed special positions of testboard, equipped for testing, adjusting, monitoring and rearranging the broadcasting networks. The number of such positions varies from one panel in small offices to 25 in the larger centers. Switching facilities have been installed at certain points to make practically instantaneous rearrangements in the networks at frequent intervals on a preselected basis. Other provision is made



Section of telephone cable with lead sheath stripped away to show the large number of wires, some of which are special conductors for carrying radio programs only at repeater stations to permit rapid reversals in the direction of transmission. This evolution—and when it is performed simultaneously by about fifteen repeater stations scattered from Chicago to San Francisco, it is a notable evolution—is made necessary by the fact that one-way amplifiers are the type which is most suitable for handling radio programs.

In addition to this apparatus, broadcasting circuits in cables are equipped with special loading coils, placed 3,000 feet apart instead of 6,000 as is the case with the usual toll circuits.

A comparison of circuits used for messages and for program transmission may further illustrate the "de luxe" nature of the facilities and services provided for the latter service.

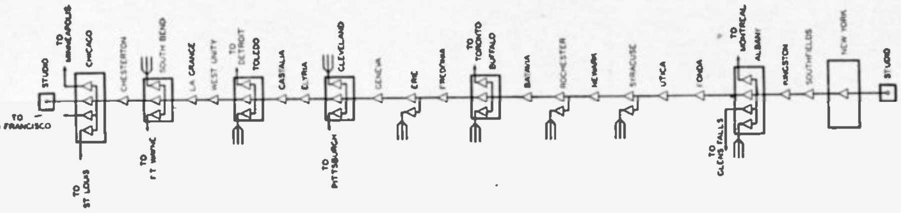
Between Omaha and Salt Lake City a telephone circuit on aerial wire passes through seven repeater stations. The operation of the circuit requires the equivalent of the full time of one technical employee. By the use of additional equipment a "phantom" can be developed from this and a similar circuit. A phantom circuit is formed by taking two pairs of wires already in use for ordinary telephone circuits and using each of these pairs as one of the conductors of the phantom circuit. This can be done without interference or cross-talk if the four wires involved have identical electrical characteristics. Thus are obtained three telephone channels over two physical circuits. "Carrier" apparatus makes possible three additional telephone conversations, or 36 "and up" telegraph messages.

The aerial wire used for a program circuit over the same route is much heavier. Twelve special amplifiers are required instead of seven ordinary ones. Three different offices along the route must have facilities for switching programs from one network to another, for feeding them to radio stations and for keeping close watch over transmission in that section. No "phantoming" is allowed and only two-thirds of the potential carrier circuits can be utilized. The work occupies the equivalent of a force of thirteen employees.

Now compare the facilities required for the two services in cable: A message circuit between New York and Chicago passes through 19 repeater offices. Loading coils are installed at intervals of 6,000 feet. The equivalent of one employee maintains the circuit. Almost every pair in the cable can be phantomed.

Along the heavier cable wires used for programs, loading coils are installed every 3,000 feet. Forty repeaters of special type are needed. At 10 of the 23 offices through which the program passes provision must be made to feed the programs to radio stations, to terminate the circuits or to switch them. The equivalent of 15 employees is needed. No phantom circuits can be obtained.

The communication system over which the vast web of program channels is maintained and controlled is a fair imitation of the nervous system of the higher order of mammals. Extensive decentralization permits the most efficient handling of the details of maintenance and operation. At the same time, a web of teletypewriter and telegraph lines gives instant contact between General Control and the various regional control offices. Incidentally, this communication along the "sidelines" of the network extends way down to the scores of repeater stations installed at intervals along the line. The resulting system re-



PROGRAM CIRCUIT 1008 ROUTE MILES

1-16 Gauge Pair Arranged for One Way Non-Phantom Operation. Loading, 1800 Coils of Special Type, 3000 Foot Spacing. Special Amplifiers, 40. Special Equipment for Terminating Circuits, Branching and Switching, 10 Offices. Plant Operating Forces Allocated to a New York-Chicago Program Transmission Circuit, 15 Men.

acts to both external and internal stimuli about as quickly as the human nervous system does to a pin point or a hot radiator.

A brief examination of a day's work in "N. R.," the general control office of the American Telephone & Telegraph Company at New York, will perhaps crystallize the nature of the telephone company's job as a carrier for the broadcasting chains.

The networks are in operation continuously for 16 hours or more daily, from "setting up" to the last slumber hour. For the telephone company staff, life begins at 1:30 a. m., which gives just time enough to test amplifiers, replace sections which are apt for one reason or another to go sour, reduce line noise on other sections, and measure volume and frequency range on each section. The tests are conducted by groups and then collectively, and "the speed of the squadron is the speed of the slowest vessel," which means there must be a high order of teamwork between the numerous offices involved in the service. It ends with the transmission of a test program over the network to be used on the first program.

That's the first and last "set-up" in the day for the program transmission staff. From then on, it's a series of switches and shifts of varying intricacy, in accordance with cues furnished in advance.

This is all right when the cues come simultaneously, but when two sets of stations have been having different programs there is as yet no kind of "wizard control" that will always bring them out exactly in step with each other. Which makes it necessary for the man at the switch to steal second or fade back to first as the exigencies of the situation require.

There are other things that make the men at N. R. wakeful. A network out of Cleveland fails and the spare must be substituted in a matter of seconds. Denver reports ice forming on the wires of the Central Transcontinental and arrangements must be made to switch to the Southern Transcontinental. Or these techical problems may be varied by a development of nationwide interest which crowds the scheduled program off the air and necessitates a complete rearrangement of the network.

Among the other sleight-of-hand which the telephone technicians must perform is the patching in of spare amplifiers here and there and the simultaneous reversal of the fifteen amplifiers between Chicago and San Francisco so that the program may flow from West to East instead of from East to West.

In the brief span of years since those first experiments in piping a program from one city to another, the network service of the A. T. & T. has reached impressive proportions. It should be remembered too that the planning and building of network facilities takes no account of another vital part of the service furnished by the telephone company. This is the constant improvement in the equipment and technique effected by the company's engineers, and the research work carried on ceaselessly by Bell Laboratories engineers—men who "are paid to be dissatisfied with telephone service."

Rapidly as the industry has grown, both in size and in technical and esthetic achievement, this steady progress in the field and in the laboratory has kept the company ready for every new demand. On blueprints in the office of the Long Lines Engineer are to be found the refinements which will make the programs of tomorrow better than yesterday's, while in the laboratories are experimental set-ups which will—on the same metaphorical time-scale—revolutionize program transmission next week.

Among the examples of these improvements may be cited the "B-22" cable circuit, with a frequency band hitherto possible only on open wire. Another development of this nature is "reference frequency" service, by which a frequency of 4,000 cycles, maintained with great exactness, is fed to two or more stations as a means of synchronizing them for operation on the same wave-length. With the number of channels definitely limited—at least, it seems so—and the demand for them increasing, it is quite possible that this development has important implications in the future of radio.

Another illustration of the work which has been anticipating tomorrow's requirements was the series of demonstrations of "auditory perspective." In one of these, on April 27, 1933, the Philadelphia Orchestra, on the stage of the Academy of Music in Philadelphia, played selections by Bach, interwoven with Spohr and Beethoven." On an empty stage in Constitution Hall, Washington, the ghosts of the players created for the audience there a complete illusion that the hundred-piece orchestra was actually before it. Microphones more sensitive than the average human ear in front of the orchestra, wire channels of exceptionally wide frequency band and loudspeakers, of equal quality, on the stage of Constitution Hall, produced at the Washington end a "sound pattern" closely approximating that which crossed the footlights in the Academy of Music. And for good measure the system expanded the volume range to the point where the 100 instruments could be made to sound like 1,000.

Such developments may be far in the future. Yet even they are not the goal.

(Continued on Page 22)

Vacuum Tubes as High-Frequency Oscillators

By M. J. KELLY and A. L. SAMUEL

The first part of this article appeared in the April issue. The remainder of the article appears in this issue. We are sure our readers wanting a thorough knowledge on this subject will find this article covers it.

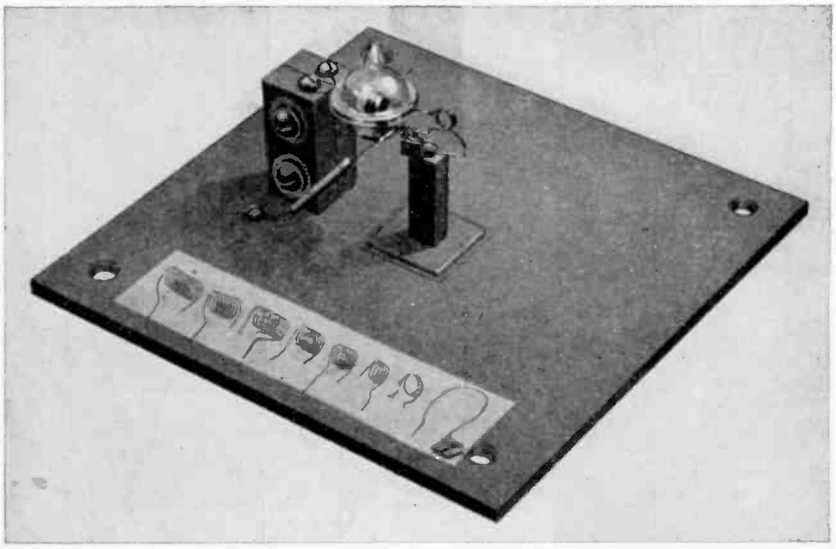


Fig. 15—A complete oscillator using a miniature receiving tube.

A Still Further Departure in Construction

The tube illustrated in Fig. 10 represents a still further departure from conventional construction with a corresponding increase in the frequency limit. Fay and Samuel report an output of 6 watts per tube at 500 megacycles and a frequency limit of 740 megacycles. Unusual features of the design are: The complete elimination of the usual press, the close spacing of the leads and the special construction of the tube elements, particularly the grid, made necessary by their small size. The grid is in the form of a number of straight wires (parallel and equidistant from the axial filament) supported by cooling collars at each end. The plate, in spite of its small size, can dissipate 40 watts with safety.

The inter-electrode capacitances of this tube are:

Plate to grid	1.8 μμf
Grid to filament	1.0 μμf
Plate to filament	0.75μμf

The output and efficiency curves, shown in Fig. 11, were obtained with two tubes in a push-pull circuit. The efficiency of the tube is about 28 per cent. at 300 megacycles, contrasting with only 18 per cent. for the previously discussed tube, while the output is only 8 watts as compared to 13 watts. The higher efficiency suggests that above 300 megacycles two of the smaller tubes are preferable to one of the large tubes. The fact that the limiting frequency varies with the applied anode potential indicates that the transit time effect is largely responsible for the decreased efficiency. This suggests modulation difficulties if the tube is used near tha upper limit of the frequency range. The outputs and efficiencies in the 400- to

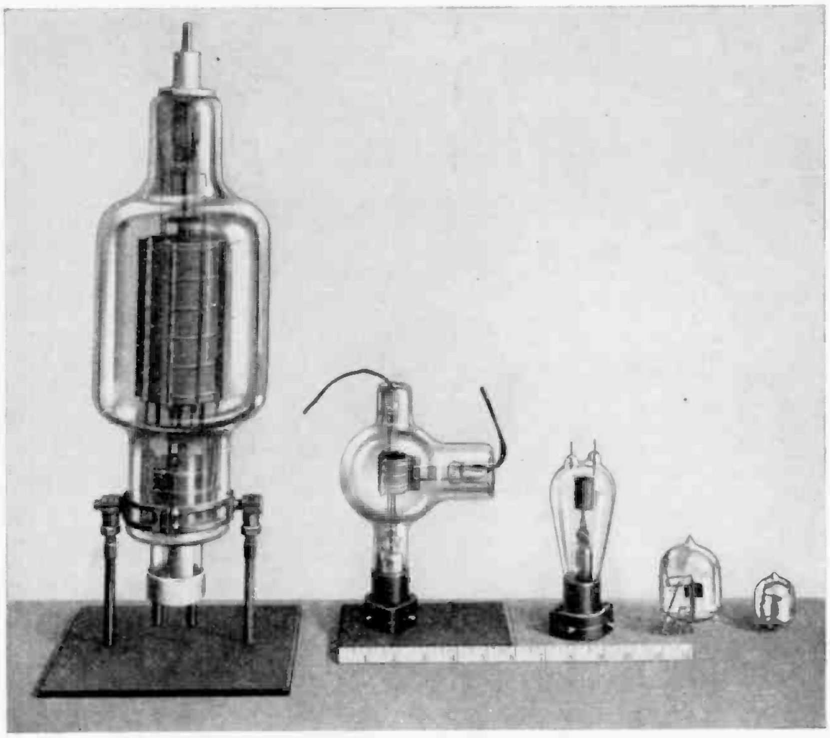


Fig. 17—Some of the tubes, previously discussed, compared in size with a lower frequency tube on the left.

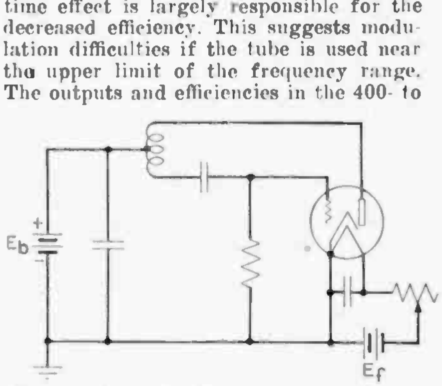


Fig. 16—The circuit diagram of the oscillator shown in Fig. 15.

600-megacycle range, although low, represent a substantial increase over the usual values obtained at these frequencies.

The relatively low efficiency at 200 megacycles is due to insufficient filament emission. In order to maintain space charge conditions near the filament, at high frequencies, the electron emission must be large enough to supply not only the actual electron current to the plate but also the charging currents to the grid filament and plate-filament capacitances. In a tube of this small size an increase in the filament emission is possible only by an impractical and unwarranted increase in the filament heating current.

The logical extension of these principles to increasingly high frequencies requires the use of closer and closer interelectrode spacings. Severe mechanical difficulties are encountered. Curiously enough the limiting factor in the power dissipating ability of the tube turns out to be the grid temperature rather than the temperature of the plate as might be expected. This comes about because of the required close grid-filament spacing, and makes necessary the adoption of some method of cooling the grid. One of the writers has constructed a series of tubes in which the grid is a tungsten

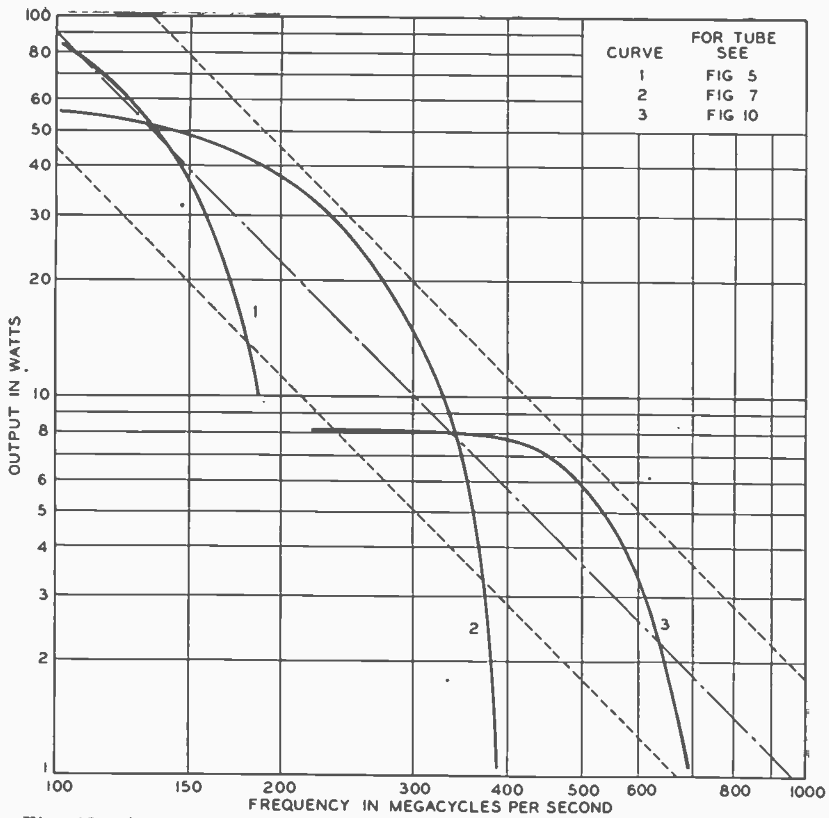


Fig. 18—A comparison plot of the outputs obtained with the tubes of Figs. 5, 7, and 10. The sloping lines are fixed values of the ratio of output to the square of wave length.

helix, each turn of which is attached to a common cooling fin projecting through a slot in the plate. This construction simplifies the mechanical problems involved and provides ample grid cooling. Two of these tubes are shown in Fig. 12. The larger one will deliver 10 watts at 670 megacycles with an efficiency of 20 per cent. and the smaller one will deliver one watt at 1200 megacycles with an efficiency of 10 per cent. These tubes are in no sense commercial, the results representing the limit that has been obtained by specially constructed tubes under controlled laboratory conditions at voltages and currents above those for which the tube would have a long life. With further advances it is reasonable to expect that outputs of this sort will be commercially realizable and that the frequency range of the negative grid oscillator can be extended beyond 1200 megacycles.

Tubes for Receiving Purposes

For receiving purposes where large outputs are not needed, the ultra-high-frequency requirements may be met by shrinking all the tube dimensions in proportion to the desired wave-length. Tubes constructed by Thompson and Rose based upon this principle are shown in Fig. 13 compared in size with the conventional receiving type tube. These tubes make use of parallel plane electrodes, the cathode being oxide coated and indirectly heated, and the grid being in the form of a mesh. A cross-section view of the triode is shown in Fig. 14. This tube will oscillate at frequencies up to 1000 megacycles in miniature replicas of the customary circuits used at longer wavelengths. A photograph of a complete oscillator is shown in Fig. 15 and the circuit diagram in Fig. 16.

Factors Limiting Ultra-High Frequencies

The limiting factor in the continued extension of the negative grid oscillator to higher and higher frequencies appears to be the dependence of physical size and output power on the operating frequency range. This dependence is well illustrated by the comparison in Fig. 17 of some of the tubes so far discussed with a standard one-kilowatt tube for which the frequency limit is approximately 75 megacycles. Dimensional considerations indicate that the linear dimensions of a series of tubes of optimum design must be decreased in proportion to the operating wave-length. Since the heat dissipating ability depends upon the surface area of the plate, the output, assuming the same efficiency) will decrease as the square of the wave-length. That this is approximately true for the tubes shown in Figs. 5, 7, and 10 may be seen by reference to Fig. 18 where the outputs as a function of frequency are plotted on a logarithmic scale. The sloping lines are for different values of the ratio of output to the square of the wave-length. With radiation-cooled tubes patterned after those illustrated, outputs of only a few tenths of a watt at 3000 megacycles can be expected. If larger outputs are to be obtained, innovations in tube design must be made.

Positive Grid (Barkhausen) Oscillator

As first reported by Barkhausen and Kurz in 1920, oscillations at frequencies greater than 300 megacycles can be produced by most high-vacuum triodes having symmetrical cylindrical structures when the grid is operated at a fairly high positive potential and the plate is held at or near the cathode potential. When so used they are variously known as oscillators of the Barkhausen and Gill-Morell types after the earliest experimenters, or oscillators of the positive grid or retarding field type to designate the arrangement of the electrode potentials. The relative ease with which such oscillations can be obtained at frequencies above 300 megacycles by the use of conventional tubes, and the widespread interest in this frequency range for communication purposes, have led to the appearance of a large number of papers on the experimental and theoretical aspects of such operation.

With the positive grid oscillator there are found to exist preferred frequencies of operation fixed by the electrode spacings and the applied electrode potentials. For the lowest preferred frequency mode of oscillation the relationship is such that the period of one complete oscillation is approximately equal to the total transit time of an electron which fails to strike the grid on its first transit, is retarded and finally turned back by the plate potential, and again missing the grid returns to the cathode. Under these conditions the relationship,

$$\frac{E_g}{n^2} = \text{constant}$$

is found to hold approximately, where E_g is the applied grid potential, n is the frequency, and the constant is a function of the tube geometry. Other high-frequency modes of oscillation can be obtained. One of these is particularly easy to excite if the grid of the tube is in the form of a simple helix. The important role played by the electron transit time in determining the frequency of the positive grid oscillator contrasts sharply with the minor role it plays in determining the frequency of the negative grid oscillator.

For maximum output it is necessary to adjust the tuning of the external circuit to correspond to the preferred frequency fixed by the applied electrode potentials. The relative dependence of the frequency upon the circuit tuning and on the applied electrode potentials varies greatly with the design of the tube. In any case the improper adjustment of either parameter results in a marked decrease in output. In general it appears that the better the tube design and the higher the operating efficiency the greater will be the dependence of frequency upon circuit tuning and the less will be its dependence upon the applied electrode potentials.

The most efficient operation of the positive grid oscillator is obtained when the space current is limited by the cathode emission, as contrasted with the most efficient operation of the negative grid oscillator when the current is limited by space charge. Not only must the space current be emission limited but it must have a fairly critical value. This makes it necessary to adjust the cathode temperature critically. Since the cathode emission characteristics are apt to change with time, frequent readjustments of the cathode temperature are usually required.

No completely satisfactory and generally accepted theory of the positive grid oscillator has as yet been given. Many theoretical papers dealing with the mechanism of oscillation have been published Some of these papers resort to pictorial explanations which, from their very nature, must leave out certain basic factors. Readers interested in a resume of the various theories are referred to the excellent review of Megaw and to the original papers. It is now recognized that any accurate theory must be based upon a general consideration of all the forces acting upon the electrons in their flight between the electrodes. This may take the form of either a particular solution of the classical electromagnetic equations for the conditions within the

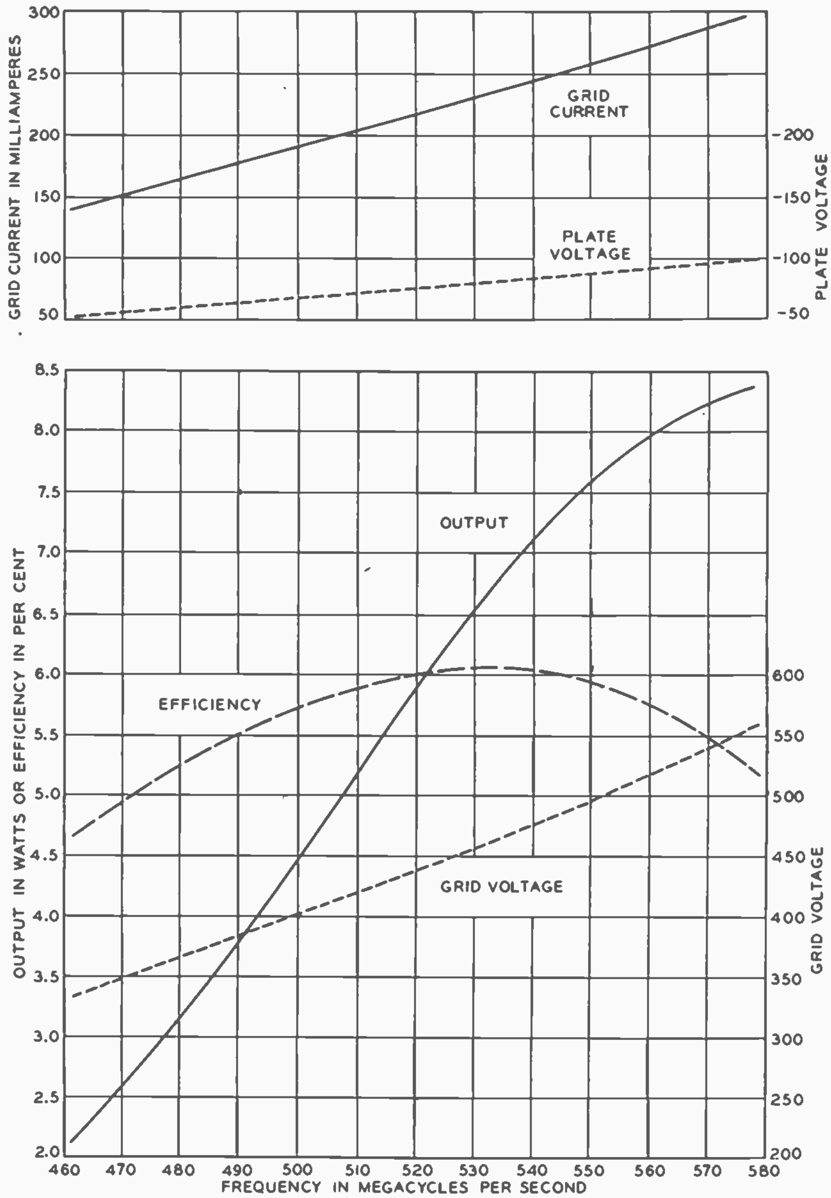


Fig. 21—Output and efficiency curves for the tube shown in Fig. 19.

tube or an analysis of the energy contributions due to individual electrons in their passage across the inter-electrode space.

Construction of a Positive Grid Tube

A representative positive grid tube of current design described by Fay and Samuel before the International Scientific Radio Union was shown on the front cover last month. This tube differs from the conventional negative grid tube primarily in the construction of the grid and in the arrangement of the leads. While designed primarily for use in the frequency range from 500 to 550 megacycles it illustrates the general problems encountered in the construction of the positive grid oscillator of this type for any frequency range.

The grid consists of a number of parallel wires supported by cooling collars at each end, the so-called squirrel cage construction. It will withstand 150 watts heat dissipation safely, and provides a minimum of circuit inductance and resistance. The grid diameter is fixed by the frequency for which the tube is designed and by the desired operating potential, such that the relationship

$$d_g = \frac{K_1\sqrt{E_g}}{n} \qquad (1)$$

is approximately satisfied, where d_g is the diameter of the grid, K_1 is a constant, n the frequency, and E_g the applied grid potential.

An indefinite increase in output at a fixed frequency by the simultaneous increase in the grid diameter and in the applied grid potential is not possible because of the limited permissible grid dissipation per unit area. The optimum grid current is found to follow roughly a 3/2 power law, that is

$$I_g = K_2\frac{E_g^{3/2}}{d_g}, \qquad (2)$$

so that the grid power will increase as the fourth power of the grid diameter while the grid area and hence the heat dissipating ability only increases as the first power of the diameter. Because of this an upper limit in output exists, fixed by the maximum permissible heat dissipation per unit area for the grid structure. The optimum grid diameter will vary directly with the wave-length for which the tube is designed, and if the ratio of the grid length to its diameter is maintained constant, the maximum available power output (assuming the same efficiency) will vary as the square of the desired wave-length.

Circuit of a Positive Grid Oscillator

On last month's front cover was shown a diagram of a positive grid tube of the straight-wire-grid type and its associated circuit. Tuned circuits, in this case in the form of so-called Lecher systems, are connected between the grid and plate leads, extending approximately a half wave-length (30 cm) beyond the lead seals. Because of the existence of preferred frequencies of operation fixed by the potentials applied to the tube electrodes, distributed-constant circuits, if used, may be operated at frequencies corresponding to harmonic modes of oscillation. In this case the length of the leads within the tube envelope has been

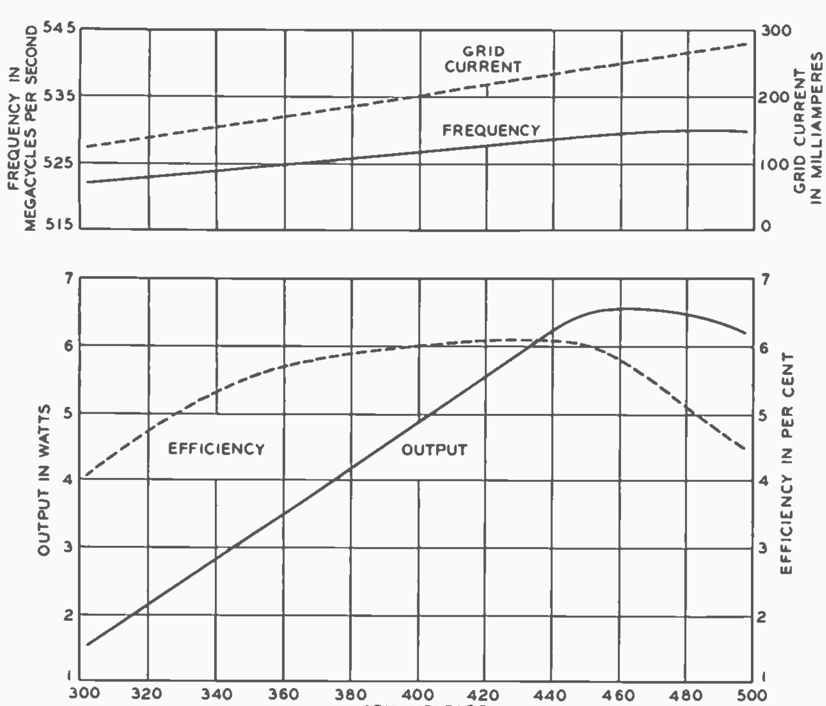


Fig. 22—Result of variation of grid voltage, tuning fixed, on tube of Fig. 19.

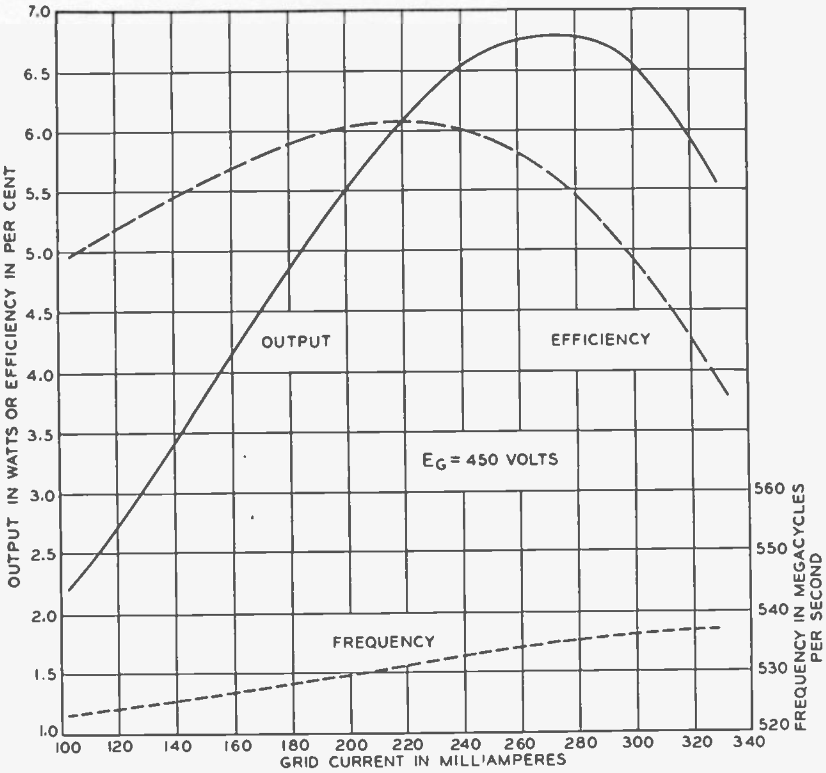


Fig. 23—Result of variation of grid current, other adjustments fixed, on tube of Fig. 19, $f = 532$ *megacycles*

adjusted so that the glass seals come at or near potential nodal points for the Lecher systems of which the leads form a part. This minimizes dielectric losses in the glass. The effective paralleling of the two sets of leads greatly reduces the resistance losses, while the balanced arrangement decreases radiation losses. Strict attention to these details is required because of the already low efficiency of the mechanism of generation.

Characteristics of Positive Grid Oscillators

The dependence of output and anode efficiency on frequency is shown in Fig. 21. These data were taken by adjusting the circuit tuning, filament current, and the grid and plate potentials to their optimum values for each frequency. The curve showing the grid voltage will be observed to follow equation (1) above, at least roughly, and a similar correspondence will be observed between the curve for the grid current and equation (2). Some variation in the required negative plate potential is observed. A maximum efficiency will be noted at a frequency of approximately 530 megacycles. The output, however, continues to increase with increasing frequency, the limit in output as well as in frequency being set by the safe grid dissipation. The outputs over the 500- to 600-megacycle range vary from 4.5 to 8 watts, comparing with outputs from 6 to 3 watts for the negative grid tube. The low efficiencies of 5 to 6 per cent are to be compared with the somewhat higher efficiencies of 19 to 11 per cent for the negative grid type tube.

The influence of the grid voltage on the frequency and on the output and efficiency is shown by the curves in Fig. 22. These data are for a fixed circuit tuning, the grid voltage being adjusted to the values indicated. This corresponds to the condition that might obtain if a grid voltage modulation scheme were to be used. The lack of linearity of the output curve and the large shift in frequency indicate that amplitude modulation by this method would be unsatisfactory. The frequency shift, large as it is, is much less than the shift observed in tubes of poorer design and correspondingly lower efficiency.

The dependence of the output and efficiency as well as frequency upon the grid current is shown in Fig. 23. These data were taken with a grid potential of 450 volts and a fixed circuit adjustment corresponding roughly to a frequency of 532 megacycles. The current to the grid was varied by adjusting the temperature of the filament. The maxima observed in both the output and the efficiency correspond to conditions for which the grid current is limited primarily by the available emission rather than by space charge. As conditions corresponding to complete space charge are approached the output and efficiency fall off rapidly. The limit on the permissible grid dissipation prevents the extension of these curves to the condition of complete space charge. Because of this dependence of output on grid current, the adjustment of filament temperature is extremely critical.

At lower frequencies the efficiency of operation of a correctly designed positive grid tube is substantially the same as that exhibited by this tube. The negative grid oscillator on the other hand, as has been shown, increases both its output and efficiency rapidly with decreasing frequency. The positive grid oscillator is, therefore, at an increasing disadvantage at lower frequencies. With the present state of development, the negative grid oscillator will give larger outputs with higher anode efficiencies at all frequencies less than about 300 megacycles.

For frequencies much higher than 600 megacycles, it is found that the power input requirements for efficient operation of tubes having grids of the straight wire type are in excess of that which can be tolerated in the grid structures. Operation at very much less than optimum input results in considerable decrease in output as indicated in Fig. 25.

Spiral Grid Barkhausen Tubes

If the grid of a Barkhausen oscillator is in the form of a simple helix, oscillations at frequencies greater than those predicted by the relationship of equation (1) are readily obtained. When so constructed they are called spiral grid Barkhausen tubes. Some experimental models are shown in Fig. 24. The tubes used in the Lympne to St. Inglevert "micro-ray link" are of this general type. Such tubes have been used to produce oscillations up to 3000 megacycles.

Because of the fact that the severe limitation on the optimum grid diameter is modified by the presence of a

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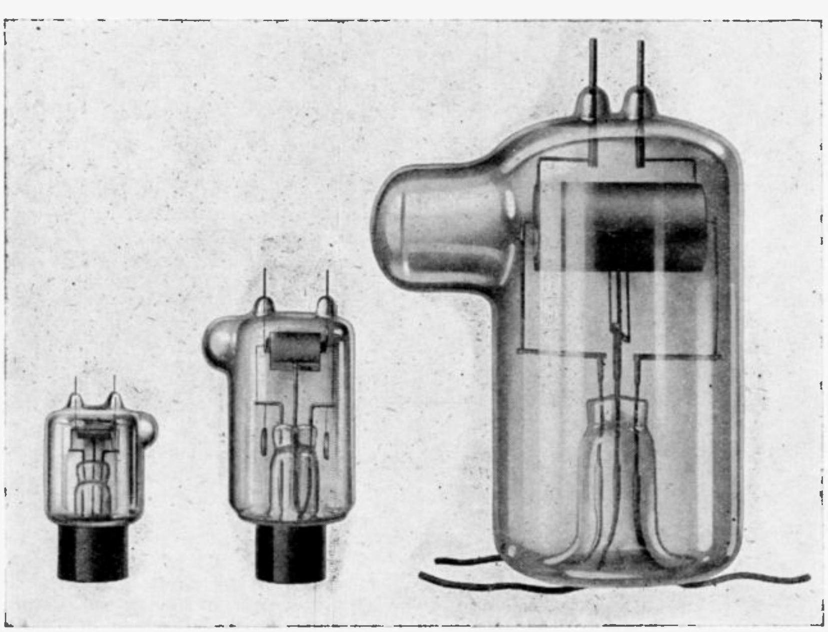


Fig. 24—Three optimum positive grid oscillators of the spiral grid type. Smallest tube designed for 2500 megacycles, largest for 500 megacycles.

The New Telephotograph System

By F. W. REYNOLDS

Member of the Technical Staff, Bell Telephone Laboratories

TELEPHOTOGRAPHY was relatively an early development in the field of electrical communication but its practical application on a commercial scale awaited improvements in terminal equipment as well as in communication channels. The past decade, however, has witnessed its commercial use both in this and other countries. During this period the Bell System operated a telephotograph network between several of our larger cities, and from the experience obtained, development work was undertaken culminating in the new 70B1 system.

The general method employed in picture transmission consists of analyzing or scanning in successive elements an area containing the graphic information and converting such information into some characteristic of an electrical current as a function of time. The resulting current is then transmitted to the receiving equipment where a process inverse to that employed for sending is used to reproduce the information in substantially the original form.

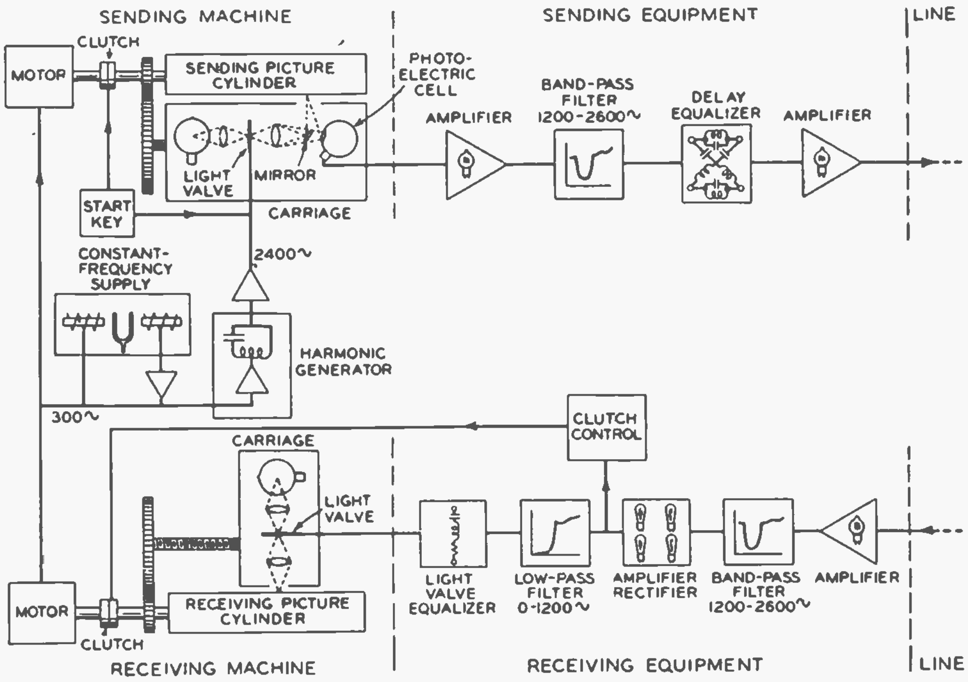
In the new 70B1 equipment shown schematically in Figure 1, the photographic print or other information on paper is wrapped about the cylinder of the sending machine which is connected thru a clutch to a constant speed motor. The latter not only rotates the cylinder but, through mechanical coupling arrangements, causes an optical system to advance parallel to the axis of the cylinder one hundredth of an inch for each revolution of the cylinder. A pulsating beam of light, rectangular in cross section and one hundredth of an inch wide, scans the complete picture area in successive parallel paths. This pulsating light, modulated by reflection from the picture, is directed to a photo-electric cell. The electrical output of the latter, after amplification, is filtered so that the frequencies used for transmission are approximately from 1200 to 2600 cycles and are only those essential for single sideband transmission. (This is the first commercial use of single sideband transmission in telephotography.) The cylinder will accommodate pictures of various sizes up to and including 11 x 17 inches, the longer dimension being the useful length of the cylinder. The speed of scanning, 20 inches per second, results in the transmission of one inch of picture per minute, measured along the axis of the cylinder. An 8 x 11 inch picture, for example, requires eight minutes for transmission.

The receiving equipment employs mechanical arrangements similar to those for sending, except that the receiving cylinder is enclosed in a housing so as to exclude light other than that from the receiving optical system. This design permits operation of the equipment in ordinary room illumination. A photographic film (or paper) is wrapped about the receiving cylinder and as the latter rotates an optical system advances (in phase with the scanning of the sending machine) and exposes each elementary area in succession. The exposure at any instant is determined by the opening of a ribbon light valve actuated by the rectified picture current.

The housing containing the cylinder is removed from the machine at the end of the transmission and taken to a photographic dark room where the exposed film is detached and the image developed. The equipment is designed primarily to transmit from a positive print and receive a negative image, consequently a geometrical reversal is necessary in order that the positive print made from the received negative shall not be reversed left to right compared with the original. This reversal is accomplished by advancing the sending and receiving optical systems in opposite directions.

It is essential that sending and receiving picture machines operate in phase. This condition is obtained in the 70B1 equipment automatically without sharing the channel or the use of line time. Each picture station is equipped with a tuning fork oscillator which supplies the frequency of 300 cycles for accurately controlling the speed of the driving motor within a few parts in a million. The motors are allowed to run continuously during an operating period and are connected and disconnected from the picture cylinders by a magnetically operated clutch. At the start of a picture transmission the closing of a key at the sending machine causes the operation of the sending clutch and a signal is sent out to operate the clutches of all receiving machines which may be connected to the network. Both sending and receiving machines may be set to stop automatically at the end of any desired length of transmission up to the maximum of 17 minutes, and can be quickly reset manually to the starting position.

Provisions have been made in a recently established network whereby any one of 24 stations can send to or receive from the others on a broadcast basis. The network can also be split, and various parts worked independently when desired. Loud speakers are provided for the continuous monitoring of the circuit as well as telephone sets to talk over the network for coordination purposes between picture transmissions. During a picture transmission the circuit is automatically held to operate one way only from the sending station, wherever it may be, to all the receiving stations using a special d-c. control circuit. The same control circuit may also be operated at any station where it is desired to broadcast operating or other information to the network and prevent interruption.



Schematic of sending and receiving equipment for one station

Airway Radio

Detroit News "Early Bird" Has Radio

From the Detroit City Airport a regular departure and arrival is the "Early Bird," an airplane owned by the Detroit News.

This plane is able to carry four persons, a half ton of papers, and flies more than 200 miles an hour.

Radio equipment includes a transmitter which is to be an auxiliary of WWJ, Detroit Station. The plane transmitter has a range of 1,000 to 6,000 kilocycles. It transmits both phone and code. The letter designation of the plane is KHPM-N, and 3,105 kc is its regular channel.

WHEN WIRELESS WAS IN FLOWER

By HERMAN SWERDLOFF

On the six hundred meter wave
  Where the ocean watch is kept,
By the Knights of the Kosmic Key
  When the seas by storm are swept;
On the six hundred meter wave
  Where a thousand tube sets peep,
Sits a Knight of the Kosmic Key,
  Listening, sound asleep.

His listening days are over
  For the sparks will sigh no more,
And now the tubes are singing
  Like birds upon the shore;
His face is weather beaten,
  His whiskers are all grey,
On many a rolling vessel
  He's spent a stormy day.

His eyes are dark and sunken
  From straining at the mill,
While copying distant signals
  That come from Frisco hill;
His fingers now seem twisted,
  He wore them at the key,
A pounding out those signals
  When they were C Q D.

His troubles now are over,
  He'll never feel a pain,
No more he'll cuss the static,
  Nor hear the sparks again;
When wireless was in flower
  And everything was spark,
It took a pile of knowledge
  To percolate an arc.

Now female "Sparks" have tickets,
  And as for brains, they're dumb,
But skippers like fair faces
  And so we're on the bum;
Our glory now is faded
  For the sparks are silent now,
And the female "Ops" are different,
  They do not savvy how.

It's hard to raise these ladies,
  They're never on the job,
They're somewhere in the fo'csle
  In love with some big gob;
They like to be romantic
  And act just like a fool,
They boast a gold diploma
  From a correspondence school.

Remember the big old coffin
  When Two Kay Double You
Went sailing thru the porthole
  And split the azure blue?
Today they call it radio,
  'Twill never be the same,
For the "Sparks" are all fair maidens
  In this "female" sailors' game.

In the days of feline whiskers
  And monster tuning coils,
The shack was filled with ozone
  And burnt condenser oils;
But now the smell is different,
  Like roses in full bloom,
When "Sparks" begins to pound her key
  She sprays it with perfume

When wireless was in flower
  The ships were wooden then,
And the "Sparks" were made of iron
  But now the "Sparks" are hens;
When the skipper wants a bearing
  He's full of courtesy,
Polite in every manner,
  For "Sparks" is now a "She."

She is a flaming beauty,
  A "Siren" of the Sea,
She's got the whole crew going
  With her smiles and flattery;
She's nice and slim on starboard,
  And about the same on port,
She's built just right amidships,
  But her stern is slightly short.

Her decks are trim and speedy,
  She carries riding lights,
She knows her navigation
  And keeps her bearings right;
She never is top heavy
  For she's balanced in the beam,
Though a little light in the fo'csle,
  She sails with plenty steam.

When wireless was in flower
  Oh how the brass did shine,
To watch old "Sparks" performing
  The passengers stood in line;
When wireless was in flower
  The "Sparks" were quite a sight,
They courted gallant ladies
  Upon the deck at night.

But those dear old days are passing
  When wireless was in flower,
And every old brass pounder
  Was the hero of the hour;
On the seven stormy oceans
  The sparks sang high and low,
When the seas ran high and heavy
  And the gales began to blow.

Remember the old Republic?
  When she went down to sea
The papers carried the story
  Of a Knight of the Kosmic Key;
But many and many's the story
  That never has been told
Of the "Sparks" who stuck to duty,
  And died so brave and bold.

When wireless was in flower
  The "Sparks" the sea did roam,
On packets and tramp freighters
  From foreign ports to home;
The "Sparks" of old were gallant
  Upon the silver wave,
They had some narrow squeezes,
  Sometimes a watery grave.

It happened out of Frisco
  When a monsoon gripped the sea,
And every man stood by the pumps
  But "Sparks" stood by his key;
The ship began to settle
  But the ocean code was kept,
They never found a trace of "Sparks"
  When the starboard deck was swept.

When wireless was in flower
  The "Sparks" were known by name,
By their deeds and heroism
  They rose to lasting fame;
Now you never hear their glory
  Nor how they played the game,
But on a granite monument
  You'll see a Komrade's name.

When wireless was in flower
  Upon the Seven Seas,
The Komrades of the dot and dash
  Shipped anywhere they pleased;
Life on the deep blue ocean
  On the deck of a rolling ship,
Rolling down the Rio
  On a South American trip.

Sailing east thru Suez
  On the road to Mandalay,
From Singapore to Hongkong
  And back to Monterey;
A trip to Raratonga
  Where the South Sea breezes blow,
Then back to dear old Frisco
  To have a sailors' "blow."

On the beach down in Tahiti
  Where the calabashes grow,
And the Polynesian beauties
  Make every "Sparks" their beau;
Along the coast of Java
  Where the coffee planters dwell,
Where the sun beats down upon the deck,
  And the air is hot as Hell.

A cruise or two thru Panama,
  How you bobbed up like a cork,
As you ploughed the seas off Hatteras
  Until you reached New York.
Three months upon a tanker,
  Oh Lord, how she did roll,
She turned upon her belly,
  And stood up like a pole.

Sailing down the West Coast
  With a cargo full of wood,
On your way to old Havana
  Where the champagne tastes so good;
A summer in Alaska
  Where at night the sun does shine,
Where the white man and the Eskimo
  Don't draw the color line.

A trip to Madagascar
  Where the fierce monsoons are born,
A voyage up the Congo,
  Six months around the Horn;
Crossing the old Atlantic
  On your way to Liverpool,
Keeping "tabs" on icebergs
  That make the air so cool.

Passing old Gibraltar
  Just off the coast of Spain,
Clearing Barcelona
  For Frisco once again;
Recall that joyous feeling
  When you were homeward bound?
On that long trip from the Orient
  To the shores of Puget Sound.

Raising Honolulu
  With a kilowatt of spark,
When wireless was in flower
  Before the days of Arc;
Remember how the signals
  Of W S A
Caused Q R M in Rio,
  Five thousand miles away?

Copying press from London
  In Australia, far away,
Clearing the "Gang" in Frisco
  While lying in Bombay;
Copying ticks from Arlington,
  And then from P O Z,
With a crystal and "Cats Whiskers"
  While in the China Sea.

The air was not so crowded then,
  The Ops used courtesy,
And everytime they signed off
  It was always "73";
These ladies use bad language
  When they pound the Kosmic Key,
"Say, use your other foot, Old Man,
  Your sigs are Q R Z."

They've changed the old "Q" signals
  That began with P R B,
And when you heard a traffic call
  It began with "Q S T."
Yes, everything was different
  When Q R S was free,
Before there was a "Tickler"
  Or "Radio Frequency."

When wireless was in flower
  Before the birth of "hams,"
In prehistoric ages
  When Noah's "Arc" had lambs;
To every old Brass Pounder
  Marconi was a god,
He gave us long range tuners
  With double sliding rod.

When wireless was in flower
  Before tubes were designed,
We never heard of grid leaks
  Nor super heterodynes;
We had no magic circuits
  Invented by some rube,
Our "plates" were in the galley
  And not inside a tube.

Recall the Old Rock Crusher
  And the spark gap's ozone smell,
When three and twenty amperes
  Crashed on the ocean swell?
We never had no trouble,
  The spark gaps always worked,
Her note was sweet and mellow,
  And the cycles never jerked.

When wireless was in flower
  The seas were always rough,
The skippers all were hard boiled,
  And the mates were very tough;
You had to be a fighting man
  And always know your stuff,
To "savvy" a belayin' pin
  When you called the bos'n's bluff.

But skippers now are gentlemen,
  Those fighting days are past,
The mates act just like chevaliers,
  For "She's" behind the mast;
The cook down in the galley
  No longer mixes hash,
He bakes her pies and pastry
  That cost a pile of cash.

"My dear Miss Sparks," the skipper said,
  As he doffed his cap at her,
"I'm glad to raise your salary
  To a hundred and fifty per;
I know that you're important
  In a grave emergency,
And all my crew are highly pleased
  With your personality."

The wireless "shack" is empty,
  It doesn't seem the same,
It has a "super pile o' junk"
  That's nursed by some young "dame."
This lady has her boudoir
  Where the Leydon jars once lay,
To keep her buttons shining bright
  She has a private maid.

But that's all passed behind us,
  Long ago and years a few,
And there are no sparks a sighing
  Upon the ocean blue;
We mourn their tragic passing
  As sweethearts mourn their loss,
For we were bosom shipmates
  Beneath the Southern Cross.

Those roisterous days are passing,
  The "Sparks" will sign no more,
For the "gang" of old brass pounders
  Are sleeping on the shore;
A thousand keys are silent,
  Their pounding days are done,
For the "Sparks" are gone forever,
  But their memory lingers on.

Vacuum Tubes as High-Frequency Oscillators

(Continued from Page 14)

tuned circuit within the tube formed by the helical grid helix, tubes of this type are particularly useful at frequencies above 600 megacycles. The former restriction on grid diameter is replaced by the requirement that the expanded length of the grid spiral be approximately 1.24 times the wave-length at which the maximum output is required, and that there be a correct proportioning of the other dimensions of the tube. The dependence of wave-length on the grid wire length is illustrated by the experimental data in Table I covering a frequency range from 460 megacycles to

TABLE I

Dependence of Wave-Length on Grid Wire Length for Barkhausen Oscillator with Helical Grid

Grid Wire Length in Cm.	Optimum Wave-Length in Cm.	Ratio
16.3	13.5	1.21
18.6	18.6	1.00
19.7	14.5	1.36
20.4	18.0	1.13
21.4	17.5	1.22
21.3	25.0	0.85
22.3	20.2	1.10
25.2	18.6	1.35
30.6	25.0	1.22
32.0	23.6	1.36
32.0	25.5	1.25
33.4	25.0	1.33
42.6	29.0	1.47
42.6	29.5	1.44
42.6	30.2	1.41
42.6	30.7	1.38
53.2	43.5	1.22
80.0	65.0	1.23
Average		1.24

2,220 megacycles. Graphic evidence of the independence of shape is shown by the largest and the smallest tube shown in Fig. 24 for which the dimensional ratios are nearly the same. The largest tube delivers several watts at 500 megacycles, while the smallest one delivers only a few tenths of a watt at 2500 megacycles. The efficiency in both cases is about one per cent. These dimensional considerations lead to the conclusion that there exists a maximum output at any given wave-length for a tube of a given design and that this output is proportional to the square of the optimum wave-length. From this it appears that the only advantage offered by the spiral grid tube over the other type is the simplification in mechanical design which permits the construction of rigid grid structures capable of high energy dissipation for the higher frequency range.

The external tuned circuit for the higher frequency mode of oscillation takes the form of a Lecher system connected between the two grid terminals.

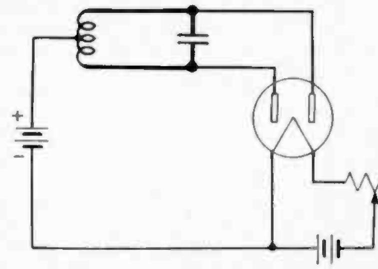


Fig. 28—Oscillation circuit of split-plate magnetron. Data for Fig. 27 taken in this type of circuit.

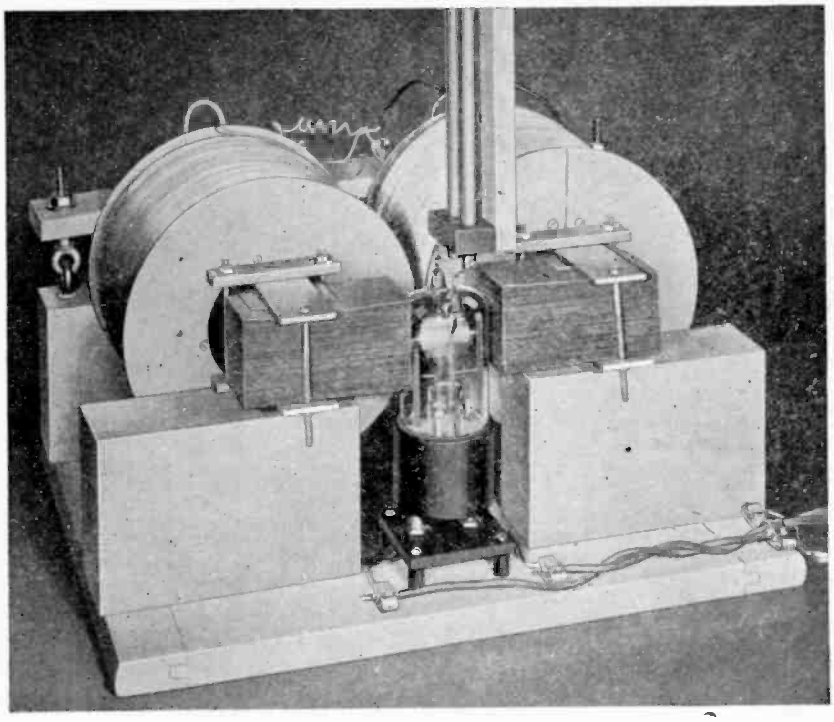


Fig. 25—An experimental model of the split-plate magnetron showing a possible arrangement of the magnetic field.

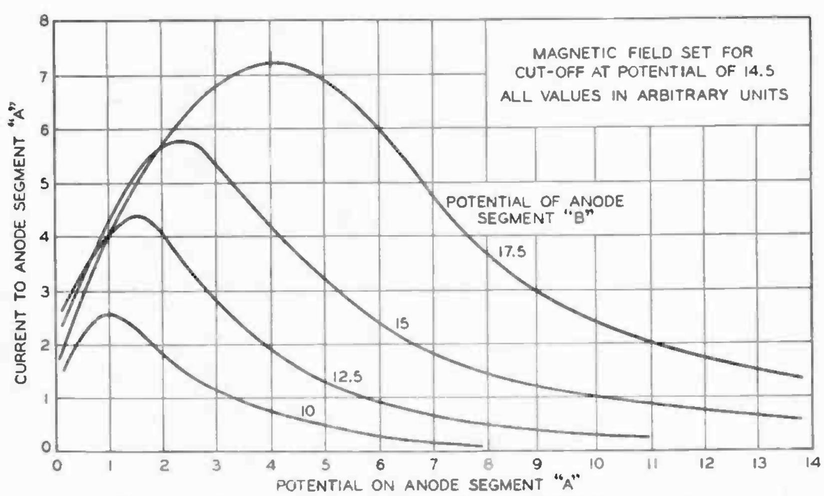


Fig. 26—Static characteristics of a split-plate magnetron.

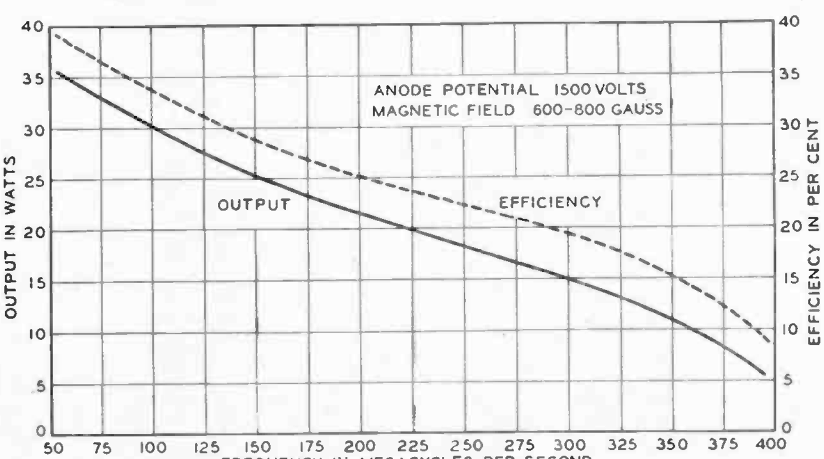


Fig. 27—Output and efficiency curves at different frequencies for split-plate magnetron

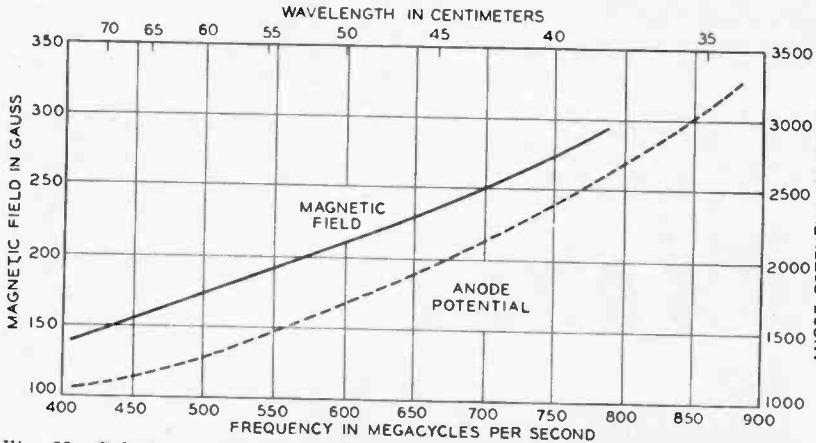


Fig. 29—Relation of magnetic field and anode potential to frequency of oscillation in magnetron oscillator of second type.

axis. The original type of tube has been largely superseded for ultra high-frequency generation by the so-called split-plate magnetron, first used by Okabe, in which the cylindrical anode is divided longitudinally into two (or more) segments to the terminals of which is connected the tuned circuit. Such a tube is shown in Fig. 25.

In the frequency range from 300 to 600 megacycles the split-plate magnetron compares favorably with the negative grid tube both in output and in anode efficiency. Its use has been limited because of the complicating factor of the magnetic field, and the attending modulation difficulties. For frequencies higher than 600 megacycles the magnetron provides larger outputs than those so far reported by other means. It has been used at frequencies up to 30,000 megacycles, a value well above that so far reported for any other type of vacuum tube.

When so connected the dependence of frequency upon circuit tuning is pronounced, as contrasted with the negligible dependence observed if the Lecher system is connected between the plate and the grid. When oscillating in the higher-frequency mode the spiral grid tube shows only a comparatively small dependence of frequency on grid potential and this may be compensated by a proportional change in plate potential. This, coupled with the fact that the output increases rapidly with increasing grid potential, makes it possible to apply various schemes of amplitude modulation. Characteristics of the type shown in Figs. 21, 22, and 23 for the straight-wire-grid tube cannot be taken except for a limited portion of the range due to the inability of the grid to dissipate the energy required in the upper portion of the grid voltage or grid current ranges.

While the spiral grid tube will also oscillate in the lower-frequency mode, its efficiency and output are considerably lower than the corresponding values for the straight-wire-grid tube previously discussed. Its field of usefulness is, therefore, largely limited to the higher frequency mode of oscillation in the frequency range above 600 megacycles.

THE "MAGNETRON" OSCILLATOR

The "magnetron" in its simplest form consists of a cylindrical diode or 2-electrode tube, with a uniform magnetic field in the direction of the electrode

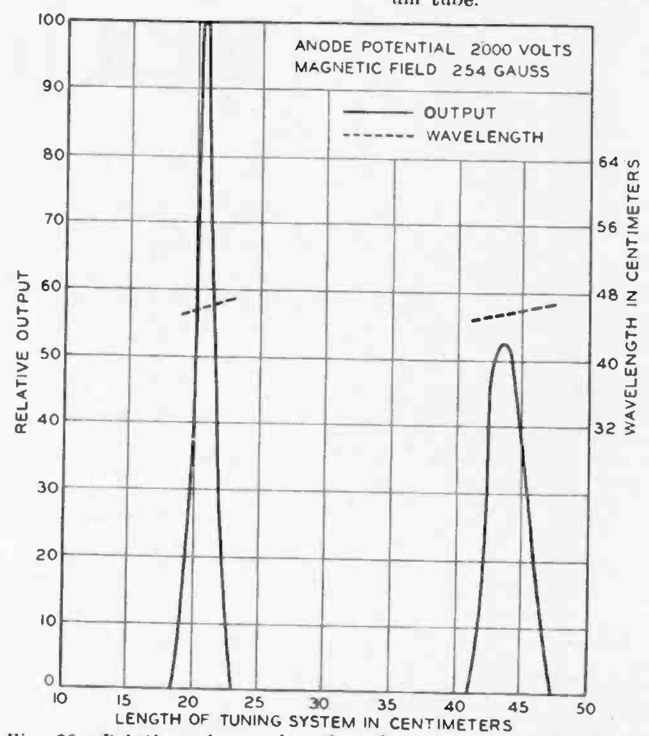


Fig. 30—Relation of wave-length and output to length of tuning system in magnetron oscillator of second type. Anode potential—2000 volts. Magnetic field—254 gausses.

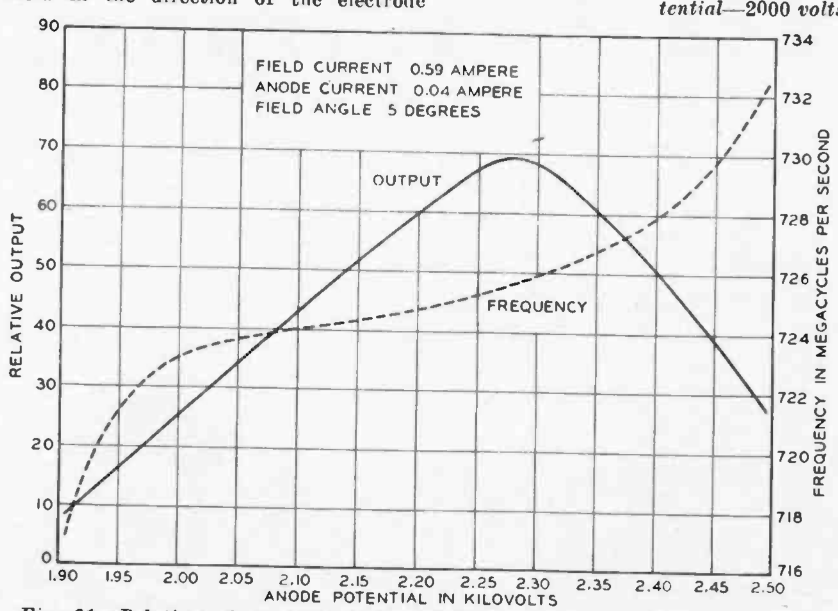


Fig. 31—Relation of output and frequency to anode potential in magnetron oscillator of second type.

The magnetron depends for its operation upon the curvature of the electron orbits produced by the magnetic field. As first shown by Hull in 1921, a critical field exists beyond which the anode current falls off rapidly to zero. This field is given by the relationship

$$H = \frac{6.72}{R}\sqrt{V}, \qquad (3)$$

where R is the anode radius and V is the potential of the cylindrical anode with respect to an axial filament. Altho the original magnetron of Hull and Elder made use of variations in the magnetic field in its operation as a generator, it was soon discovered that oscillators could also be produced with steady fields by two somewhat different mechanisms. The one, first pointed out by Habann, makes use of a negative resistance effect observable in the static characteristics and the other, first described by Zacek, involves the electron transit time in a way quite analogous to the way in which it is involved in the

(Continued on Page 20)

It's also a Monument to

RCA RADIOTRONS

At Radio City . . . entertainment crossroads of the nation . . . monument to radio excellence . . . hub of the National Broadcasting Company . . . there are hundreds of radio tubes: tubes big and little, receiving and transmitting, whose glowing cathodes represent the vital spark of life at the very nerve center of a great radio system.

These tubes are RCA Radiotrons. Their unfailing performance is perhaps as great a testimonial to the name "RCA Radiotron" as the towering magnificence of Radio City is to the advancement of radio broadcasting. Whether for communications or entertainment RCA Radiotrons are the choice of those who know—the standard by which all other radio tubes are judged.

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RCA

Vacuum Tubes as High-Frequency Oscillators

(Continued from Page 18)

positive grid triode. Both mechanisms have been used to produce oscillations at ultra high frequencies.

Negative Resistance Type

Data reported by McArthur and Spitzer on a split-plate magnetron tube are illustrative of the negative resistance type of behavior. Static characteristics taken by varying the potential of one anode with the magnetic field held constant for different values of the potential on the other anode are shown in Fig. 26. The pronounced negative resistance effect is obvious. This negative resistance characteristic can be utilized in producing oscillations.

Output and efficiency curves for this tube as an oscillator are shown in Fig. 27. These data were obtained by connecting a "tank" circuit, tuned to the desired frequency, across the two anodes, as shown in Fig. 28. Each anode delivers energy to the oscillating circuit during alternate half-cycles, so that in effect, it is equivalent to a push-pull oscillator. The limiting frequency as set by the interelectrode capacitances and lead inductances (corresponding to the similar limit for the negative grid tube) is 450 megacycles. The decrease in output before this limit is reached is due to resistance and radiation losses and to the effect of electron transit time.

The magnetron, as contrasted with the negative grid tube, will oscillate with circuits having a high decrement. However, for its most efficient operation the effective anti-resonant impedance of the tuned circuit when loaded must be approximately 10 times the value required by a triode with the same anode dimensions. The load resistance that can be obtained at high frequencies is only a fraction of this value, so that the efficiency becomes increasingly less with higher frequencies. A further limitation is due to the fact that the electron current is concentrated on only a small part of the anode surface. This reduces the safe anode dissipation unless the anode is designed to have a high thermal conductivity. Because of these limitations, the ratio of output to the interelectrode capacitance may be only slightly more favorable than the corresponding ratio for a triode of the same anode dimensions.

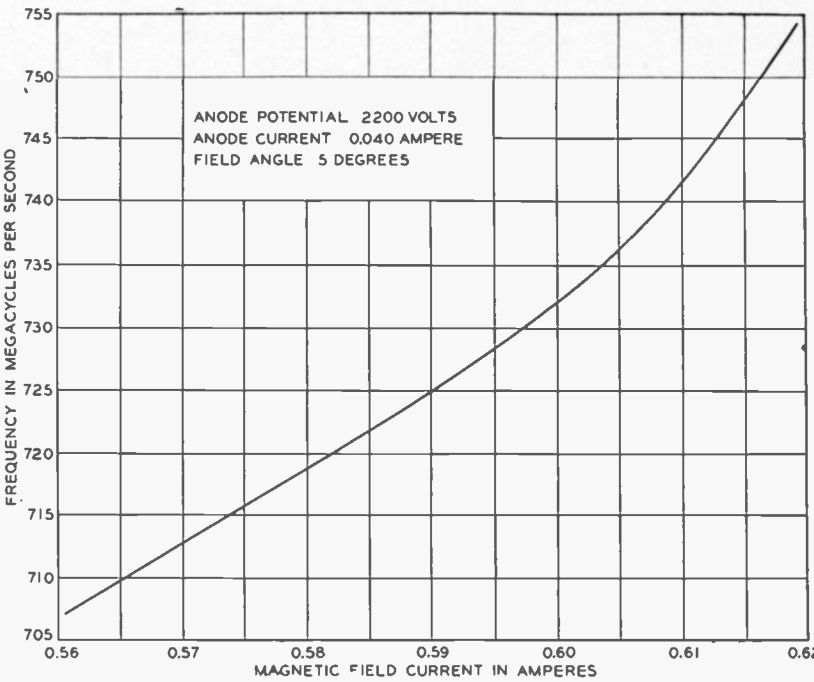


Fig. 32—Relation of frequency to magnetic field current in magnetron oscillator of second type.

Type Depending on Electron Transit Time

When the magnetic field of a split-plate magnetron is adjusted to near the critical value given by equation (3), oscillations can be produced whose frequency will depend primarily upon the time of flight of electrons between filament and anode in a way closely resembling the behavior of the positive grid oscillator in its lower frequency mode of oscillation. For best output, the field must be above the critical value. To fix the time of flight and hence the frequency of oscillation, the magnetic field and plate voltage must be adjusted to certain values roughly expressed by the empirical relationship

$$\lambda H = 13{,}100, \qquad (4)$$

where λ is the wave-length in centimeters and H is the field strength in gausses, which must also satisfy equation (3). It is found that for best operation the magnetic and electric fields within the tube should not be exactly perpendicular. This lack of perpendicularity may be achieved either by tipping the magnetic field relative to the tube axis or by introducing end plates within the tube and maintaining them at a fixed positive potential.

Kilgore has given complete information concerning this type of oscillator. In Fig. 29, taken from his paper, is shown the dependence of field strength and anode potential on the desired frequency. The existence of a preferred frequency fixed by these values is confirmed by the data in Fig. 30 relating the output and wave-length with the length of the attached Lecher system. The decreased output shown at the second peak is due to the added losses introduced by the extended length of the system. The outputs shown on these curves are not in watts, but represent relative readings of the field strength near the oscillator. With optimum adjustments 7 watts at 715 megacycles is reported, the efficiency being about 8 per cent. The dependence of output and frequency on the applied anode potential is shown in Fig. 31, and the dependence of frequency on the current in the magnetic field coil in Fig. 32. The importance of the adjustment of the field angle is shown by the data in Fig. 33.

An output of 2.5 watts at 3160 megacycles has been reported by Wolff, Linder and Braden. They find that the efficiency of the tube is much improved by using end plates in place of the tipped magnetic field. Cleeton and Williams have been able to obtain oscillations at 30,000 megacycles with a magnetron tube.

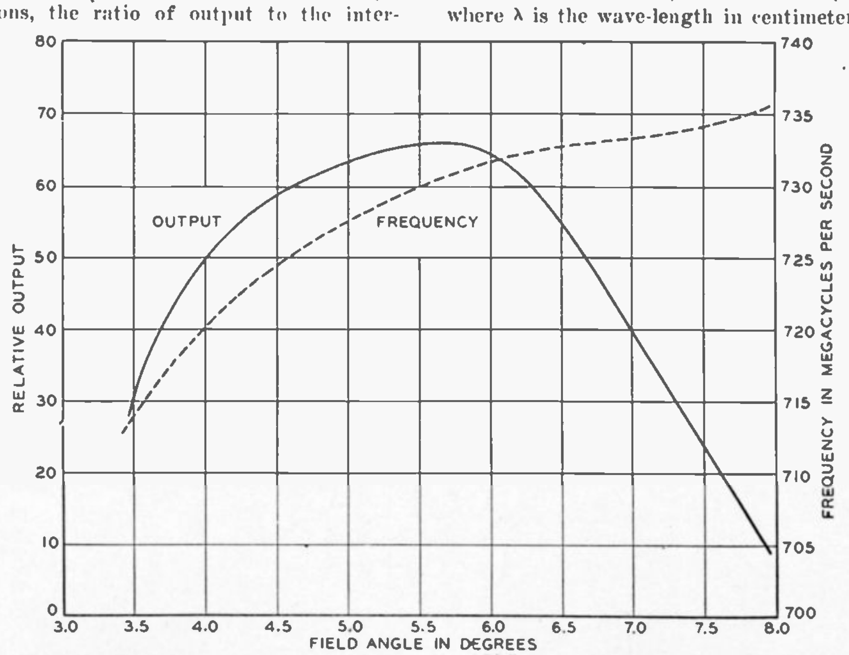


Fig. 33—Relation of output and frequency to field angle in magnetron oscillator of second type.

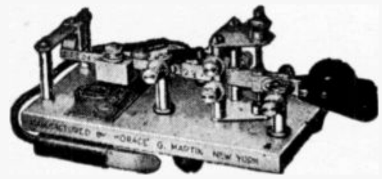
AMPLIFICATION

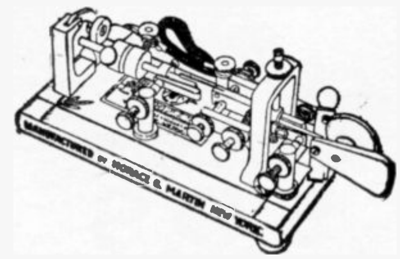
The use of the conventional thermionic triode as an amplifier greatly exceeds its use as an oscillation generator in communication applications. Its ability to amplify has contributed much more to the development of our present-day long distance communication, whether by wire or by radio, than has its ability to oscillate. The complete utilization of ultra-high frequencies as carrier channels in communication will also, no doubt, be dependent upon the development of suitable amplifiers for this frequency range. Although certain forms of pseudo-amplification are possible with tubes of the Barkhausen and magnetron types, the negative grid triode and multi-element tubes derived therefrom are the only devices availible for very high frequencies which will amplify in the sense that the output is an enlarged undistorted replica of the input.

As the frequency of operation of the negative grid triode is increased, difficulties in securing stable operation as an amplifier and in realizing the full gain indicated by the tube constants are encountered. These difficulties, as is well known, are in the main due to the tendency of the amplifier to oscillate or "sing" because of feed back through the grid-plate capacitance. This may be overcome either by the introduction of a compensating capacitance somewhere in the circuit, so-called neutralization, or by the introduction of an electrostatic shield or screen within the tube envelope between the grid and plate, giving the screen-grid tetrode. Neutralization schemes fail at very high frequencies because of the inductance of the tube leads which makes difficult the correct location of the neutralizing capacity and because of transit-time effects which shift the phase of the needed compensation. However, conventional screen-grid tetrodes and pentodes are available which fuction satisfactorily over the major portion of the frequency range covered by the conventional 3-element tube as an oscillator.

For frequencies above approximately 60 megacycles specially designed tubes are required. Because of the similarity in the special frequency requirements, it is expected that there will be found a succession of multi-element tubes for amplification use, each rated for a band of frequencies, patterned after corresponding triode oscillators. The special frequency requirements for the amplifying tube are even more severe than those for the triode oscillator, so that the multi-element amplifying tube will in general cease amplifying at a frequency somewhat lower than the frequency limit of oscillation of the corresponding triode oscillator.

Thompson and Rose have described small screen grid tubes which will amplify at frequencies of 300 to 400 megacycles. One of these tubes is shown in Fig. 13. Their characteristics are similar to those of the conventional screen-grid tube in many respects. The very great reductions in inter-electrode capacitances, lead inductances, and transit time make possible the construction of receiving circuits using tuned radio frequency amplification at these very high frequencies. The ratio of the frequency limits of the corresponding triode as an oscillator (1000 megacycles) to the frequency at which amplification was reported (400 megacycles) is typical and illustrates the apparently inevitable failure of the amplifier to keep pace with the oscillator in the struggle toward higher and higher frequencies.





The Photo-Electric Effect
(Continued from Page 6)

in the interatomic spaces of a metal with a velocity that is proportional to the frequency of the light-ray impact together with a partial impact of kinetic energy received from the light hv, less the energy of escape. Why the total energy of the light-ray cannot be transferred to the freed electron in the form of kinetic energy is attributed to the fact that a minimum work is required to disengage an electron from the inter-atomic spaces in the metal. That part of the radiation energy used to liberate electrons cannot be imparted to the freed particle on account of certain laws regarding the conservation of energy and momentum. The deeper electrons are in the inter-atomic spaces in the metal, the more quanta will be required for their liberation; therefore, the velocity of the freed electrons will be somewhat retarded due to the work expended bringing electrons to the surface of the metal. It is on account of this fact that some metals require many hundred absorbed quanta to free an electron. That part of the energy and momentum carried by light-quanta which was not imparted to the electron is deflected obliquely from the path of original impact and goes forth to form new quanta whose energies and frequencies are of lesser magnitude.

According to observations of photoelectric phenomena, the photo-electric effect begins at the moment light-quanta irradiates the surface of the photo-emittor. The photo-electric efficiency is based on the amount of absorbed quanta necessary to liberate an electron. The possible lag before electric emission takes place has been observed to be within $3(10^{-9})$ seconds after irradiation, according to investigators Lawrence and Beams.

The quantum photo-electric formulation as developed by Albert Einstein is stated by the following law:

$$\tfrac{1}{2}mv^2 = hv - hv_0$$

where $\tfrac{1}{2}mv^2$ is the kinetic energy of the electron; h, the universal constant; v, the frequency of the light-rays; and hv_0, the minimum energy required for electronic escape.

Photo-electric Mechanism

NOBODY KNOWS THE PHOTO-ELECTRIC MECHANISM. In fact, modern so-called wave mechanics, which is a mathematical statement of facts, has made it impossible to picture things on a mechanical basis because there is no mechanics which is applicable. Mechanics was developed by Newton from the actions of gross machines. Atoms behave differently and there had to be invented a new type of mechanics or better equations to explain the facts that have no analogue in ordinary mechanics. The photo-electric mechanism has bothered physicists up to 1915 and later because they attempted to account for atomic behavior by Newtonian mechanical interpretations. What was needed was a new mechanics based on the very phenomena (quantum phenomena) occurring in the atom which has just been discovered. On the basis of this new system of so-called mechanics, we now have what is called wave-mechanics.

As far as it may be illustrated, see Figure 1, the photo-electric mechanism by which photo-electricity is conveyed from the light-sensitive surface P to the collector ring R is very simple insofar as it is possible to understand a mechanism. The light passing through collector ring R strikes the photo-sensitive surface P. A large portion of the light is reflected. Of the light which was not reflected, the residual portion causes the electrons to oscillate just at the surface of the metal. If the oscillations are of sufficient amplitude or better energy, to overcome the attractive forces holding the free electrons in the metal, the electrons will be liberated and escape. Making P negative drives the freed electrons across to R. Some electrons, of course, are liberated from the surface of the collector ring R. These are dragged back to R by the positive charge and do not escape. It is important to note here that the photo-electric current was NOT carried by molecules. It is carried by negative electrons liberated as above. If there is a gas present, like oxygen, in the photo cell the electrons may attach and form ions that then carry the current which were formed from electrons.

Photo-Electric Conduction

A photo-sensitive surface is rendered conductive by irradiating it with light-rays of appropriate wavelength. Photoconductivity starts the moment the photo-electric effect takes place; that is, the slightest exposure to light-quanta results in the ejection of electrons which are attracted to that part of the electrical field whose difference in potential is greater than that of the emittor. It is these electrons, collectively, which constitute the flow or current. The amount of electrons emitted is proportional to the number of absorbed quanta and the extent to which the photo-surface was exposed to the influence of light. The number of electrons emitted is proportional to the intensity of illumination. There is no explanation to the fact that the initial velocity of the photo-electrons are independent of the intensity of light, but experimental conclusions are contained in the nature of equations which are given in the Einstein photo-electric law, which is deduced on quantum mechanical basis, and therefore has no mechanical explanation. The essence of the quantum theory was derived from the experimental fact that $hv = \tfrac{1}{2}mv^2$.

Summary

In conclusion, the total energy of liberated photo-electrons is directly proportional to the light intensity. Therefore, a continuous progressive variation in the intensity of light-rays impinging upon a photo-sensitive surface will cause the emission of electrons to be in direct proportion to the intensity of illumination. Witness, the reproduction from sound-film in the modern talking picture.

The exposition given herein to the quantum theoretical formulation as regards photo-electricity is not intended to be a critical account of the subject discussed. For extended information, reference to more comprehensive discussions would welcome interest.

Piping Radio Programs to a Nation
(Continued from Page 10)

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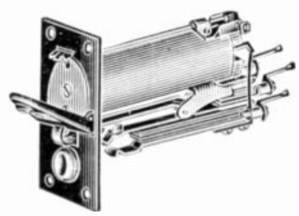

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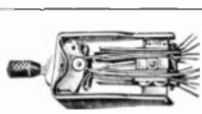

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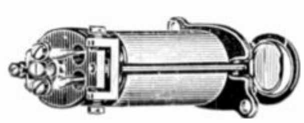

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