PROCEEDINGS OF

The Institute of Radio Engineers

Volume 13 OCTOBER, 1925 Number 5

CONTENTS

GENERAL INFORMATION

The Proceedings of the Institute are published every two months and contain the papers and the discussions thereon as presented at the meetings in New York, Washington, Boston, Seattle, San Francisco, or Chicago.

Payment of the annual dues by a member entitles him to one copy of each number of the Proceedings issued during the period of his membership.

Subscriptions to the Proceedings are received from non-members at the rate of $1.50 per copy or $9.00 per year. To foreign countries the rates are $1.60 per copy or $9.60 per year. A discount of 25 per cent is allowed to libraries and booksellers.

It is understood that the statements and opinions given in the Proceedings are the views of the individual members to whom they are credited, and are not binding on the membership of the Institute as a whole.

PUBLISHED BY

THE INSTITUTE OF RADIO ENGINEERS, INC.

37 WEST 39TH STREET, NEW YORK, N. Y.

EDITED BY

ALFRED N. GOLDSMITH, Ph.D.

OFFICERS AND BOARD OF DIRECTION, 1925

Terms expire January 1, 1926; except as otherwise noted

PRESIDENT
John Howard Dellinger

VICE-PRESIDENT
Donald McNicol

TREASURER
Warren F. Hubley

SECRETARY
Alfred N. Goldsmith

EDITOR OF PUBLICATIONS
Alfred N. Goldsmith

MANAGERS

(Serving until January 1, 1926)

Edward Bennett
Lloyd Espenschied
John H. Morecroft
Louis A. Hazeltine
John V. L. Hogan

(Serving until January 1, 1927)

A. H. Grebe
H. W. Nichols

(Serving until January 1, 1928)

Melville Eastham
A. E. Reoch

WASHINGTON SECTION

ACTING EXECUTIVE COMMITTEE

CHAIRMAN
Comm. A. Hoyt Taylor
Navy Department,
Washington, D. C.

SECRETARY-TREASURER
C. B. Mirick,
Naval Research Laboratory, Bellevue
Washington, D. C.

BOSTON SECTION

CHAIRMAN
George W Pierce
Harvard University,
Cambridge, Mass.

SECRETARY-TREASURER
Melville Easthan
11 Windsor St.,
Cambridge, Mass

SEATTLE SECTION

CHAIRMAN
Charles E. Williams
1017 East Harrison St.,
Seattle, Washington

SECRETARY-TREASURER
R. H. Berkheimer
1426 Elizabeth Street,
Bremerton, Washington

SAN FRANCISCO SECTION

CHAIRMAN
Major J. F. Dillon
526 Custom House,
San Francisco, Cal.

SECRETARY-TREASURER
D. B. McGown
Custom House,
San Francisco, Cal.

CHICAGO SECTION

CHAIRMAN
Montford Morrison
Acme International X-Ray Company
341 West Chicago Avenue
Chicago, Illinois

SECRETARY
L. R. Schmitt
Research Laboratory
Morkrum Kleinschmidt Corporation
Chicago, Illinois

VICE-CHAIRMAN
Prof. J. T. Tykociner
Electrical Engineering Laboratory
University of Illinois
Urbana, Illinois

SECRETARY
Wm. Harper
Harper Radio Laboratory
Chicago, Illinois

INSTITUTE ACTIVITIES

Technical Papers Being Prepared for Early Presentation at New York Meetings

Among the important papers now being written for presentation at meetings of the INSTITUTE in New York, during the Fall and Winter months, are the following: "Sources of 'A' and 'B' Power for Broadcast Receivers," by W. E. Holland; "Progress in Short Wave Transmission," by Frank Conrad; " 'B' Battery Sources for Broadcast Receivers," by Harry Houck; a paper on "Primary Battery Sources of Power," by W. B. Schulte; "Radio Engineering Instruction Methods," by C. M. Jansky, Jr.; "Crystal Control in Broadcasting," by M. C. Batsel and G. L. Beers; "Automatic Reception of Time Signals," by L. A. Hazeltine; "Radio Interference Mitigation," by J. O. Smith, and "Testing for Trouble in Radio Broadcast Receivers," by Lee Manley.

Institute Emblems, or Badges

All Fellows, Members and Associates of the INSTITUTE should provide themselves with a badge of membership. The badge is made in the form of a class-pin and is of 14-karat gold, beautifully finished in enamel and gold lettering. The Fellows' badge is of blue lettering on a gold background, Members' badges in gold letters on a blue background, and Associates' badges in gold lettering on a maroon background. When desired, the member's initials are engraved on the reverse side of the badge.

Badges sell for $3.00 each and may be procured from the Secretary, THE INSTITUTE OF RADIO ENGINEERS, 37 West 39th Street, New York.

Papers at Section Meetings

Members of the INSTITUTE are advised that technical papers dealing with radio subjects may be scheduled for presentation at Section meetings, when desirable, instead of being presented at New York meetings of the INSTITUTE. Sections now are established at Washington, D. C., Boston, Massachusetts, Chicago, Illinois, San Francisco, California, and Seattle, Washington.

Papers intended for presentation at Section meetings may be forwarded to the Chairman, Meetings and Papers Committee, THE INSTITUTE OF RADIO ENGINEERS, 37 West 39th Street, or to the Section Chairman.

M. I. Pupin

Dr. M. I. Pupin, elected President of the American Institute of Electrical Engineers for the year beginning August 1, 1925, is the second engineer to have attained the office of President of the American Institute of Electrical Engineers and President of THE INSTITUTE OF RADIO ENGINEERS.

Dr. Pupin was President of the I. R. E. in the year 1917. The other A. I. E. E. President who served as President of THE INSTITUTE OF RADIO ENGINEERS is Dr. A. E. Kennelly. He was at the head of the A. I. E. E. in 1898-1900, and of the I. R. E. in 1916.

Auxiliary Radio Language

The recently held International Conference of Radio Amateurs, at Paris, France, appointed a committee to study and report upon the problem of an auxiliary language for use in communication, correspondence, and comversation between members of the international units of the organization. About twenty artificial languages were considered, including Esperanto and Ido, as well as a few national languages. After considerable debate, in which the Scandinavian representatives strongly urged the adoption of English as the approved auxiliary language, the committee reported in favor of Esperanto.

Advertisements

Members of the INSTITUTE will have noted the improved make-up and display of the advertising pages of the PROCEEDINGS in recent issues. The value of the PROCEEDINGS as an advertising medium has made it possible for the INSTITUTE to procure copy for a full-page advertisement from each advertiser, in each issue.

Direct benefits will follow if, in writing to advertisers on the subject of apparatus listed or described, members of the INSTITUTE will mention that the advertisement was seen in the PROCEEDINGS.

Digests of United States Radio Patents

For some time past the PROCEEDINGS has carried a "Digest of United States Patents Relating to Radio Telegraphy and Telephony," in the last fifteen to twenty reading pages of each issue. The cost of publishing this matter is considerable and the question will shortly be before us as to whether it is economically desirable to continue the publication of this information.

Members of the INSTITUTE who are interested are asked to advise the Secretary whether or not this particular information is of real value to them. Decision in the matter will be based upon the views expressed or written to the Secretary.

Institute Technical Papers

Members of the INSTITUTE desiring to present papers should keep in mind that papers intended for presentation at meetings, or for publication, must be forwarded to the Chairman of the Meetings and Papers Committee, THE INSTITUTE OF RADIO ENGINEERS, 37 West 39th Street, New York, at least sixty days before the date of presentation. This is necessary in order properly to provide for editing, scheduling, proof-reading, and printing.

Toronto Section

The first meeting of the proposed Toronto Section of THE INSTITUTE was held at the University of Toronto on the evening of September 25th.

Additions to Membership

At the September meeting of the Board of Direction there were elected to membership in THE INSTITUTE one Fellow, thirty Members, ninety-nine Associates and nine Juniors. Ten of the Members were transferred from the Associate grade.

Meeting of the Board

The September meeting of the Board of Direction was held at INSTITUTE headquarters, 37 West 39th Street, New York, on the evening of September 1st. Those in attendance were: J. H. Dellinger, President; Donald McNicol, Vice-President; Alfred N. Goldsmith, Secretary; W. F. Hubley, Treasurer, and the following Managers: J. V. L. Hogan, A. E. Reoch, Melville Eastham, and A. H. Grebe.

THE EFFECT OF THE SOLAR ECLIPSE OF JANUARY 24, 1925, ON RADIO RECEPTION*

By

Greenleaf W. Pickard

(Consulting Engineer, The Wireless Specialty Apparatus Company, Boston, Massachusetts)

(Communication from the International Union of Scientific Radio Telegraphy)

During the brief interval of totality, a solar eclipse cuts off nearly all radiation over an area of several thousand square kilometers, and for an interval of several hours there is a material reduction of light over a considerable part of the earth's sunlit hemisphere. The actual light intensity within the central shadow is of the same order as full moonlight; a reduction of of about one hundred thousand times, while in the adjacent portions of the penumbra over nine-tenths of the light is cut off. It would naturally be expected that the effect of an eclipse upon radio communication would be in some wise similar to a night effect, altho less in magnitude because of its shorter duration and smaller area.

Altho there have been solar eclipses ever since this earth had a moon, and radio communication for over a quarter century, it is only in the past twelve years that observations of the eclipse effect upon radio reception have been made. I have appended to this paper the rather meagre bibliography of this subject, which altho distinctly contradictory at first reading, nevertheless shows that a solar eclipse has a distinct effect upon the signal strength from a distant station. In the majority of reports of observations made during past eclipses, the signal intensity has increased during the middle of the eclipse, altho in a few instances decreased reception was observed. Most of the prior observations were merely ear estimates of signal intensity, and the large number of negative observations obtained clearly indicates that in general the eclipse effect is small. The ear is grossly insensitive to slight and relatively slow changes in sound intensity; unless the change occurs quite abruptly a two-to-one variation will usually escape notice. Furthermore, the earlier eclipse

*Received by the Editor, March 25, 1925. Presented before The Institute of Radio Engineers, New York, April 1, 1925.

observations were mostly made on spark transmission, and we recognize today that such highly damped radiation does not show the marked fading, sunrise and sunset effects characteristic of continuous wave transmission, and for this reason would be less apt to show a well-defined eclipse effect. The explanation of this difference is a rather obvious one, if we assume these effects are due to interference between different transmission paths to the receiver, and consider the matter from an optical standpoint. If we pass monochromatic light into any form of interferometer, the interference fringes obtained are sharply defined, but if white light is used the fringes become overlapping spectra, and definition is impaired or lost. In conducting radio transmission over considerable distances at night, we appear to be using a gigantic interferometer, with some agency beyond our control continuously and irregularly changing the length of one of the paths to the receiver, and therefore, the penalty we now pay for the use of the otherwise desirable continuous or monochromatic radiation is a marked accentuation of these bothersome effects. For so long as we employ point sources of monochromatic radiation, with maximum radiation in the horizontal plane, and with single point receivers, every broadcasting station will have its zone of severe fading, and radio direction finders will continue to be erratic around sunrise and sunset. It is perhaps fortunate that we have not yet applied the simple remedies for fading to our broadcasting system, for if this had been done, there would have been no eclipse effect for me to investigate.

In making my plans for the radio observation of the eclipse of January 24th, 1925, I therefore decided to confine my attention to continuous wave transmission, and to use continuous recording at as many points as possible. I also decided to center my attention on those transmission frequencies which I had previously found gave the greatest night effect, and so far as was possible to space transmitters and receivers at the distance of maximum fading; that is, to frequencies within the present broadcasting band, and distances of the order of two hundred kilometers. In order that the higher frequencies should also be observed I asked station 2XI at Schenectady to transmit at approximately four megacycles, which was recorded in New York City, and observed at many other points. At the other end of the radio spectrum quantitative measurements by the telephone comparator method were made under Dr. Austin's direction at Washington on the 57-kilocycle radiation from station 2XS at Rocky Point, Long Island, and by the American

Telephone and Telegraph Company on trans-Atlantic reception.

As the object of my work was to record electric field changes, and not directional effects, open antennas were used at all recording stations, loosely coupled to super-heterodyne receivers. The plate circuit of the second detector was opened and the primary of an intermediate frequency transformer inserted, and the secondary w nding of this transformer was closed thru a crystal detector and the recorder galvanometer. The filament and plate voltages were held rigidly constant, and there was no observable change in voltage amplification during the five days of the eclipse schedule. The large open antennas employed also increased the stability of the receivers, for with the relatively large input available a very moderate voltage amplification sufficed. As I did not know how large the eclipse effect might be, I provided a variable coupling from the antenna to the amplifier, calibrated in terms of galvanometer deflection. In this way not only could the deflection of the galvanometer be adjusted either way by a known amount, but the input to the receiver and also the output to the crystal detector was always kept within definite and small limits. The manual type of recorder devised by Mr. H. S. Shaw[1] was used at all of the recording stations, altho at a number of my observing stations frequent galvanometer readings were used in its place.

Many other groups and individuals made valuable radio observations during the eclipse, altho these were in the main of a qualitative character, depending chiefly upon aural estimates of signal intensity. Prominent among these was the "Scientific American," which by an ingeniously timed transmission from four broadcasting stations reached a well-organized group of several thousand broadcast listeners. The preliminary analysis of the "Scientific American" reports, to which I shall later refer, has brought out some very striking facts. The Zenith Radio Company placed a portable broadcasting station at Escanaba, Michigan, almost in the center of the path of totality, while the Edison Light Company of Boston installed their portable station WTAT on the Coast Guard Cutter "Tampa," and broadcast an eclipse program from a point on the Atlantic Ocean just south of Marthas Vineyard, Massachusetts, and near the center of the shadow path. Excellent directional observations were made at Ithaca, New York, under the direction of Prof. Merritt of Cornell University, using stations WGY and WEAF, and a well-

[1] "Short Period Variations in Radio Reception," Pickard, Proceedings of The Institute of Radio Engineers, Volume 12, April, 1924, Figure 2, page 123.

marked eclipse effect was noted. This paper must, however, deal principally with the records and observations made by my own group of stations, as the mass of outside data—some of which is even now coming to hand—is so vast that many months will be required for any useful analysis aad correlation.

Figure 1 shows that portion of the eclipse network with which this paper deals. At the extreme western end is the Escanaba station operating at 1,120 kilocycles. Aural observation of their transmission by hundreds of broadcast listeners gave as the principal eclipse effect a strengthening of the signal approximately coinciding with maximum shadow. It is unfortunate that I did not have time to arrange for at least one continuous record from Escabana, as the western end of the totality path was traversed by the shadow very shortly after sunrise, and the night effect was probably very strong at that time.

Broadcasting station WGR, of the Federal Telephone and Telegraph Company at Buffalo, New York, operating at a frequency of 940 kilocycles; WGY of the General Electric Company at Schenectady, New York, 790 kilocycles; 2XI, the experimental station of the General Electric Company, also at Schenectady, and transmitting at 4 megacycles; and WBZ of the Westinghouse Electric and Manufacturing Company, at 890 kilocycles, at Springfield, Massachusetts, maintained a constant and lightly modulated transmission from 7.30 to 11.00 A. M., 75° Meridian Time, on January 22nd, 23rd, 24th, 25th, and 26th, 1925. Station WEAF of the American Telephone and Telegraph Company, at lower New York City, operating at 610 kilocycles, with 250-cycle tone modulation, transmitted from 4.00 to 11.00 A. M. on January 23rd, 24th, and 25th.

Under my personal direction at Ithaca, New York, records were made of the transmission from WGR, WGY, and WEAF. At Schenectady, New York, Mr. W. C. Lent, of Union College, made galvanometer readings of reception from WBZ on the eclipse morning. At Hamilton, Massachusetts, Mr. F. W. Dane, of the Wireless Specialty Apparatus Company, made galvanometer readings of reception from WGY on the mornings of January 24th and 25th. At Fitchburg, Massachusetts, under the direction of Mr. T. Parkinson, of the Bureau of Standards, readings and records of reception from WBZ and WGY were taken. At Leominster, Massachusetts, near Fitchburg, Mr. H. Powers took readings from WGY. Massachusetts Institute of Technology station 1XM, at Cambridge, Massachusetts, under the direction of Prof. A. E. Kennelly, took galvanometer readings of reception from WBZ on January 24th and 25th. Mr. A. F. Murray made records on the eclipse morning of stations WGY, WEAF, and WTAT at Newport, Rhode Island. At Middletown, Connecticut, records were made under the direction of Mr. H. S. Shaw from WGY and WBZ. At Easthampton, Long Island, a phonograph record of reception from WGY was made by Dr. E. E. Free. At the laboratory of the Radio Corporation of America, in upper New York City, and well within the path of totality, records of WGY and 2XI were made by Mr. Arthur Van Dyck, on the mornings of January 22nd, 23rd, 24th, 25th, and 26th, under the direction of Dr. Alfred N. Goldsmith. At Washington, D. C., Dr. C. B. Jolliffe, of the Bureau of Standards, made records of reception from WGY on the 22nd, 24th, 25th, and 26th, while at the U. R. S. I. laboratory in Washington Dr. L. W. Austin supervised the measurement of field intensity from 2XS on the mornings of the 23rd and 24th.

At Philadelphia, Pennsylvania, galvanometer readings were taken under the direction of Prof. Bazzoni of the University of Pennsylvania of reception from WGY and WEAF. Considerably before the time of totality, reception at Philadelphia had fallen to its flat day-time level, and the curves do not show any effect which could be attributed to the eclipse.

At McGill University, Montreal, Canada, Mr. E. L. Bieler observed reception from WEAF. At Montreal, however, the signal fell to the background level after sunrise, and the curve does not show any effect which could be laid to the eclipse.

At Annapolis, Maryland, Mr. G. D. Robinson made galvanometer readings at one minute intervals from WGY, on the mornings of the 24th and 25th. His results show on the eclipse morning a distinct minimum during the middle of the eclipse, which was only 95 percent complete at his point.

At the higher frequencies, in addition to the records made at New York City from 2XI, this same station was observed by Mr. F. W. Dunmore at the Bureau of Standards in Washington, the principal effect noted being a slight decrease in signal during the maximum shadow. Major Mauborgne of the Signal Corps, observing in Washington, 3.5-megacycle signals from Canadian 9AL at Toronto, observed a marked increase in signal during maximum eclipse at Washington. Under the direction of Dr. A. H. Taylor observations were made at Bellevue (near Washington) and elsewhere on two groups of frequencies, one ranging from 3 to 5 megacycles, and the other above 5 megacycles. The former group of frequencies showed an increase of signal strength during the eclipse and a decrease as the sunlight returned, while the higher frequencies, particularly those about 7.5 megacycles, were effected in reverse manner, the shadow decreasing and the sunlight increasing the signal strength. Miss E. M. Zandonini of the Bureau of Standards, observing Washington reception of signals from a 2-megacycle station at Newburgh, New York, noted that at the time of maximum shadow in Washington there was a brief sharp increase in audibility. At the present time my analysis of the high frequency data is so far from complete that I can only give this general conclusion: For those frequencies and distances which are better by night than by day, the eclipse improved reception; for frequencies and distances which are normally better by day than by night, the eclipse decreased reception. In other words, the eclipse effect for the higher frequencies appears to be a pure night effect.

Whenever we record reception from a distant broadcasting station thru the day and night, we find that the record for at least an hour or so before and after noon is quite flat, that is, relatively free from fluctuations. But an hour or more before sunset the fluctuation amplitude begins to increase, and by an hour or two after sunset reaches approximately its normal and high night time value. This continues thru the night, but about an hour before sunrise the fluctuation amplitude begins to fall, as does also, tho to a lesser degree, the mean field, until at about sunrise the mean field has reached nearly its day time level, and the fluctuations have been reduced to a relatively small amplitude. But there are frequent exceptions to this, of which the eclipse morning at most receiving points was one, where the fluctuation amplitude remained high for a long time after sunrise.

We must admit that there is as yet no entirely satisfactory explanation of these phenomena. But most of our transmission hypotheses are in agreement in considering the night field at moderate distances from the transmitter—200 kilometers for example—as made up of two components, one transmitted along a direct or low level path and the other by an indirect or high level route, the second path either changing continually in actual length or in phase. At short distances—five kilometers for example—the energy reaching the receiver by the indirect or high level path is probably negligible, while at great distances—1,000 kilometers for example—the high level path is the principal agent in forming the field at the receiver. According to this general assumption, a record taken thru dawn and sunrise from a station two hundred kilometers distant, and showing the usual gradual decrease of fluctuation amplitude, may be resolved into two components, one consisting of a curve of mean values, and the other of fluctuation about these mean values. The mean field, taken over any interval which is long as compared with the most prominent fluctuation period, may be interpreted as an approximate measure of the reception along the direct path, while the fluctuation amplitude represents the reception by the indirect or high level path. The decrease of fluctuation amplitude as the sunlight begins to fall thru the air may be taken to mean that either the high level path itself is in some way impaired by the effect of the sunlight, or that it is masked by increasing ionization below, which would attenuate the waves both in their ascent and descent.

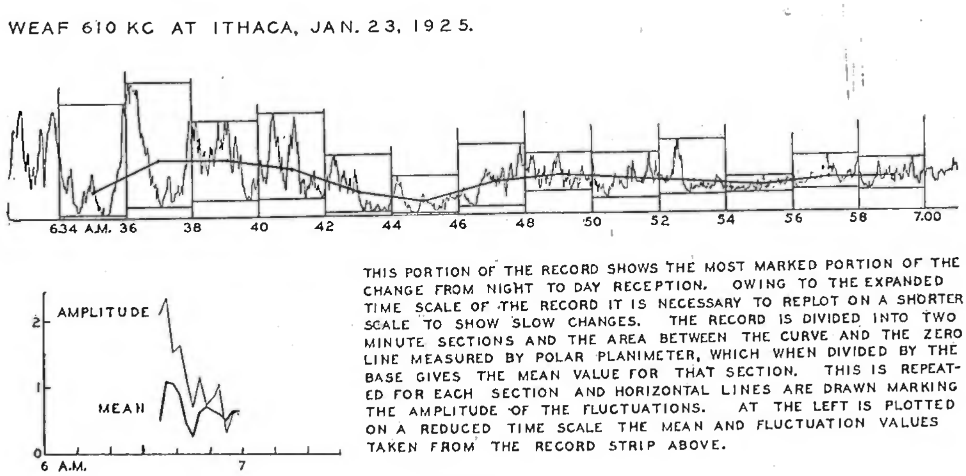


FIGURE 2

I have applied this method of analysis to all of my eclipse records, and the process by which this was done is sufficiently shown in Figure 2. The original record, a portion of which appears in the upper part of this figure, was taken on January 23rd at Ithaca, from station WEAF. For that particular morning this part of the record contains the steepest part of the fall in fluctuation amplitude. As shown in the figure, the record strip is first divided into two-minute sections, and the area between the curve and the base or zero line is measured with a planimeter. This area, divided by the length of the base, gives the mean height of the curve in that section. Repeating this process for each section gives a series of mean values, which when linked give the heavy-line curve shown on the record strip. Also, as indicated on the figure by the short horizontal lines, the amplitude of fluctuation in each section is measured.

The original record, made by the manual recorder, is on a rather drawn-out time scale, the motion of the paper being approximately 1.6 cm. per minute, so that long period small amplitude changes do not show very well. Therefore, as shown in the lower left-hand part of this figure, the separated mean and amplitude values are replotted on a greatly condensed time scale.

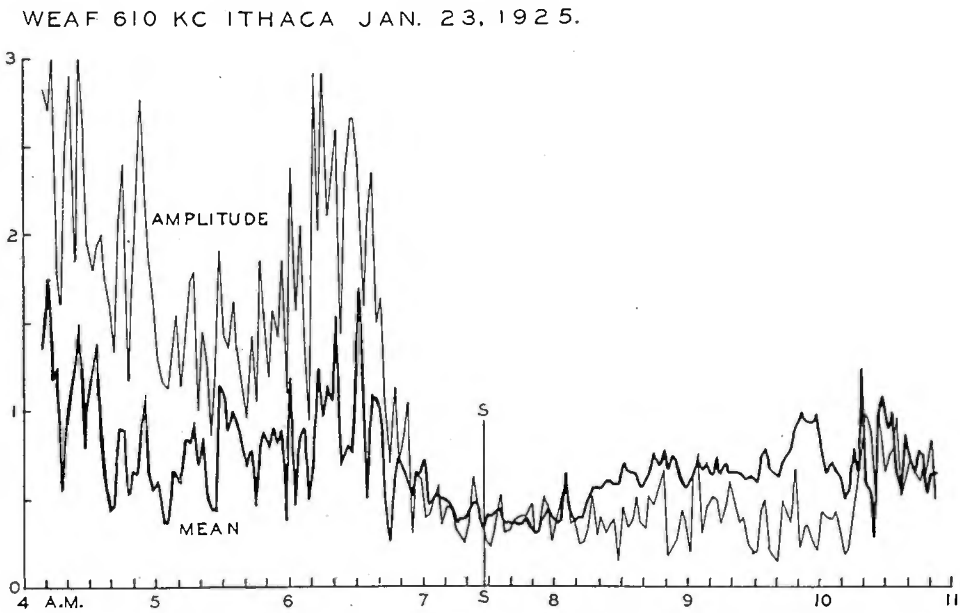


FIGURE 3

The entire morning record, of which Figure 2 is a portion, is replotted in Figure 3. The vertical line S-S marks sunrise at Ithaca, and, so far as the curve is concerned, apparently determined a "low." About an hour before sunrise there is a marked peak in both curves, and preceding this, about two hours before sunrise there is another low. This is quite a normal before-sunrise performance, which was in fact repeated for this station on the eclipse morning.

After sunrise, however, mornings differ greatly. At Ithaca the fluctuations died out soon after sunrise on the 22nd, 23rd, and 25th, while continuing appreciably for over two hours after sunrise on the 24th and 26th. At other recording points the mornings did not arrange themselves in the same order. At Washington the 25th showed the maximum persistence of night effect thru the forenoon, while at New York City all the forenoon records, save the 24th and to a lesser degree the 22nd, are quite flat. If this difference is due to varying ionization below the high level path, it is entirely possible that lower level conditions, even those below the isothermal layer, are involved, in which event we may find some interesting correlations with weather. Another possible deduction from the frequent persistence of the night effect thru the forenoon is that sunlight does not entirely wreck the high level path, but merely masks this path by a low level ionization, which varies from day to day. In other words, the path may be there all the time, but the waves are prevented by low level conditions from either getting up to it, or coming down again. In the morning a station far to our west, and still in darkness, might deliver its waves quite freely to the high level path, but at our sunlit receiving point they would pass over us unobserved.

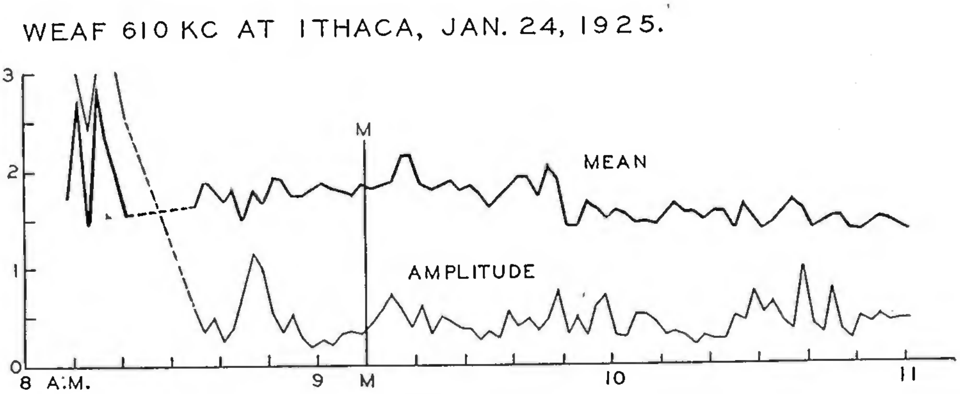


FIGURE 4

Coming now to the eclipse records, Figure 4 is Ithaca reception of WEAF on the eclipse morning. The dotted-line portion of this record between 8.22 and 8.35 A. M. represents a thirteen-minute breakdown on the part of WEAF. The mean curve shows a slight rise, reaching a maximum about ten minutes after the middle of the eclipse, which is indicated on all the eclipse records by a vertical line M-M. The amplitude curve, on the other hand, shows a distinct dip before the middle, and a peak shortly after. It might well be said of this record that similar fluctuations occur at other times, as for example at 10.25 A. M., and so, standing by itself, this record must be considered inconclusive.

Figure 5, of WGY reception at Ithaca, altho quite similar to Figure 4, shows a fall and rise of both mean and amplitude curves which is not duplicated at other points on this record. The effect is most marked, as might be expected, in the amplitude curve, which reaches a minimum value shortly before the middle of the eclipse, and then rises to a maximum some twelve minutes after.

The record of WGR reception at Ithaca, shown in Figure 6, is a very striking one, the principal feature being a high and

WGY 790 KC AT ITHACA, JAN. 24, 1925.

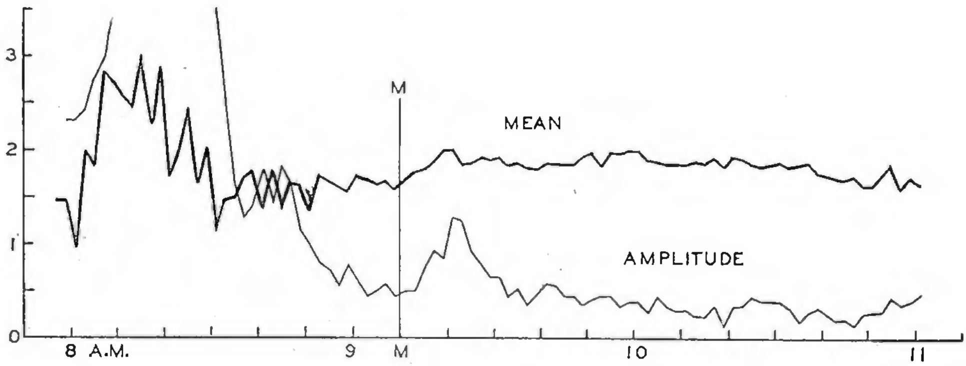


FIGURE 5

WGR 940 KC AT ITHACA, JAN. 24, 1925

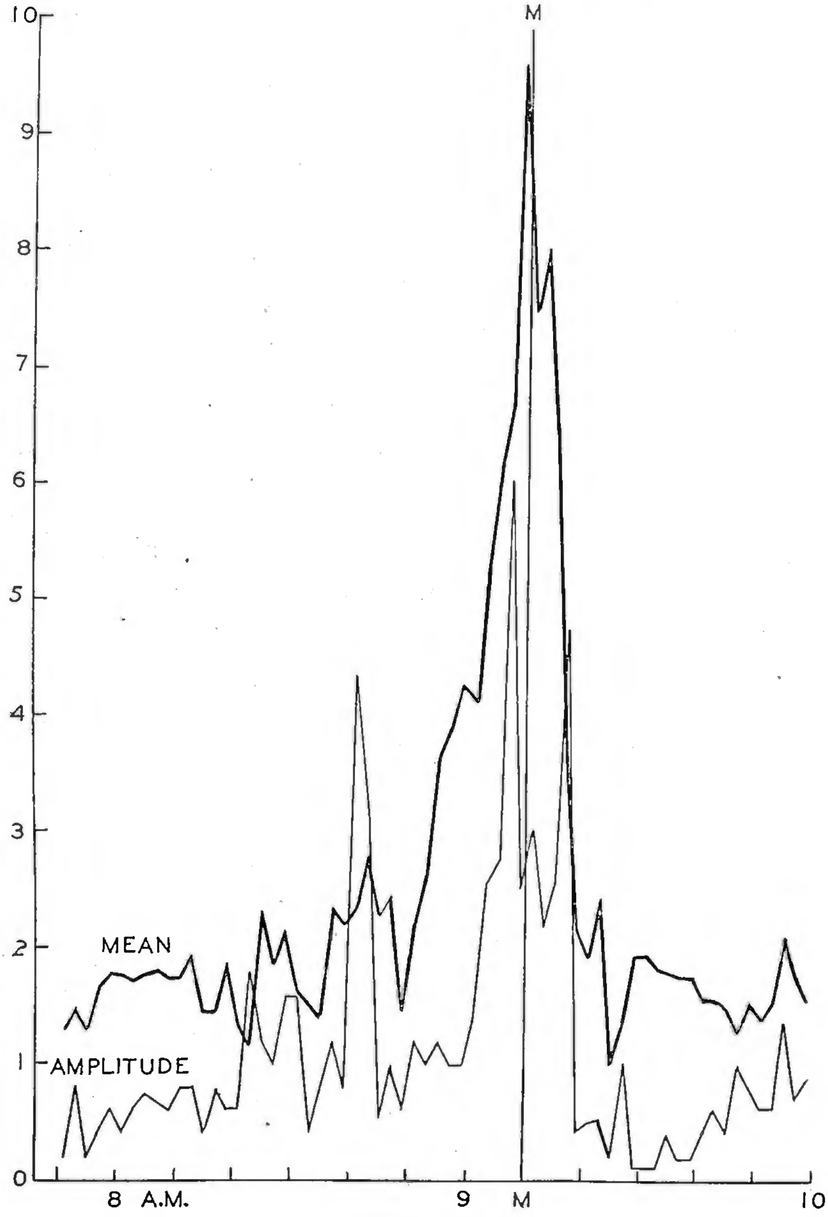


FIGURE 6

sharp peak practically at the middle of the eclipse. This is the maximum effect obtained at any of my recording stations, and at first sight is quite different from the effect shown in the preceding figures. Buffalo and Ithaca were both nearly in the middle of the shadow path, and are separated by a distance which is but little greater than the width of the shadow spot, so that for a short time the transmitter and receiver were nearly joined by darkness. Another striking feature about this record is that, unlike the preceding figures, the mean field and amplitude rise from 8.00 to 9.10 A. M., slowly at first, and then with greater and greater steepness. First contact of the eclipse at Ithaca was at 8.00 A. M., and so, disregarding minor fluctuations, the signal intensity from WGR rose approximately at the rate at which the sun's light was reduced. And after the middle of the eclipse, the intensity fell off at about the rate the light came on.

Leominster and WGY are both outside and to the north of the shadow path, altho the eclipse was approximately 99 percent complete at both transmitter and receiver. The Leominster record of Figure 7 shows a general lowering of mean field for

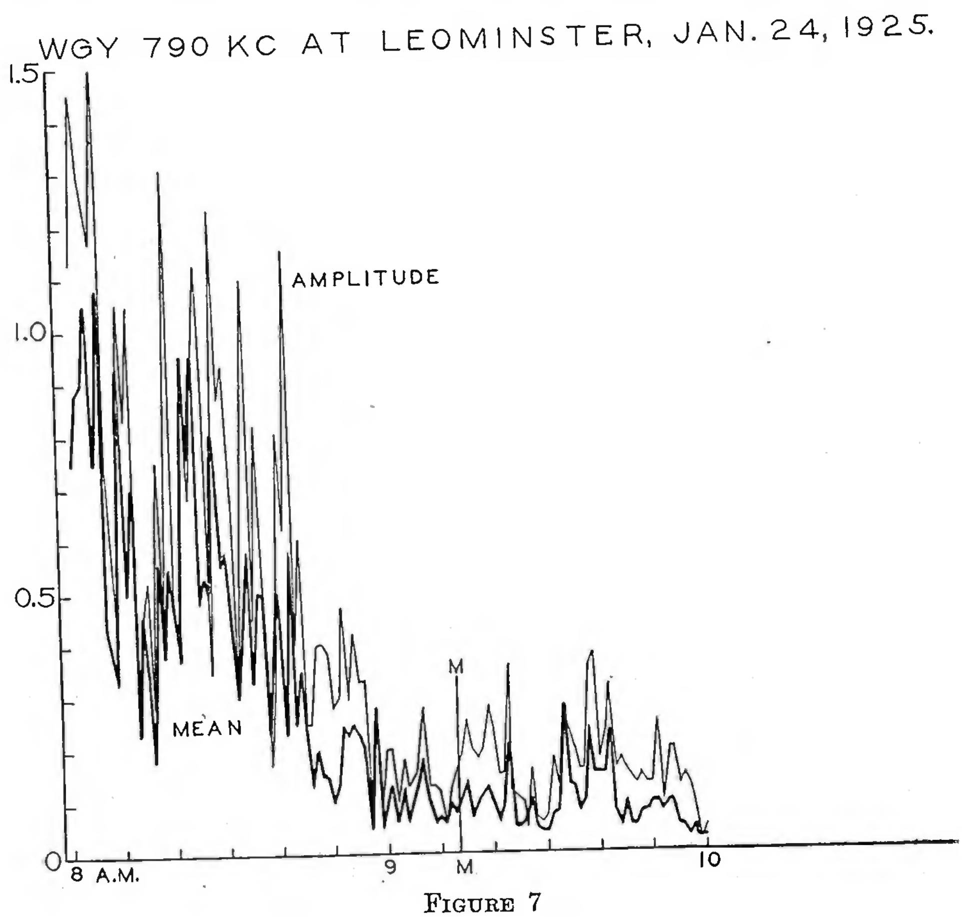


FIGURE 7

nearly half an hour at the middle of the eclipse, and superposed on this general lowering is a fall before and a rise after the middle which resembles that shown in Figures 4 and 5. But a still more marked fall and rise center on 9.30 A. M., so this record is not by itself conclusive.

Next to the Buffalo-Ithaca record of Figure 6, the reception of WGY at Hamilton, shown in Figure 8, is one of my most striking records. Altho the transmission path, as in the preceding figure, was wholly outside the shadow path, the fall and rise of both mean and amplitude curves are most strongly marked. The early portion of the Hamilton record shows a large night effect, which may be the explanation of the magnitude of the eclipse effect.

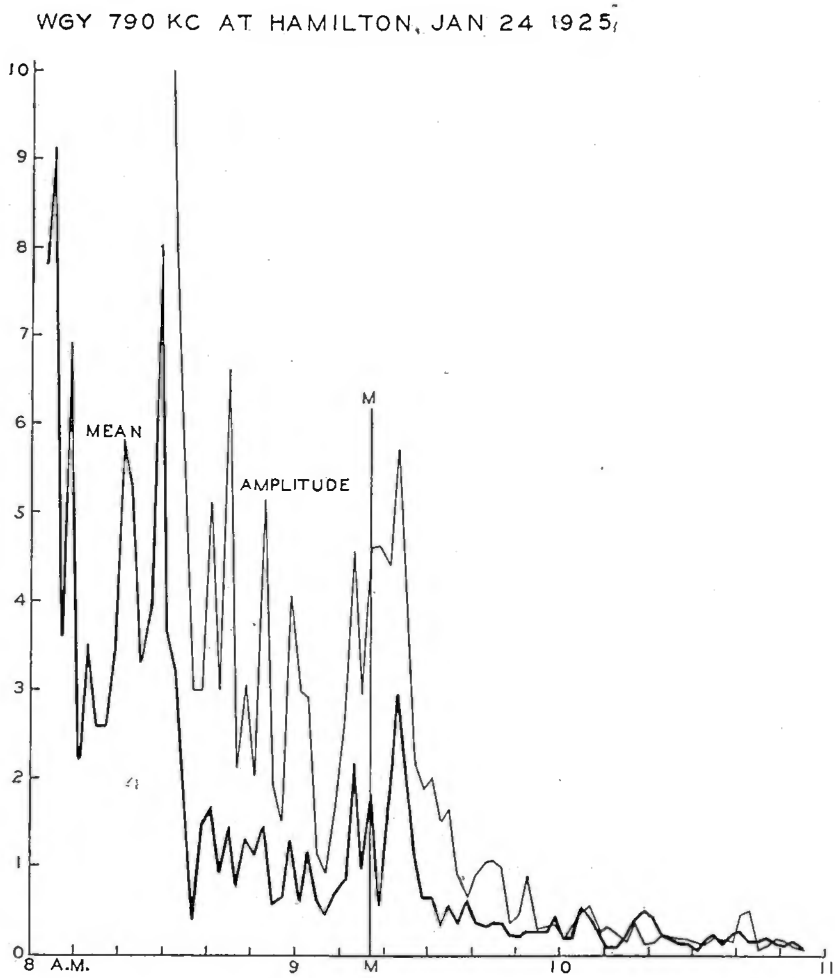


FIGURE 8

Figure 9, of WGY reception at Middletown, is not unlike the record shown in Figure 5. The eclipse effect is clear, altho a similar change of greater amplitude centers on 8.30 A. M. The transmission line from WGY to Middletown, as may be seen by reference to Figure 1, is quite similar in its relation to the shadow path to the line joining WGY and Ithaca, so that if this is any criterion, the records should be alike.

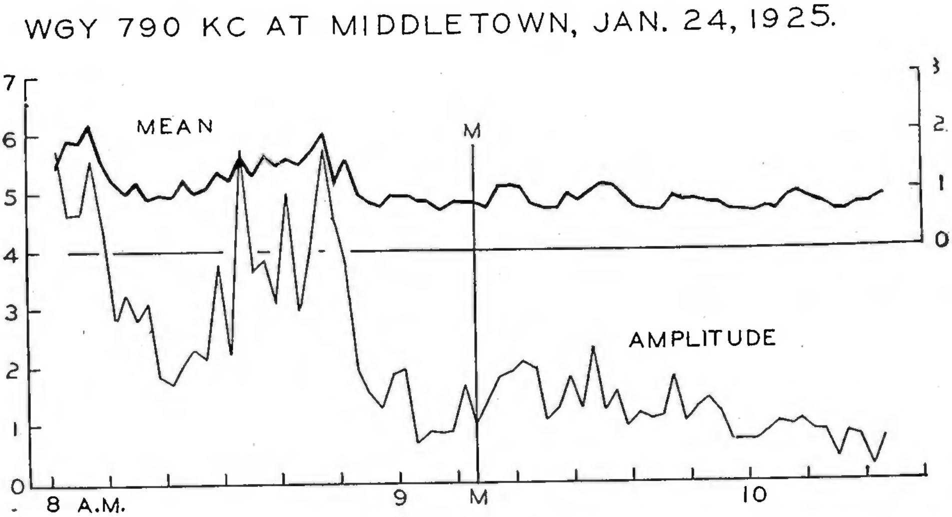


FIGURE 9

New York City reception from WGY, shown in Figure 10, exhibits a mean field which rises slowly from 7.30 to 9.22 A. M., and then slightly declines again. The amplitude curve shows a marked fall before totality, and a still more marked rise afterward, but similar effects appear at other points, as at 8.20 and 10.10 A. M. The transmission here is from a transmitter out-

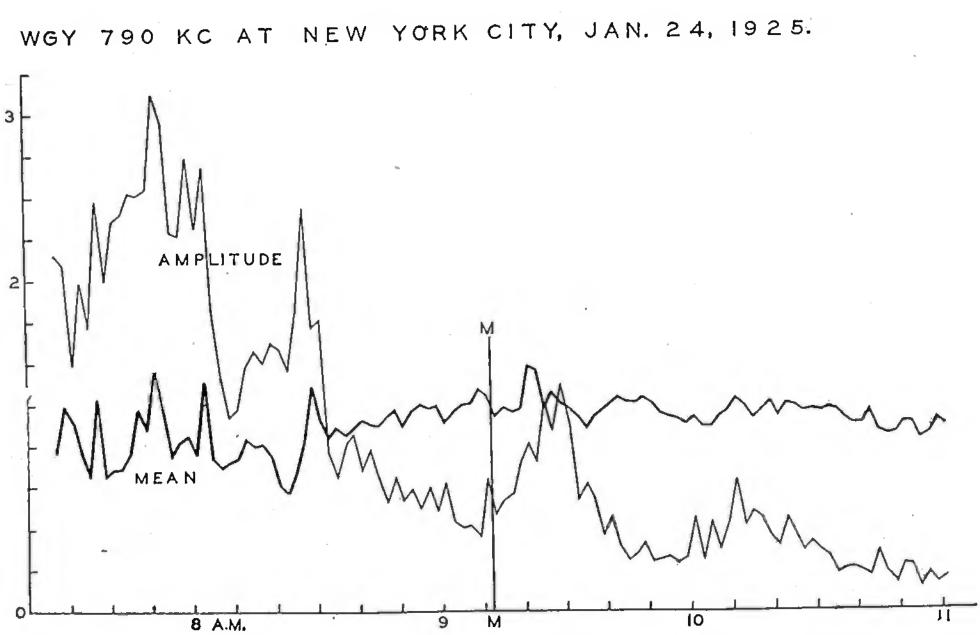


FIGURE 10

side and to the north of the shadow path, to a receiver inside but near the southern boundary of the path.

Rocky Point, the transmitter of the record shown in Figure 11, was nearly at the center of the path of totality, while the receiver at Washington was well outside and to the south. The record from beginning to end, save for the eclipse effect, is flat, and the fall and rise is unmistakable. It should be noted that this record is in ordinates which are proportional to field values, whereas in the other records which I have shown they are in field-square units. The 26 percent increase at the peak of this curve would, therefore, correspond, on the other records, with an increase of about 60 percent. Reception at such a low frequency is usually quite free from the short period fluctuations so common to the broadcasting band, and so altho this record was made from readings taken at five-minute intervals, a continuous record would probably have looked much the same.

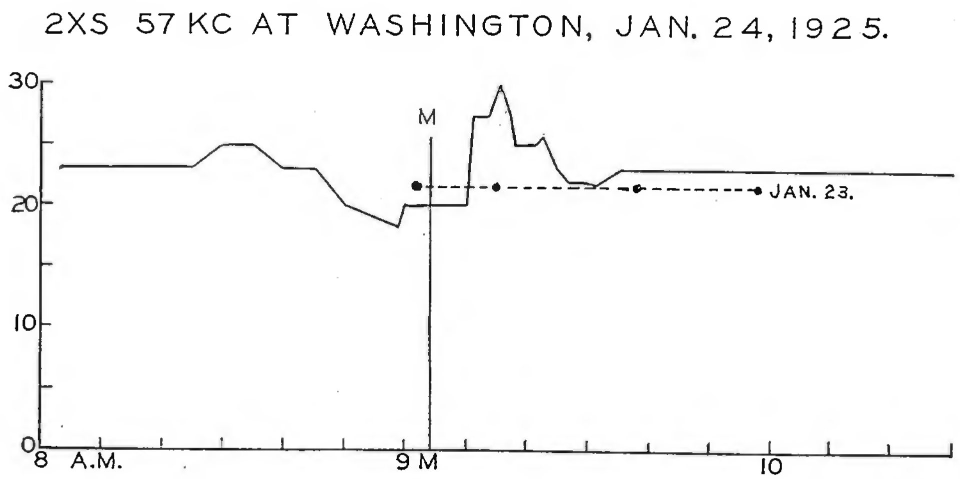


FIGURE 11

The record shown in Figure 12 is of WGY reception at Ithaca on the 26th, which at this receiving point most nearly corresponds with the eclipse morning. Altho slightly irregular, it would be difficult to find a pseudo-eclipse effect here.

WGY reception in New York City on the 22nd is shown in Figure 13. At this receiving point the morning of the 22nd most resembled the eclipse morning, altho it must be admitted that the resemblance is not very close. A pseudo-eclipse effect appears on this record at 8.35 and another at 8.55 A. M.

In Figure 14 I have shown Cambridge observations of WBZ on the 24th and 25th, which at this receiving point and for this particular station were similar mornings. The eclipse record shows the fall and rise of both mean and amplitude curves, altho the peak values occur nearly at the middle of the eclipse, instead of later.

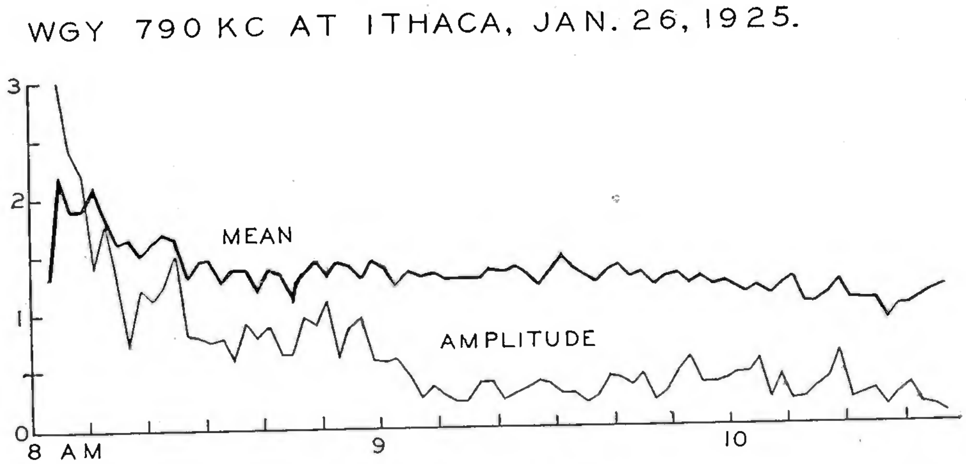


FIGURE 12

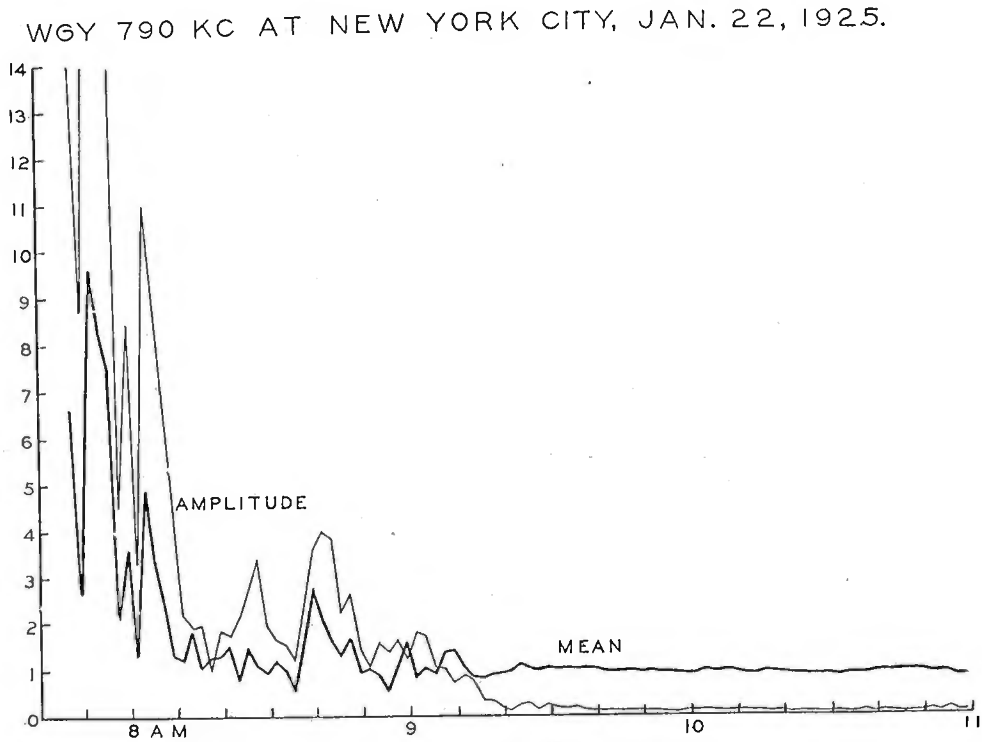


FIGURE 13

Figure 15, of Schenectady reception from WBZ, shows principally an increase centering on the middle of the eclipse. The smoothness of the curve before and after this increase is due to the fact that readings were taken at much greater intervals on these parts of the curve.

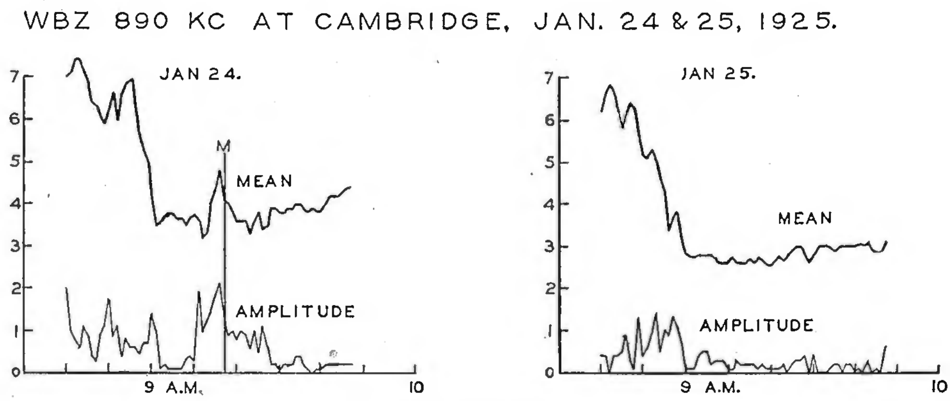


FIGURE 14

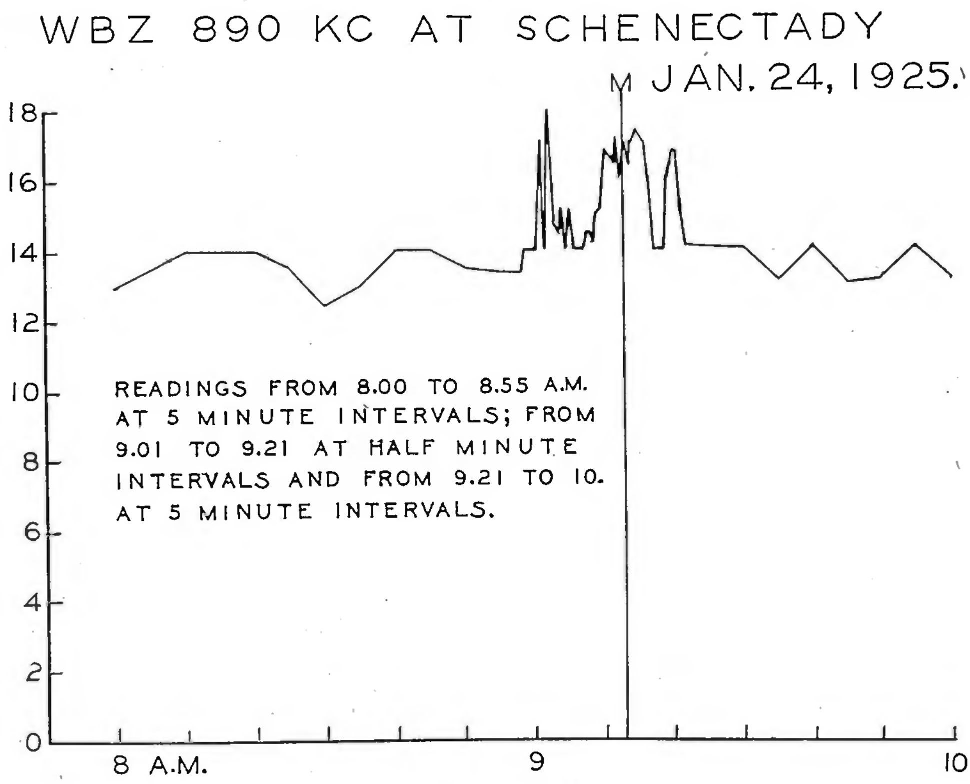


FIGURE 15

In Figure 16 I have attempted to bring out the general eclipse effect by taking four of my records, multiplying in each record the ordinates by such a factor as would bring the amplitude at the eclipse middle to approximately the same value, and than making an arithmetical average of the four. Altho this gives rather a shot-gun pattern for the points, I think that the dotted-line curves which I have drawn are fairly representative. This figure must not be taken too literally, and there is probably little significance in the apparent phase difference between the mean and amplitude curves.

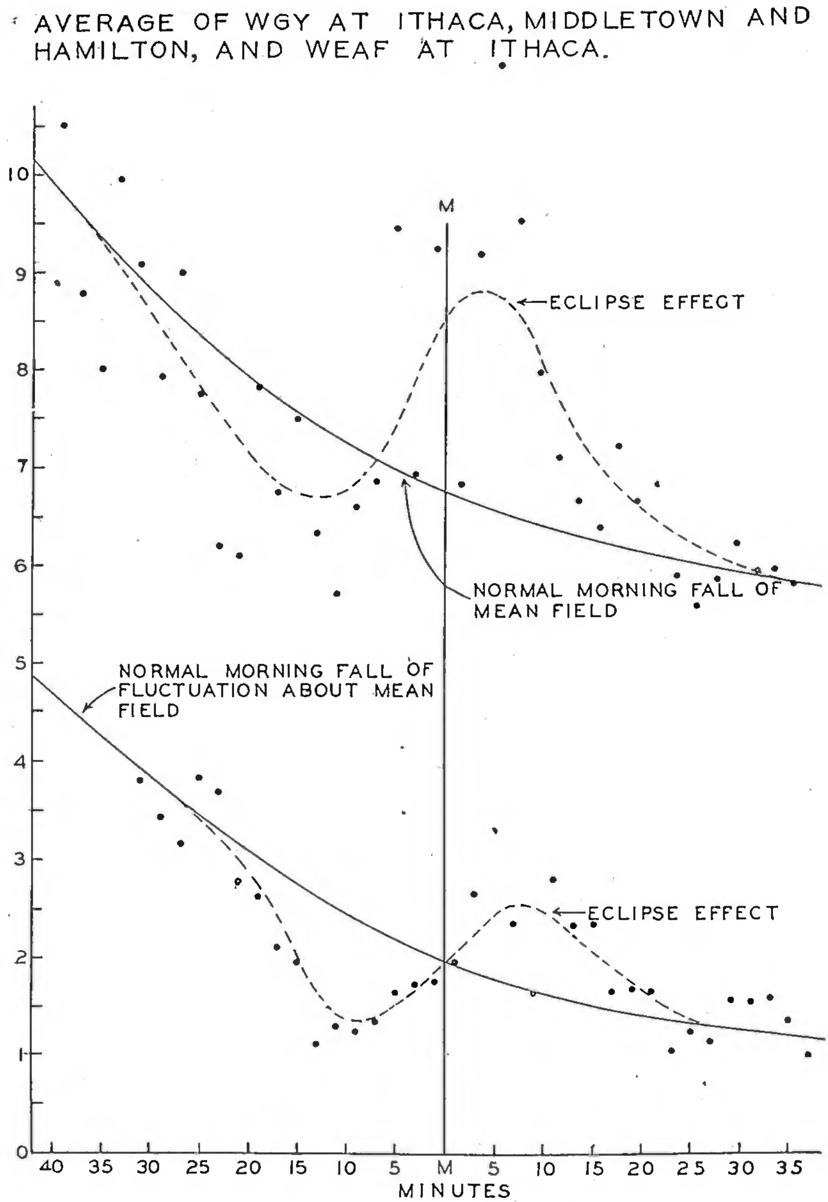


FIGURE 16

These morning records strongly remind one of an ebbing tide. There is the same incessant, periodic wash of waves, the same occasional high wave, and the same difficulty at any one moment in deciding whether the tide is going out or coming in. And it is this very irregularity in the recession which makes it hard to separate the eclipse effect from a mere coincidence. As I have pointed out above, there are few of my records which, taken by themselves, bear an unquestionable mark of the swift passage of the eclipse shadow. But when in record after record, both of different stations at the same receiving point, and of the same station at different receiving points, we find repeated the same fall and rise, there can be little doubt but that we have found at least one of the effects of a solar eclipse on radio reception. And having found it, there can be little question but that its proper name is the Nagaoka effect. For in 1914, H. Nagaoka,[2] from purely theoretical considerations[3] announced that the intensity of signals should be weakened as an eclipse begins, pass thru a minimum, rise rapidly to a maximum, and then slowly decrease.

To explain satisfactorily the Nagaoka effect would require knowledge which we do not yet possess; detailed information of the pressure, composition, and ionization of our atmosphere at all levels, the exact effect of sunlight on this ionization, and finally just how the passing wave interacts with the ions. Probably the knowledge we have gained of the eclipse effect will find its immediate principal value in checking present-day transmission hypotheses.

The transmission of radio waves thru the atmosphere is, of course, a purely optical matter; we are merely working in the extreme infra-red as compared with the visible spectrum. From an optical standpoint the atmosphere is a highly complex medium, with equally complex effects upon any radiation which traverses it. As the atmosphere is of greatest physical, and therefore optical density at the surface of the earth, and rapidly becomes less dense as we go aloft, it is the equivalent of a prism with its base on the ground, and all radiation in a horizontal plane is therefore curved downward. This effect, which is practically limited to the first few kilometers of the air, accounts for a curvature approximately 25 percent of that of the earth, so that if this globe were four times bigger that it is, and had the same atmosphere, all horizontally emitted radiation would maintain the same level indefinitely, instead of going off at a tangent.

Because of the presence of gas atoms, and particularly on account of the fact that many of these atoms are ionized or electrically charged, the atmosphere must be regarded as an imperfect dielectric; optically considered it is something between a transparent insulator and a metal. This imperfect dielectric is subjected to at least two fields which have an optical effect; the earth's magnetic field, and the normal electrostatic field, which amounts to several hundred thousand volts across the whole atmosphere. Any radiation traversing the air will, there-

[2] "Effect of Solar Eclipse On Wireless Transmission," H. Nagaoka, "Mathematico-Physical Soc.," Tokyo, Proc. 7, pages 428-430, December, 1914.

[3] "Effect on Radio-Telegraphy of Atmospheric Ionization," H. Nagaoka," "Mathematico-Physical Soc.," Tokyo, Proc. 7, pages 403-412, October, 1914.

fore, show both the Faraday and Kerr effects, that is, there will be a magnetic rotation of the plane of polarization of the waves along the direction of the magnetic field, and an analogous effect due to the electric field. That at least one of these effects—the Faraday—may be a large one for radio waves has very recently been suggested by Messrs. Nichols and Schelleng.[4]

It has been recognized for a long time that the optical properties of metals are quite different from those of transparent substances. A prism of glass bends light toward its base, while a metal prism often deviates light in the opposite direction, that is, it would appear that the light was propagated in the metal at a higher velocity than in vacuo. A very full discussion of this effect in metals has been given by Prof. R. W. Wood,[5] which leads us directly to our most recent attempt to explain the bending of waves around the earth.

One of the most promising of the many generalized explanations of the phenomena of radio transmission is the Eccles-Larmor[6] hypothesis. It appears to be the only one which has been numerically expressed without involving some grotesque amount or arrangement of ions in our upper atmosphere. Larmor first points out that true electrical conductivity in the air would act principally rapidly to attenuate or damp out the waves, and only secondarily to change their speed or course. But if the wave passes into a highly rarefied and only slightly ionized portion of the atmosphere, where the ions may be freely swayed to and fro by the passing wave-fields, there may be a change of speed without any damping of the wave. This change of speed or bending of the wave to conform to the earth's curvature will take place most effectively at some high level where the mean free path of the ions is so long that there may be many alternations of wave-field between two successive collisions with atoms or other ions. The ions at this high level will, therefore, sway freely under the alternating field, and interact without material dissipation of energy, increasing the velocity of the wave without either attenuation or scattering. Finally, as the effect is proportional to the number of ions present and to the square of the wave-length, each transmission frequency has a different level for its path, and very high frequencies may travel at quite a low level without absorption.

---

[4] "Propagation of Electromagnetic Waves Over the Earth," H. W Nichols and J. C. Schelleng, "Science," Volume LXI, Number 1576, pages 288-290, March 13, 1925.

[5] "Physical Optics" 2nd Edition, 1914, pages 456-475.

[6] "Philosophical Magazine," December, 1924.

The picture we may make of such transmission is one of radiation struggling its way up from the transmitter, with severe absorption in the lower levels, particularly by day, but finally reaching a level at which it bends around the earth without loss, forming there what may be called a wave-sheet. As this wave-sheet spreads out in all directions around the transmitter, energy is showered down from it to the surface of the earth, again subjecting itself to severe attenuation in passing the lower strata. At very short distances, the receiver will be principally affected by waves which are transmitted more or less directly and at a low level; at moderate distances there will be a summation of both directly transmitted radiation and that dropping down from above, while at long distances the only material field at the receiving point is that coming down from the wave-sheet.

All this accords well with the observed phenomena of fading. At short distances there is but one path of transmission, with no interference and hence no fading; at moderate distances the fields due to the two paths are nearly equal in magnitude and so produce the maximum interference effect or fading, while at long distances the high level path is practically the only one to the receiver, and fading becomes much less violent. If the ionization which creates the wave-sheet were constant over considerable periods of time, there would be no fading, merely a diurnal change in intensity. At moderate distances from the transmitter there would be formed on the surface of the earth a stationary interference pattern, and a fixed receiver would remain in either a weak or a strong field, depending upon the accident of its position. At great distances there would be no interference pattern, and all receivers over very considerable areas would receive practically equal and non-varying signals.

But as a matter of every-night observation, we find rather rapidly varying signal intensity at moderate distances, and at long distances a less rapid fading. It would appear from this that the wave-sheet was far from smooth and constant, but was instead traversed by varying indentations and bulges, due to non-uniform and varying ionization. At moderate distances this would act to vary the intensity and path-length of the high-level route to the receiver, producing a strong and complex interference with the direct-path radiation. At the longer distances, where the directly transmitted wave is no longer an appreciable factor, the corrugations in the wave-sheet would produce plural path transmission down to the receiver, and fading is still observed, altho different in character and less severe than that at moderate distances.

I have already had the honor of presenting before this INSTITUTE a large number of reception records[7] which fully show the change in fading with distance. It would naturally be expected that when a certain limiting distance was exceeded, there would be little or no change in the character of the fading, so that, save in the matter of intensity, there would be very little difference here in the East between reception from Chicago or from California.

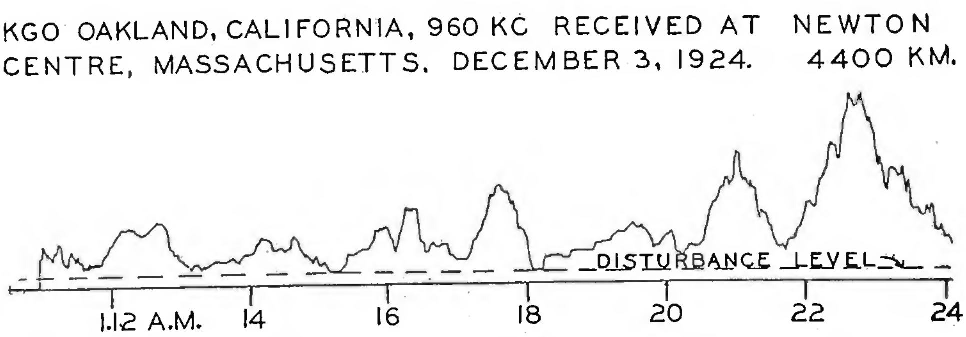


FIGURE 17

Figure 17, which is a reception record taken in Newton Centre, Massachusetts, from KGO at Oakland, California, shows a fading curve which is very much like that of Chicago stations of similar transmission frequency. This record is also interesting in that it shows a low disturbance level on that particular night; unfortunately this is not normal at my receiving point.

There is every reason to believe that the irregularities in the wave-sheet are in general small in area, and therefore individually affecting relatively small reception areas on the earth below. This is indicated by my repeated observations[8] of different fading curves for slightly separated receiving points. And if the wave-sheet is at or near the auroral level, the non-uniform appearance and rapid motion of the auroral streamers is perhaps an indication that the ionization at these high levels is also non-uniform and rapidly moving or varying. There is in fact some support for the conception of a moving series of irregularities in the wave-sheet, which would carry a more or less constant interference pattern over the ground below; the fading tests con-

[7] See these PROCEEDINGS.
[8] See these PROCEEDINGS.
[9] "A Study of Radio Signal Fading," "Scientific Papers of the Bureau of Standards," Number 476, 1923.

ducted by the Bureau of Standards[9] indicated something of this sort in the so-called "traveling curves" which they discovered.

It is always difficult to make a diagram of a generalized explanation, and altho I have attempted this in Figure 18, I trust no one will construe it too literally. For simplicity I have shown merely a cross-section of the radiation on one side of a transmitter. At short distances there is little or no fading, as there is but one path to the receiver. As the receiving point is moved further

NORMAL NIGHT TRANSMISSION ACCORDING TO ECCLES-LARMOR HYPOTHESIS.

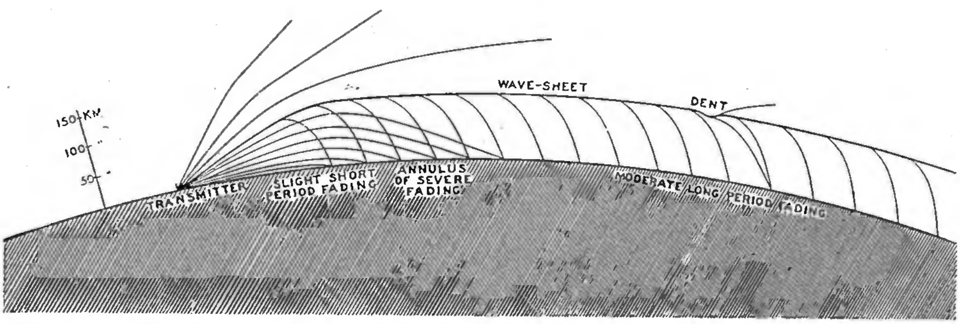


FIGURE 18

away from the transmitter, some energy begins to drop from above, and slight fading commences. I have quite uniformly found that at short distances—11 kilometers for example—the fading is not only of small amplitude as compared with the mean field[10] but shows a predominance of the shorter periods. This might be explained on the supposition, as indicated by the first descending line on my figure, that at short distances the indirect path to the receiver does not go all the way up to the level of the main wave-sheet, and is, therefore, subjected to different and perhaps more frequent irregularities that at the higher levels. As the distance further increases, the direct and indirect paths to the receiver deliver fields of approximately equal amplitude, and an annulus of violent fading is encountered, at a distance of between one and two hundred kilometers. Passing beyond this, the direct path transmission rapidly ceases to be a material factor, and less severe, longer period fading is found, due to varying or moving irregularities in the wave-sheet, which scatter energy up or down, depending upon the sign of the curvature, and so produce two or more paths down to the receiver, with consequent interference. One such dent is shown at the right of the figure; actually we must assume that the wave-sheet is full of them.

[10] My PROCEEDINGS article, Figure 11.

Coming back to the eclipse, it may at first sound fanciful to say that the moon's shadow dents in the wave-sheet, dispersing waves both up and down, and as this dent rapidly plows its way across the wave-sheet it accounts for the effects shown in my eclipse records. But, after all, this is no more fantastic to my mind than are some of our earlier and still tenaciously held transmission guesses, such for example as the conducting and reflecting Heaviside Layer. The moon's shadow diminishes solar radiation thru the air, the production of ions lessens, the ions in the shadow begin to recombine, and the total ionization falls. The wave-sheet within the shadow is now at a lower level than before, and has been literally dented in by the shadow.

It is evident that the distribution of wave-field on the earth's surface, resulting from the upward and downward deflection of energy at the edges of the traveling dent, will depend upon the relation of transmitter, shadow spot, and receiver. While, as I have shown above, the eclipse effect was generally a small one, yet, as in the instance of reception at Ithaca from Buffalo, a rather striking increase was found, which could hardly have escaped a broadcast listener's observation. At Easthampton, Long Island, a phonograph record of reception from WGY showed a marked decrease in intensity, beginning eleven minutes before totality, and lasting until twenty minutes after. A preliminary analysis of the "Scientific American" reports has clearly shown that the way in which the signal changed depended largely upon the position of the receiver with respect to the shadow path and the transmitter, and this may be summed up as follows:

When the transmitter and receiver were outside and on the same side of the path of totality, there was a gradual increase in signal strength, beginning about twenty minutes before the eclipse middle, and falling off again some ten minutes later. If the decrease before the middle of the eclipse has been too slight or gradual for aural observation, this effect, so far as the broadcast listener is concerned, appears in my records at Figures 8, 14, and 15.

When the transmitter and receiver were outside and on opposite sides of the path of totality, there was a decrease in signal strength beginning a few minutes before totality and lasting until well after. Mr. Robinson's galvanometer readings at Annapolis of reception from WGY show this effect.

When both transmitter and receiver were within the path of totality there was a relatively sharp increase in signal strength practically coincident with totality, which fell off rather rapidly as the sunlight returned. Ithaca reception of WGR, shown in Figure 6, checks this very nicely.

In correlating my records with those of the "Scientific American" and other outside agencies, it now seems that one effect, suitably distorted to fit each case, will explain nearly all the observations. It is only necessary to assume that as the relative positions of shadow, transmitter, and receiver change, the relative magnitude of the Nagaoka fall and rise change also.

In Figure 19 I am once more showing something which must not be interpreted too literally. I have here illustrated in a general way how the simple Nagaoka effect will explain what are to the broadcast listener apparently opposite changes. In 1 the transmitter and receiver are both in the shadow path, and altho the signal first falls, and then rises, the accentuation of the rise makes it only part of the effect which is likely to be noted by the ear. In 2 the receiver is in the path, and the transmitter is outside, and with this arrangement my records show the fall and rise to be similar in magnitude. In 3 both transmitter and receiver are out of the shadow path, but on opposite sides, and this apparently accentuates the drop to such an extent that to ear observation it is the only effect.

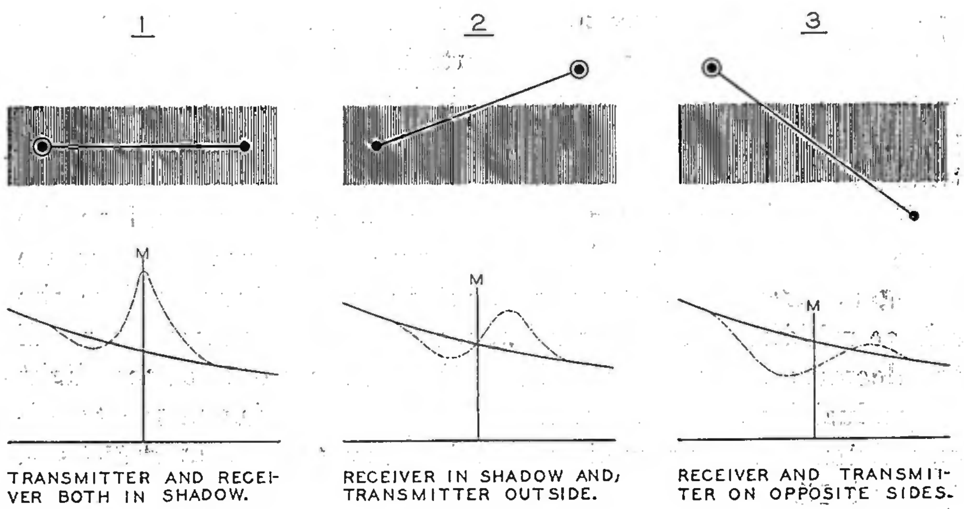


FIGURE 19

The many reports from observers of the eclipse broadcasting from station WTAT on the Atlantic Ocean were very kindly placed at my disposal by the Edison Light Company of Boston, and I have made a preliminary analysis of these reports, simply on the basis of whether or not the observer noted any change in intensity during the eclipse. Nearly half the reports stated that there was no change in intensity, and nearly all of those noting a change found an increase reaching a maximum either at or shortly after totality.

I have embodied these results in Figure 20, the light circles indicating points where observers reported no change, and the dark spots points where an increase was noted. It is interesting to find that observers only fifty kilometers from the transmitter reported an increase during totality. As the figure shows, the greater part of the transmission was over water. Broadcast listeners as far away as Illinois, Canada, and Florida heard the broadcasting on the eclipse morning, but these distant listeners unfortunately failed to report whether or no the intensity varied.

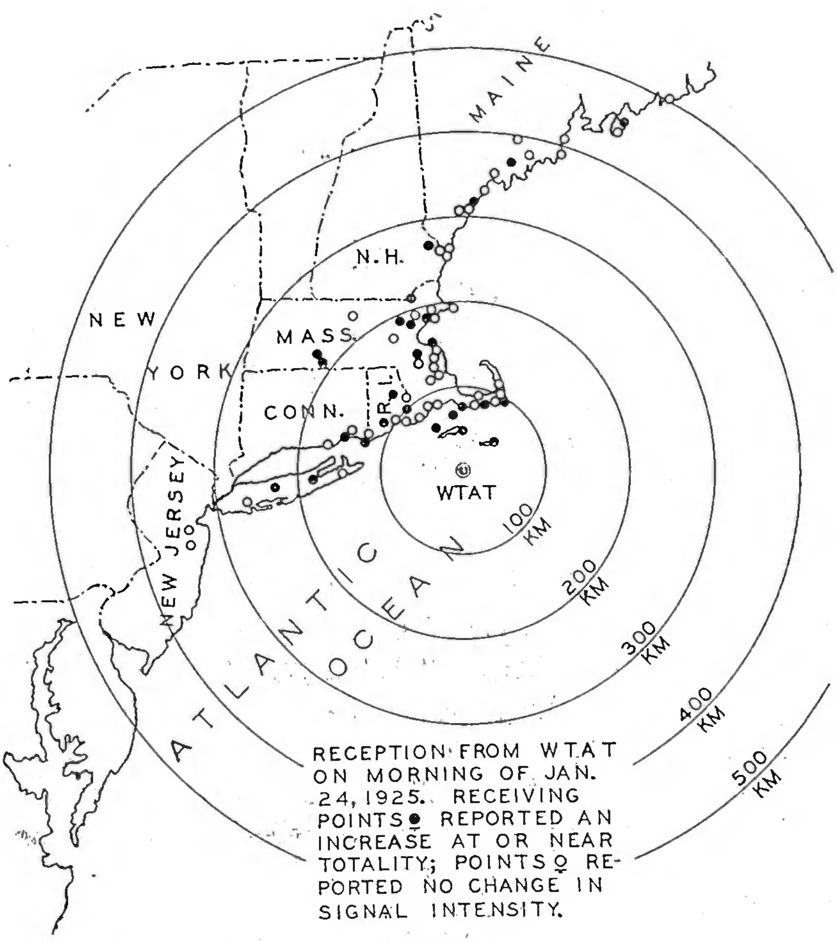


FIGURE 20

Our experiences with low-power broadcasting stations, which are normally on land and working overland, are such as to make this daylight transmission from a hundred-watt radiophone transmitter rather surprising. This particular transmitter had often been used in the past at points on shore in the vicinity of

Boston, but so far as my information goes it was then never heard by daylight at any such distances. Altho this is probably in no sense an eclipse effect, it may indicate the advisability of anchoring all of our coastal broadcasters off shore.

In conclusion I wish to express my appreciation of the cooperation so freely given by the Federal Telephone and Telegraph Company, the General Electric Company, the Westinghouse Company, the American Telephone and Telegraph Company, and the Radio Corporation of America. Without the transmission from their stations this work would have been impossible. I am deeply indebted to my assistants at Ithaca, Messrs. W. E. Bostwick, D. W. Exner, C. W. Garthlein, R. M. Holmes, C. J. Paddon and E. E. Zimmerman, and for the many courtesies extended to me by the Department of Physics at Cornell University, where my recording station was located. I am very grateful to Dr. Alfred N. Goldsmith, not only for his organization of the broadcasting stations for the eclipse schedules, but for the excellent recording work which was done under his direction. I also wish to thank my associate in this work, Mr. H. S. Shaw, who personally set up and directed the recording station at Middletown, and the many organizations and individuals which sent me valuable eclipse data and records. Finally, great credit must be given the Bureau of Standards, which not only took a very active part in the work, but also acted as an efficient clearing house for the distribution and collection of instructions and data.

BIBLIOGRAPHY OF ECLIPSE EFFECTS

"Influence of the Eclipse of the Sun, April 17, 1912, on the Propagation of Electric Waves," A. Turpain, "Comptes Rendus," 154, pages 1457-1461, May 28, 1912.

"Propagation of Long Electric Waves During the Solar Eclipse," W. H. Eccles, "Nature," 89, pages 191-192, April 25, 1921.

"Effect of the Solar Eclipse on Wireless Telegraph Signals," W. H. Eccles, "Electrician," April 26, 1912, page 109.

"Effect of the Solar Eclipse on Wireless Telegraph Signals," Schledermann, "Electrician," May 31, 1912, page 329.

"Influence of Solar Eclipse on Propagation of Hertzian Waves," A. Boutaric and G. Meslin, "Comptes Rendus," 154, pages 1746-1747, June 17, 1912.

"Reception of Radiotelegraphic Signals from the Eiffel Tower during the Solar Eclipse," Flajolet, "Comptes Rendus," 154, pages 1488-1491, June 3, 1912.

"On Certain Phenomena Accompanying the Propagation of Electric Waves Over the Surface of the Globe," W. H. Eccles, "Electrician," September 27, 1912, pages 1015-1019.

"Wireless Telegraphy Measurements at Marburg and Graz During the Recent Eclipse of the Sun," E. Take and M. Vos, "Deutsch. Phys. Gesell., Verh.," 14, 18, pages 837-843, September 30, 1912.

"Wireless Telegraphy and the Eclipse of the Sun, April, 1912," F. Kiebetz, "Phys. Zeitschr.," 13, pages 890-892, September 15, 1912.

"Telefunkenzeitung," Number 6, page 89, 1912.

"Radio-Telegraphy During the Solar Eclipse of May 29, 1919," "Nature," 104, pages 323-324, November 20, 1919. Report to Section A of British Assoc. at Bournemouth.

G. W. Pickard (by letter): The records taken at the laboratory of the Radio Corporation of America in New York City, of the 4-megacycle transmission from 2XI at Schenectady, could not be reduced and replotted in time for insertion in my paper, so I therefore take this opportunity to present them.

The transmission from 2XI was interrupted every five minutes by keying, and in reducing these records I have taken the mean value for each five-minute period. In Figure 21, which is of reception on the morning of January 22nd, a general decrease is

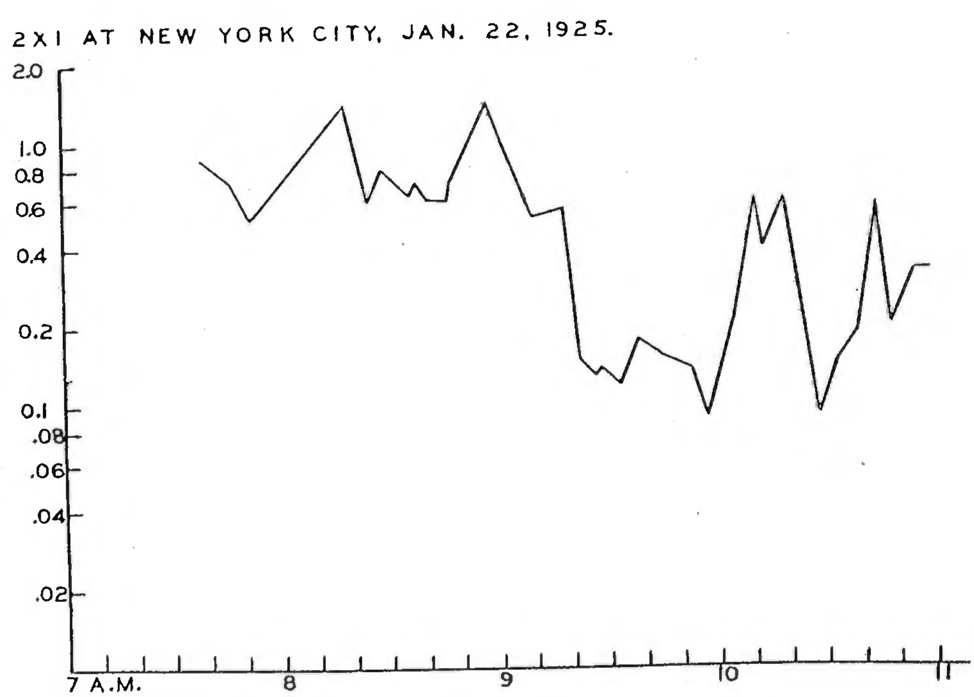


Figure 21

shown, the detector current changing over ten-fold, corresponding to a field decrease of over three times.

The morning of January 23rd, shown in Figure 22, is strikingly different from the preceding morning, the decrease in detector current being from 1,000 to less than 0.02; a range of over fifty thousand times, or a change in field of over two-hundred-fold.

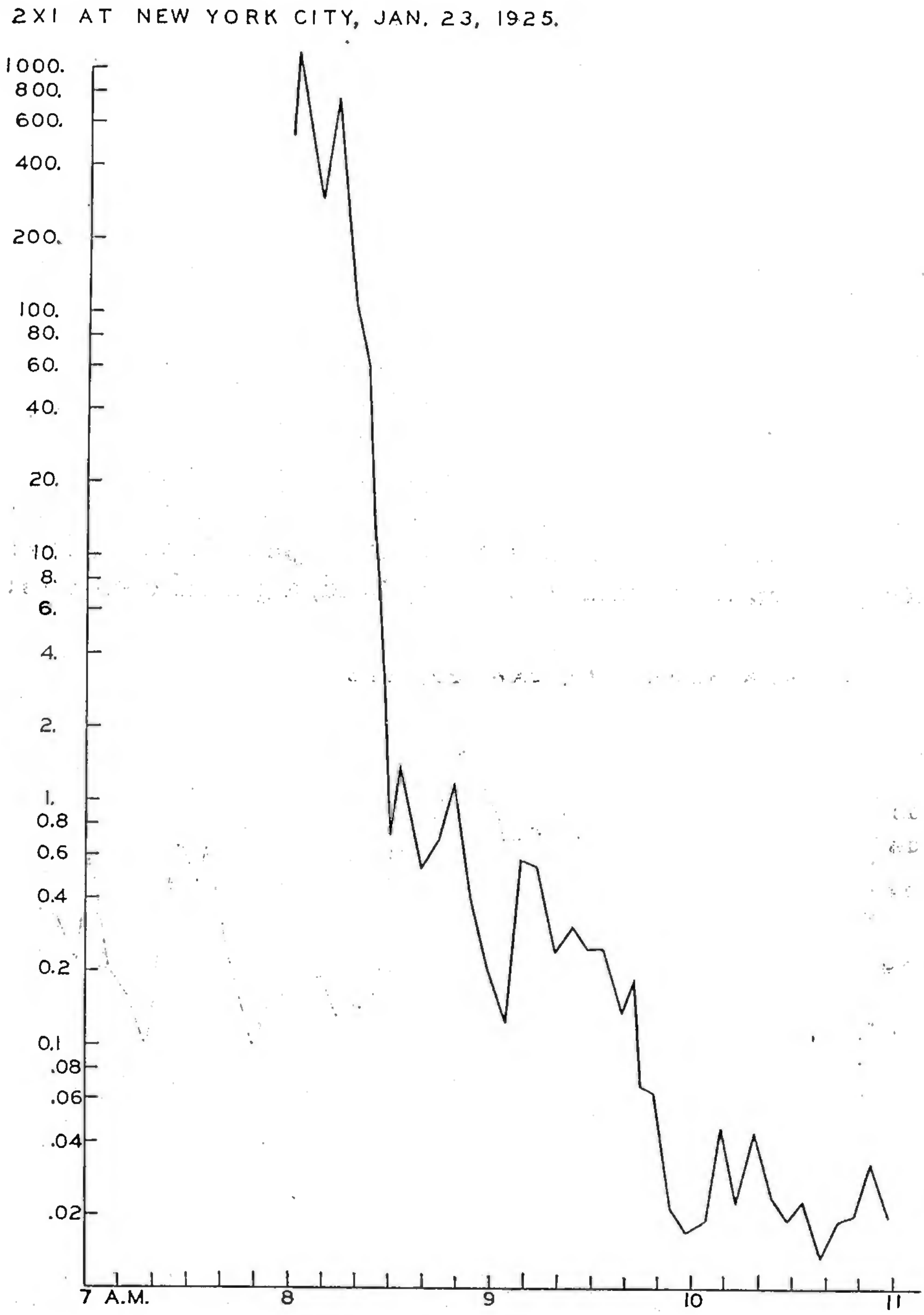


FIGURE 22

Figure 23 is the record of the eclipse morning, and at first sight it appears to be a complete reversal of the Nagaoka effect. But the rise to the peak value at 8.05 A.M. commenced sometime before the first contact, and so could not be an eclipse effect. From 8.58 to 9.46 A.M. the note of 2XI was inaudible, and over this period only the background was recorded. It would seem than this marked decrease was an eclipse effect, for it is not duplicated on any of the other four morning records.

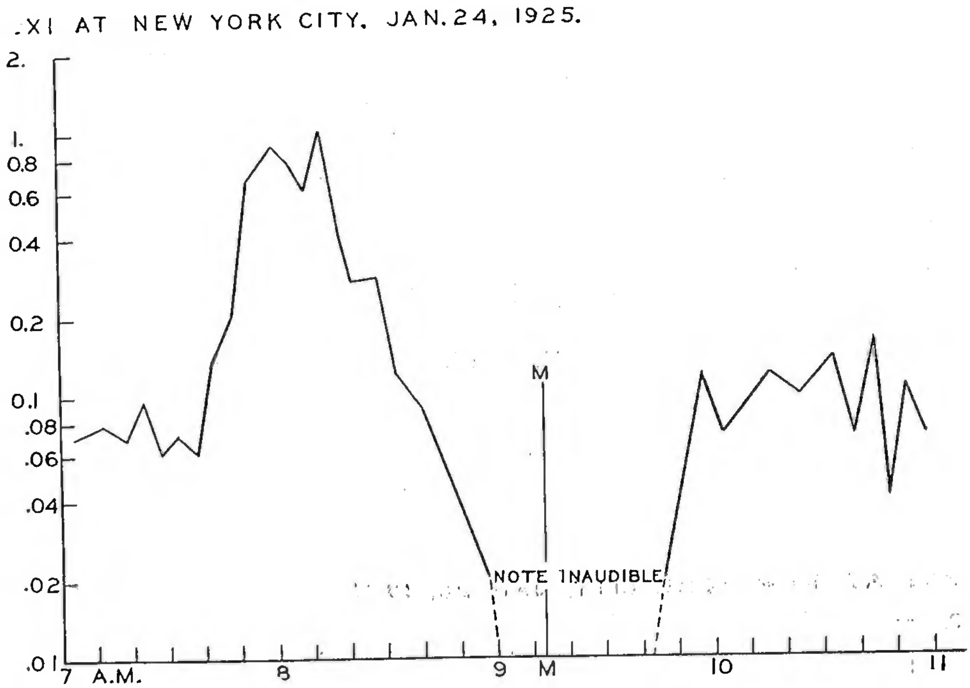


FIGURE 23

I have already mentioned the fact that WGY reception in New York City at 790 kilocycles gave flat records on January 23rd, 25th, and 26th. But, as appears from Figure 22, the morning of January 23rd was far from flat for 4-megacycle reception. So far as this single observation goes, one might say that it indicated transmission at a different level, agreeably according to the Eccle-Larmor hypothesis. Its real significance is that we need more such data before we can reach a definite conclusion.

Early in my paper, I said that one would naturally expect the eclipse effect to be similar to a night effect. I have recently obtained a series of sunset records at Newton Centre, Massachusetts, from WGY at 790 kilocycles, and as it seems relevent here, I give in Figure 26 an average of three of these records.

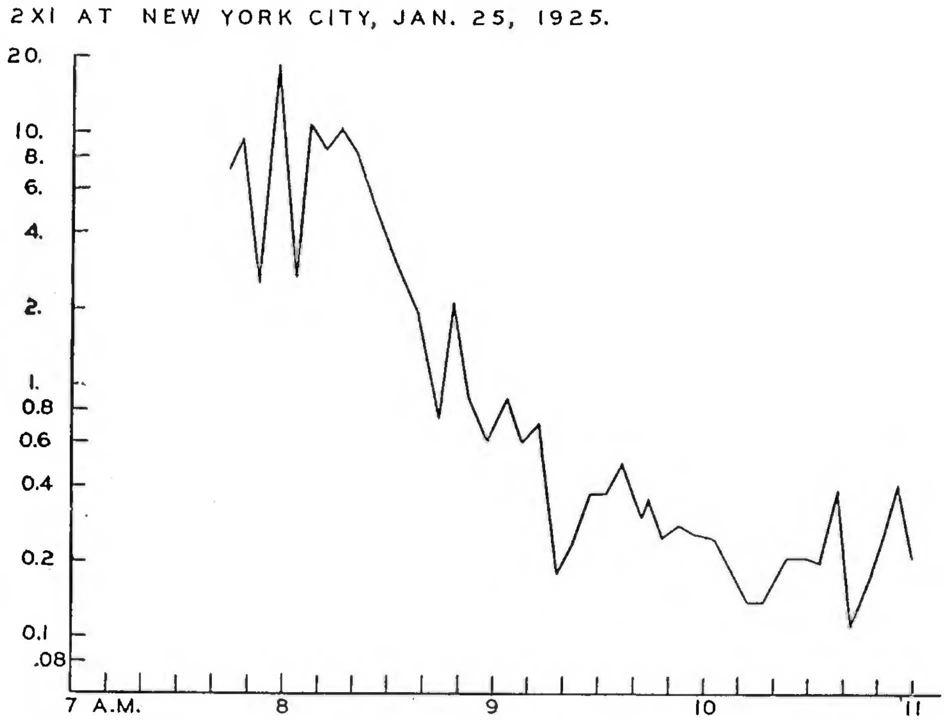


FIGURE 24

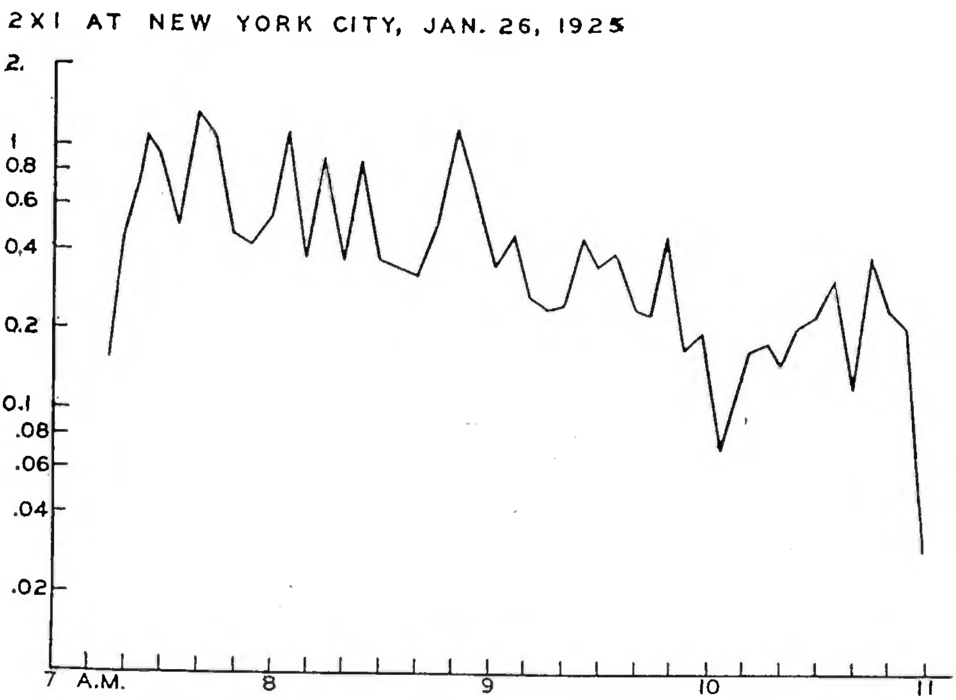


FIGURE 25

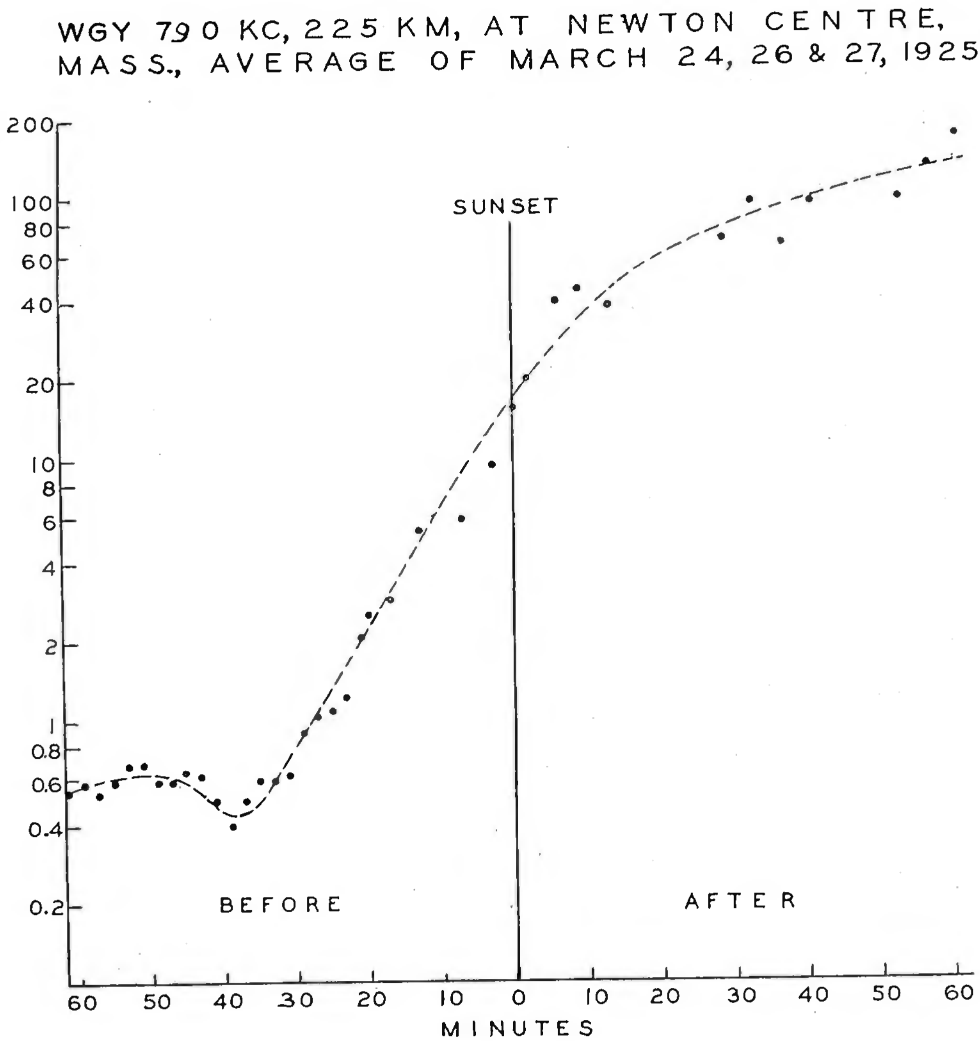


FIGURE 26

The dip at some thirty-eight minutes before sunset at Newton is not accidental; it appears on all the records, and altho not exactly at the same time on each, it was not wiped out by averaging. The rise from this dip to sunset is nearly a straight line, and as the ordinates of this figure are logarithmic, this means that the rate of detector current change was constant over this period.

TRANS-OCEANIC RADIO STATION—WARSAW, POLAND*

By

William G. Lush, Fred E. Johnston, and J. Leslie Finch

(Radio Corporation of America, New York)

History and General Features

By William G. Lush, Engineer in charge of Construction

In 1921, the reborn Polish State felt the necessity of having a system of international communication quite independent of the facilities of the surrounding nations; and it was decided by the authorities to erect a high power radio station for this purpose.

After a proper weighing of the kinds and capacities of the various forms of modern equipment it was decided to entrust the furnishing and erecting of the necessary apparatus, together with the engineering supervision of the enterprise, to the Radio Corporation of America.

A very considerable amount of work was required on the part of the Polish authorities and the executives and engineers of the Radio Corporation at New York in order to bring this matter not only into technical agreement with the very difficult conditions then obtaining for construction projects in Poland, but also that the project might be financed in such a manner as to be acceptable to both parties to the contract; which was finally signed on behalf of Poland on the first of August, 1921, by the Polish Minister at Washington, Prince Casimir Lubomirski and his commissioners and engineers, Stanislaw Arct, Hipolit Glivic, and Eugeniusz Stalinger; and on behalf of the Radio Corporation by Mr. Edward J. Nally, as president, and Mr. Lewis MacConnach, as secretary. The actual work in Poland was with the department making the contract, the Ministry of Posts and Telegraphs; headed during the greater part of the time by Mr. Jan Moszczynski, as Minister. The contract matters were handled by Mr. Stalinger as Chief Engineer for the Ministry of Posts, Mr. Stalinger being assisted in his work by Mr. S. Olszewski, the engineer appointed by the Ministry of Public

*Presented before The Institute of Radio Engineers, New York, January 7, 1925 Received by the Editor, January 7, 1925

Works to take care of the building and tower construction. The whole work was reviewed from time to time by a council of Ministers having supervisory powers. This Council consisted of the Minister of Posts and Telegraphs—chairman; the Minister of War, the Minister of Public Works, the Minister of Finance, and the Minister of Commerce and Industry.

In February of 1922 the Radio Corporation sent out Mr. Lush as Engineer in Charge of Construction and later Mr. Johnston joined the organization to take care of the receiving station, central office and the connecting lines with the rank of Assistant Engineer in Charge. He was followed by Mr. P. A. Baker of the General Electric Company and the latter's assistant, Mr. E. L. Marsh, who set up the transmitting set, power machinery, and antenna, except that the Diesel engine was erected by Mr. P. Derieckx of Carel Frères, of Ghent. Mr. Finch, who has charge of transmitter design for the Radio Corporation, came to Poland shortly before the completion of the station and took charge of adjustments, tuning and all final work prior to acceptance of the station by the Polish Government.

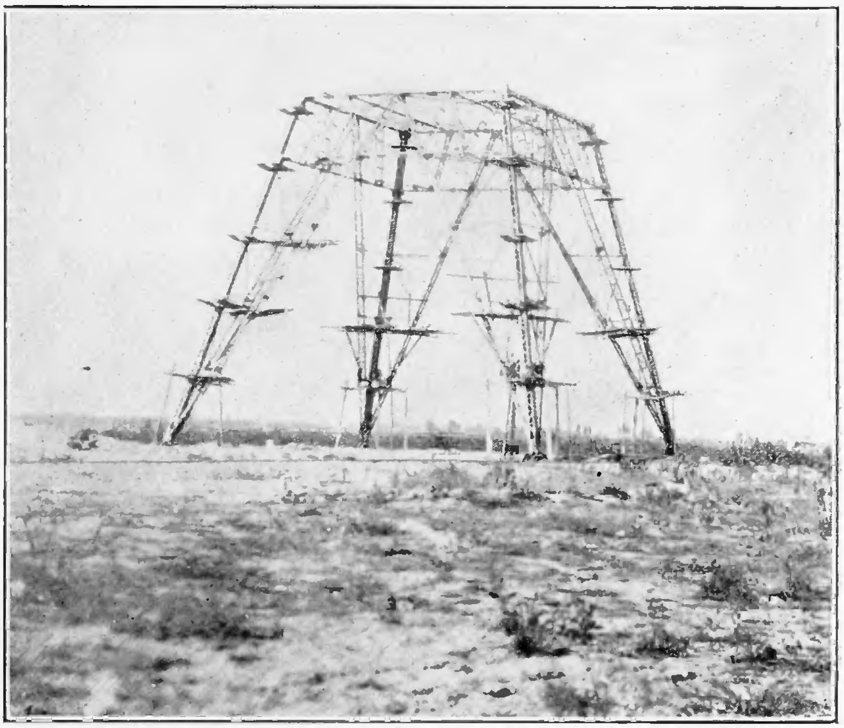


FIGURE 1—Base Section of One of the 400-foot Self-supporting Towers

The problem of site for the station had been satisfactorily solved by the selection of a very flat open stretch of land about ten kilometers from the center of Warsaw. This land was free from obstructions on account of its previous use as a cleared area to permit gunfire from a circle of forts which surround the city but which are now dismantled. This site is very well suited for a radio station as it is almost entirely free from vegetation of any height and water is met at from one to three meters below the surface, thus giving excellent conditions for ground connections.

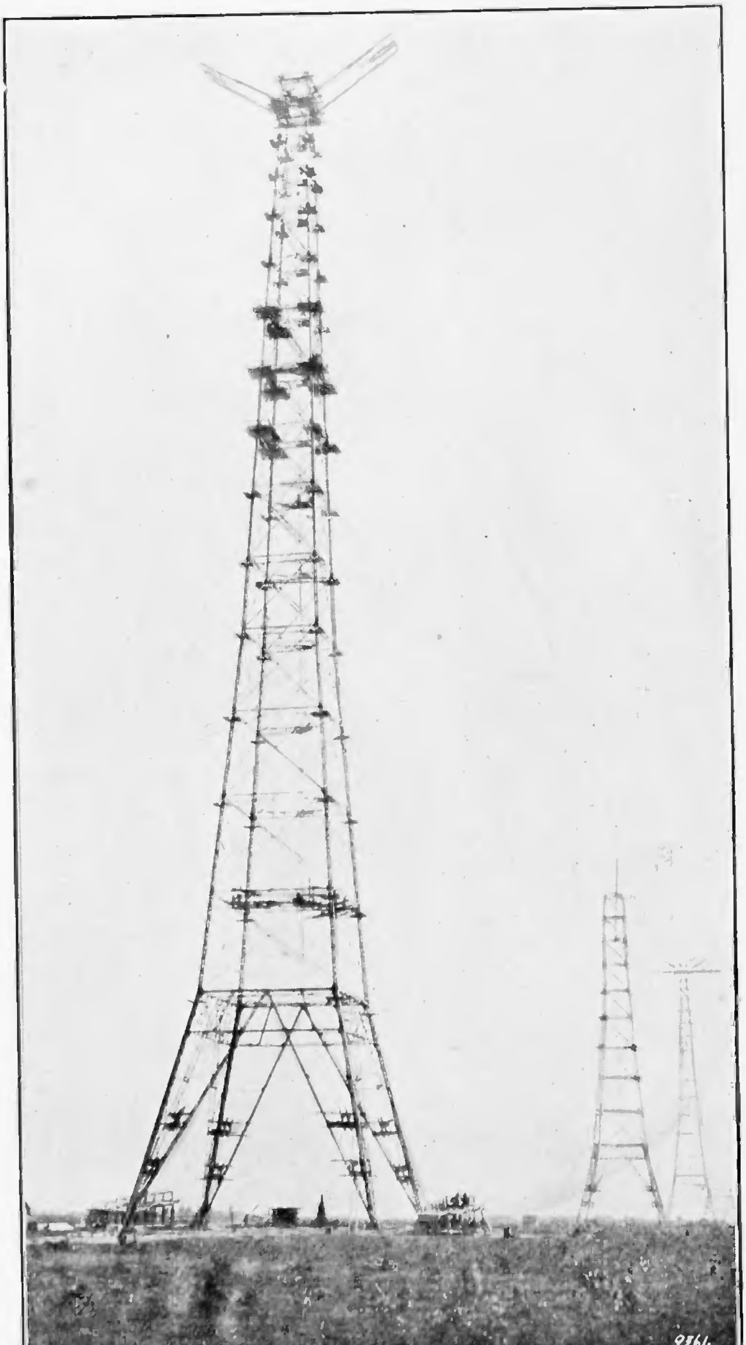


FIGURE 2—Three of the Towers in Construction Showing Cranes for Hoisting 75-foot Cross-arm Sections

The problem of shipments was a rather hard one. At the time of making the contract it was not certain as to just how much in the way of manufacturing facilities or the ordinary materials for electrical construction could be had from local or European sources and it was therefore necessary to make the shipments from the United States extremely complete.

The shipments came thru the port of Danzig and thence by the Polish State Railways to Warsaw, where the material was reloaded to a sixty centimeter military railway which reached the site of the station at Fort 2A.

The conditions in Poland were still somewhat disturbed, although steady improvement was noticeable. In consequence it was necessary for the Government to place guards over all shipments from the time that they left Danzig until they reached the ammunition casements at the fort. These casements were used as storehouses and proved most convenient for that purpose. In spite of the difficulties of transport and of training men to handle the expensive and unusual equipment, the loss by theft and breakage was very small.

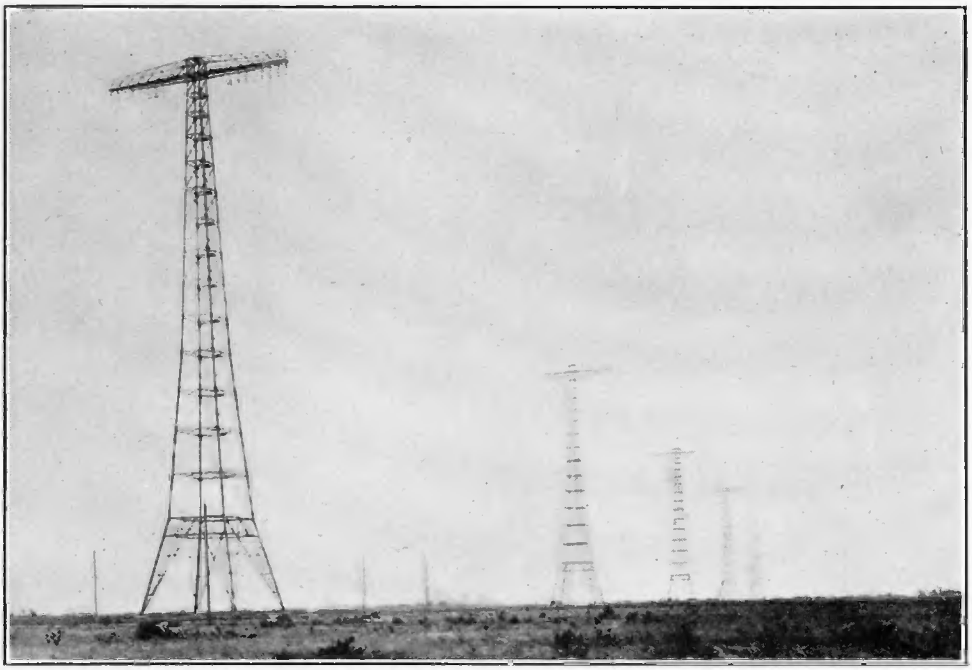


FIGURE 3—Line of Towers Showing Half of the Antenna

A problem of first importance was that of establishing an organization. This the contract provided that the Polish Government should do, but as the conditions regarding labor were much upset and as there were also present the difficulties which are common to all governmental projects thruout the world, when the enterprise is of a novel sort, it was decided that the Radio Corporation would also undertake the handling of labor, reimbursement being made at actual cost. A special engineer, Mr. Waclaw Pogorzelski, was employed for this purpose and he was able to build up, as the needs of the work required, a labor organization entirely competent to perform the tasks in hand, in spite of the fact that the war had for the most part swept away the former supply of skilled workmen.

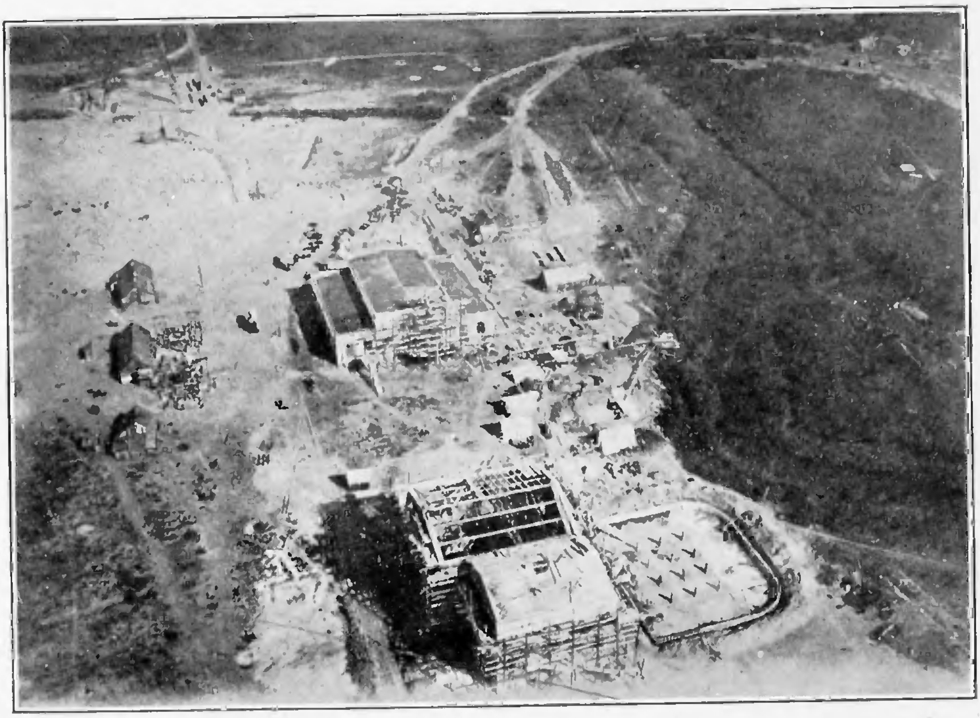


FIGURE 4—Aerial View of Radio Building and Power House Taken From Top of Tower Nearest Station; Taken During Construction of Buildings

Mr. Pogorzelski had spent some time in the United States and was, therefore, conversant with American as well as Polish methods, which contributed substantially towards the successful handling of this question. The Polish workman was found to be very skillful in carrying out a task once it was properly explained to him. While the rate of progress was not as great for any given amount of labor as with the highly trained personnel that we have in the United States, the results, under the circumstances, were very good and the men deserve much commendation for the way in which they endeavored at all times to carry out the recommendations and instructions of the engineers. It was found that the key to success in handling the labor was to keep absolutely and to the letter all promises made to them in any way regarding conditions of working and promotion. With this established as a principle, we had a satisfactory amount of labor and were able to avoid almost all the strikes which occurred elsewhere during the period of construction.

The general working arrangement was to divide the construction into parts such as the laying of the ground wires, the installation of the alternators, the building of the tuning coils and the like. With any one division a gang of workmen would be assembled and these men would be shown their task by the engineer to whose activities this particular piece of work belonged, he giving his instructions thru the medium of an official furnished by the Government, who had a knowledge of the two languages. After a sufficient amount of work had been completed, one of the men would be selected to act as foreman and push the task to completion. The Polish officials were each able, of course, to supervise several of these activities, and while they were not all engineers, nevertheless each man was selected for his position with a view to his being a part of the permanent operating force later. This working principle was embodied in the contract and was found to be as successful in practice as any that could have been used.

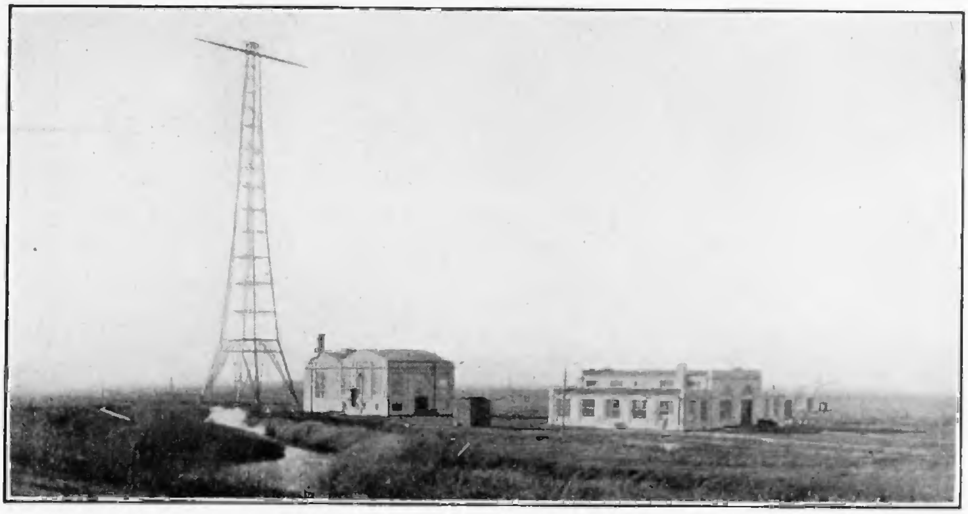


FIGURE 5—General View of Completed Station, Looking West

The building of the station itself aroused great interest. The Pole is always interested in things which tend to increase his knowledge and improve his education, and it was noticeable that there were constant excursions to the work composed of all classes of society, from peasants and workmen, to the state officials.

The keenest interest was manifested by the students, the universities being hard at work to introduce modern engineering practices of all sorts into Poland.

While the materials for the electrical construction were supplied by the Radio Corporation, the Polish Government made its own contract for the buildings themselves, the boilers (Fitzmer and Gamper, Manufacturers, Sosnowiec, Poland), and the towers which were built by Rudski and Ska, of Warsaw. The local fabrication of the towers effected a most substantial economy.

The station buildings themselves are two in number, a power house and transmitting station proper. Both of these structures are built with thick brick walls covered with ornamental cement plaster on the outside and in the true architectural feeling of Poland, with heavy pilasters, entablatures, and heavy doors; the whole, however, expressing in shape and line the use for which the buildings are intended. The interior is beautifully finished in flat tints and devoid of any ornamentation except that furnished by well-proportioned spaces.

FIGURE 6—Part of Ground Laying Crew, Showing Trenching Shovels Used in Laying Ground Wire System

The transmitting station is a comparatively low building, having one story and monitor, with ventilators in the roof over the machinery hall. It is also furnished with a well-lighted office, store-room, baths, steam-heating plant and well-appointed machine shop, the latter equipped with an American lathe and the other necessary tools.

The power house is a tall building with rather straight lines and two pitched roofs, the one covering the boiler-room and the other the machinery hall.

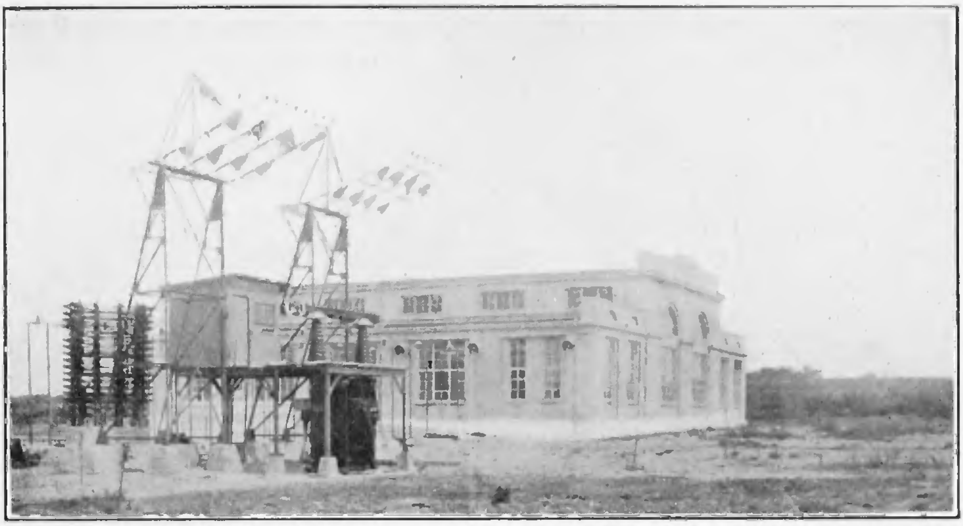


FIGURE 7—View of Radio Station and Terminal of One Antenna Wing, Station Tuning Coil, and Sleet Melting Transformers

The erection of the towers presented somewhat of a problem owing to the water in the soil, which is sand and clay, but this was successfully overcome with the use of concrete piles where the condition required them. Much of the concrete was mixed by hand, as contractor's machinery in Poland is not elaborate and everyone was used to the old method of dry ramming until after some time the force was sufficiently well trained to adopt the wet method for intricate pieces of work, such as the alternator foundations.

The staff quarters are much larger than is usual in American stations because under the Polish system of living each employee must be furnished not only with living rooms, but with a place to cook his food; even for those who rate only one room, a cook stove must be provided. Community dining-rooms, as in the United States, do not work well in Poland. Therefore, two large apartment houses were erected at the fort, giving ample and most comfortable quarters.

FIGURE 8—General View of Completed Station Looking South-east

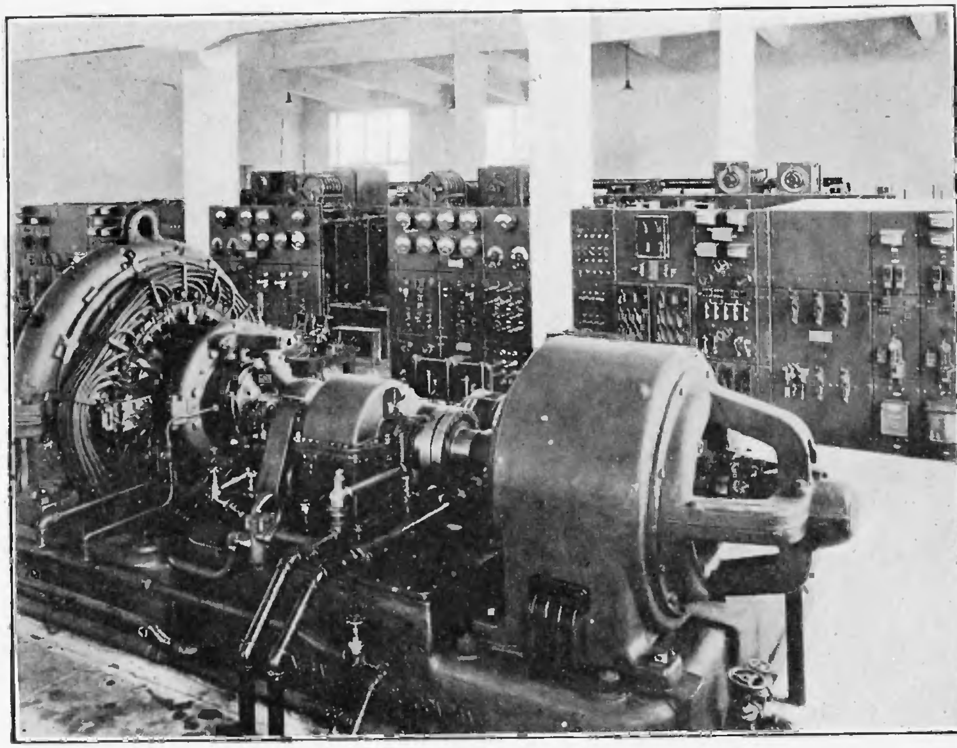


FIGURE 9—Interior of Radio Building Showing one Alexanderson Alternator and the Switchboard

It was necessary for the American personnel on this contract to be most particular in their dealings with everyone in Poland to avoid arousing, however unintentionally, any prejudice thru lack of acquaintance with the customs of the country, which has come to have an established formal etiquette as the natural outcome of the many years of history which lie behind it. Therefore, it was found at once that some of the rough and ready methods of action in common use on the projects in the United States would not apply and it was necessary to substitute, therefore, carefully thought-out ways of doing business, more in conformity with Polish ideas. One very happy result of this was that when something had been finally decided upon it was a fixed matter and could be depended upon to remain unchanged. It should be said at this point that the representatives of the Radio Corporation received at all times most courteous treatment at the hands of the Polish Government, that there is in Poland a sentiment very favorable to mutual relations between Poland and the United States and a very high degree of confidence that enterprises undertaken by reputable United States concerns will be carried out.

The station was opened for commercial traffic in October, 1923, and was formally turned over to and accepted, in November, 1923, by the Polish Government in the persons of the President of the Republic and the Minister of Posts and Telegraphs. The Radio Corporation personnel remained in Poland for some time after this formal opening to render such assistance as might be necessary in training and advising the Polish staff.

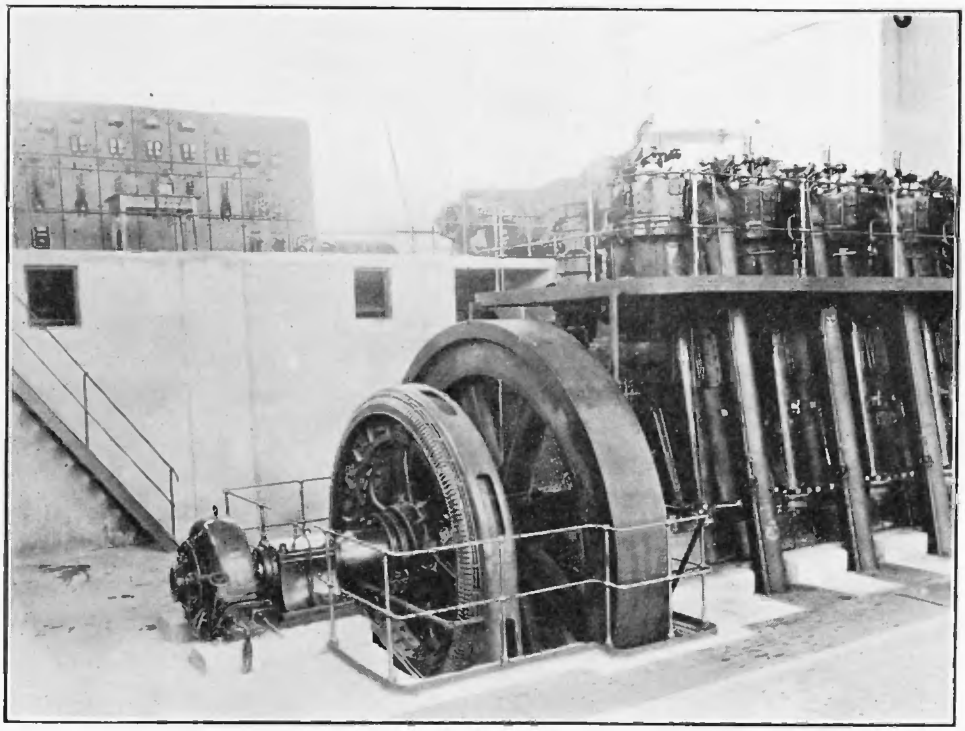


FIGURE 10—Interior of Power House Showing Diesel Engine and Steam Turbine and Switchboard in the Balcony in Background

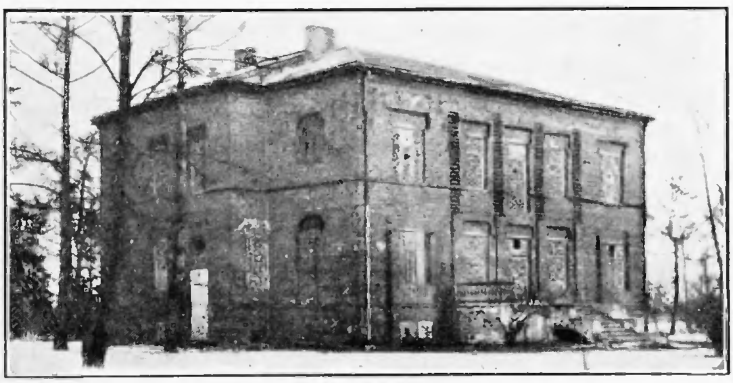


FIGURE 11—Receiving Station Before Being Remodeled

In conclusion to these general remarks, the writer would express his belief that, provided proper consideration is given to local conditions, and to those with whom business is done, Poland does not present any insurmountable difficulties in the carrying out of important contracts by any American enterprise which honestly intends to fulfil its moral and legal obligations.

Transmitting Station

By J. Leslie Finch, In charge of Transmitter Design

The transmitting end of the Warsaw station embodies the Alexanderson system, including the Alexanderson radio frequency alternator, the magnetic amplifier, and the multiple tuned antenna, and is essentially the same as is used in all of the high-power stations of the Radio Corporation of America. In the Warsaw station two complete 200-kilowatt alternator equipments are employed. These can be operated either singly, both at the same time or in parallel and will develop full power over a range of wave lengths from 18,000 meters to 21,000 meters. They are capable of operation in connection with the antenna at telegraphic speeds as high as 80 words (400 letters) per minute.

Figure 12—Receiving Station After Completion

The antenna is supported by ten towers of the self-supporting type. The towers are each 400 feet (123 meters) high and have cross arms at the top 150 feet (48 meters) long. These towers are placed in a straight line 1,250 feet (384 meters) apart, the radio building being located between the fifth and sixth towers.

There are 16 antenna cables running parallel with each other thruout the length of the antenna. They are supported by means of insulators and spreaders below the cross-arms of the towers. These cables are brought down to anchorages at each end of the

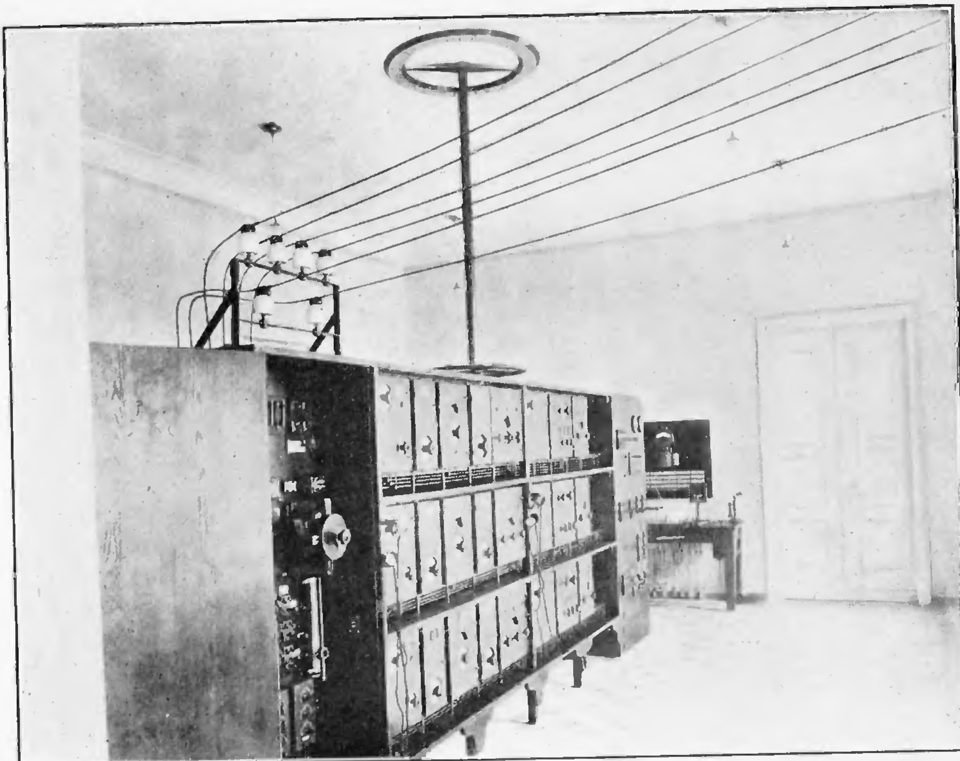


Figure 13—Interior of Completed Receiving Station Showing Three Long Wave Receivers Installed

antenna is usually used in connection with one alternator. In this way a total antenna current of 1,000 amperes is obtained from a power input to the antenna of 200 kilowatts.

At the wave length now employed, 18,350 meters, the antenna voltage with 400 kilowatts in the total antenna or with 200 kilowatts in either half is over 180,000. This voltage has been used without difficulty under all weather conditions. It will be noted that this voltage is much higher above ground than that employed in power transmission lines at the present time, since the 220,000-volt developments used only 127,000 volts, above ground. This voltage is maintained without visible corona. In order to maintain this condition it was necessary to protect all points otherwise subject to corona with suitable corona shields and to round off all sharp corners. The antenna cables used are 5/16 inch (8 mm.) diameter. One such cable supported singly at the same height as this antenna would develop corona at less than 100,000 volts. In the space between the towers the individual cables serve to shield each other and at the towers and near the earth the insulator fittings, spreader members, and the like, act as sufficient shielding except for the cables next to the towers. These were shielded by paralleling the antenna cables for a short distance each way from the tower with a second similar cable. Corona on the downleads was prevented by constructing them in the form of a rattail or cage of 5 inch (13 mm.) diameter.

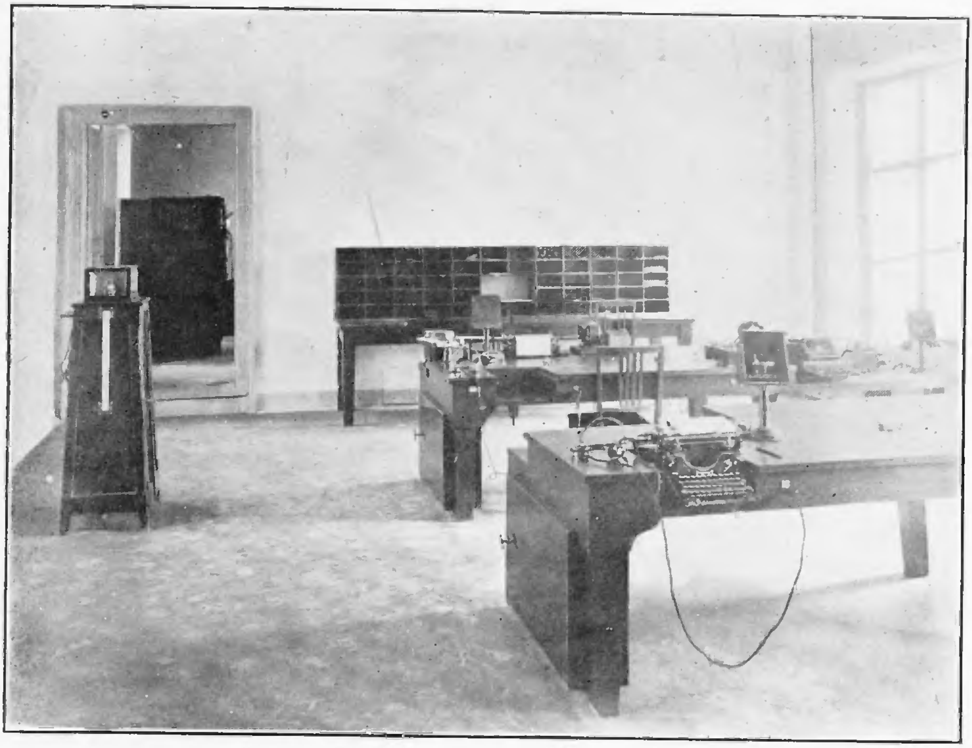


FIGURE 14—Interior of Operating Room of the Central Office

In order to remove ice from the antenna cables, which collects during sleet storms, they are arranged so they can be heated by passing current thru them from the same source of power as is used to drive the alternators. Provision is made at the radio building end of each antenna half to separate the antenna cables and connect the heating current leads. At the intermediate towers the antenna cables are kept separate for sleet-melting purposes by means of condensers. This is accomplished by suspending the antenna cables from the spreaders, which also serve as connecting conductors to the downleads, by means of short tubular insulators, inside of which are placed condensers of about one microfarad capacity, the end fittings of the insulators acting as terminals of the condenser. These condensers are essenially equivalent to direct connections for radio frequency currents and are equivalent to insulators for the power frequency sleet-melting currents.

The towers supporting the antenna are protected from overloads by suspending the antenna cables from the spreaders with weak links. In case of possible failure of the power supply for the station during sleet storms, the cables might become loaded with ice past their breaking point. Then when some of the cables had parted, the towers might be subjected to twisting stresses greater than they would withstand. This is impossible with the weak links, since they are adjusted so that they will give way before the cable tension has reached the breaking point.

The power supply at this station is furnished from a local plant adjacent to the radio building. Two generator units are provided, one a 500-kilowatt steam turbine and the other a direct connected 750 horse power Diesel engine generator set. Each unit generates power at 2,200 volts, 50 cycle, 2 phase. These units may be used separately, each to drive one radio frequency alternator, or they may be paralleled and used to drive both of the alternators. The operation of these two units in parallel has proven entirely satisfactory despite their widely different characteristics and the rapidly fluctuating load.

Receiving Station

By F. E. Johnston, Assist. Engineer in Charge of Construction.

The receiving station for the Warsaw transoceanic station is located in the outskirts of the village of Grodzisk, a small manufacturing and farming center, located about 19 miles (30 km.) southwest of Warsaw and on the main line railway between Warsaw and Cracow.

An old and much war-scarred school building was remodeled for use as the receiving station. It was large enough to permit apartments for the normal station staff being built in the same building. As is the case with most of the buildings in Poland, it has thick brick walls; these were covered with cement plaster on the exterior and the building presents an architectural appearance very much in keeping with the buildings at the transmitting station.

The wave antenna, as invented and developed by Messrs. Beverage, Rice, and Kellogg, and described in a paper presented before the American Institute of Electrical Engineers, is used. This antenna is 16,200 meters long and extends in a southeasterly direction from the station building, the center line of length being on a great circle bearing to New York and nearly at right angles to the direction of the transmitting station. In construction it resembles an ordinary telegraph line, consisting of two number 10 (2.5 mm.) hard drawn copper wires supported by 20 feet (6 m.) wooden poles spaced 150 feet (46 m.). A 4-foot (1.2 m.) wooden cross-arm is attached to the pole tops at the ends of which the wires are supported on 22,000-volt glass insulators. The wires are transposed at every tenth pole.

It was found that most of the static arriving at Warsaw came from the south and southeast; thus due to its directional properties, the wave antenna gave a very great improvement in signal-to-static ratio over that obtained by the loop or loop and vertical method of reception. The station was also supplied with two outdoor type right angle loops, each 250 feet (77 m.) long and 9 feet (2.8 m.) above ground for the lower turns and 21 feet (6.5 m.) above ground for the upper turns. Each loop had twelve turns of number 12 hard drawn copper wire spaced 10 inches (23.6 cm.). An indoor loop was also provided, which was 8 feet (2.46 m.) square, wound with 100 turns of number 10 copper wire. These latter loops were installed for emergency use in case of failure of the wave antenna due to heavy sleet or storms.

Three sets of Radio Corporation standard long wave receiving sets were installed. These sets have a normal wave length range from 6,000 to 30,000 meters and are of unit construction, each unit being in a metal case which is well grounded. The parts of each unit are mounted on a panel of insulating material and a base so that all parts are within the metal case; the case is fitted with an aluminum hinged door thru which the controls work in such a manner that the door and dials of the controls form a complete shield. The back of the case, as well as the door, is removable so that all parts of each unit are readily accessible.

The filament and plate supply to all units requiring them are carefully filtered, both within each unit and at the source, to prevent disturbances entering the units via the battery leads. This precaution is necessary as all of the sets are operated from a common plate and filament supply. For normal operation the filament and plate supply is furnished by a 10-volt and 125-volt direct current generator, respectively, with storage batteries floating across the leads. The batteries absorb a large percentage of the commutator ripple and remain at full charge ready to take over the load in case of failure of the primary source of power.

The primary source of power is furnished by two gasolene engine-driven direct-current generators. These generators deliver 220 volts direct-current, and are located in a small building about 200 feet from the receiving building. For furnishing power to the sets, two motor generator sets are provided, each set consisting of a 220-volt motor direct connected to a 10-volt direct-current generator and a 250-volt, 3-wire direct-current generator. These machines are located in a room adjacent to the receiving apparatus room.

The plate battery consists of 180 cells of lead type storage batteries arranged in three groups of 60 cells each: these cells are rated at 15 ampere-hour capacity. In normal operation two of these groups are used for supplying 220 volts to the plate of the oscillator in the synchronous detector unit and a tap taken at the connection point of the two groups serves to supply the 120 volts required by the amplifier units.

The filament battery consists of 8 cells of lead type storage battery arranged in two groups of 4 cells each, thus providing two 8-volt filament batteries. These cells are rated at 720 ampere-hour capacity and in case of emergency one group is sufficient to supply three sets for eighteen hours.

As no operating is done at the receiving station the output from the sets is put directly on to telephone lines to the central traffic office in Warsaw. Sufficient jacks are provided in a control panel for monitoring the signals and transferring signals from one line to another. For this transfer of signal, four special telephone lines were installed by the Polish Government. They differ from the normal telephone lines in Poland only that they are of bronze wire instead of the usual galvanized iron which is used extensively for telephone work in Europe.

Central Office

The central office is located in the Central Telegraph Office of the Ministry of Posts and Telegraphs in Warsaw. Complete telegraphic control of the station is centered at this office.

The four telephone lines from the receiving station as well as the three control lines to the transmitting station terminate here. Equipment for manual or automatic sending and receiving is provided, together with two radio receiving sets for monitoring the transmitted signal.

A system of local communication between the central office, the receiving station and the transmitting station is maintained over the tone or control lines by telephone, there being sufficient spare lines for this purpose. The necessary communication is thus quickly and easily handled and the personnel at the transmitting and receiving station need not be trained telegraphists, except as their other duties require this knowledge.

January 3, 1924.

SUMMARY: A brief history and description of the Warsaw Trans-oceanic Radio Station as constructed and installed for the Government of Poland by the Radio Corporation of America is given.

A technical description of the details of the system used is not given, as the system is similar in all respects to that in use in the United States by the Radio Corporation. Papers on this system have been given before this INSTITUTE and before the American Institute of Electrical Engineers by Messrs. Alexanderson, Beverage, and others.

THE APPLICATION OF THE X-L FILAMENT TO POWER TUBES*

By

J. C. Warner and O. W. Pike

(Research Laboratory, General Electric Company, Schenectady, New York)

One of the chief problems in connection with the design of vacuum tubes has always been to secure a suitable material for making the cathode. Several properties are essential. The life should be long. The power required to heat the filament to the proper operating temperature should be as low as possible. The filament should not change greatly during the normal life of the tube. Also, for a given power consumption and total electron emission the filament should be comparatively long.

The fulfilment of the first two requirements, which are too often at variance with each other, usually means a relatively low operating temperature, the exact choice of which, for any one material, must often be a compromise between life and efficiency.

At the present time the only three materials which have been used to any great extent in power tubes are pure tungsten, oxide-coated platinum or platinum alloy, and X-L or thoriated tungsten.

The X-L filament as used in receiving tubes such as the UV-199 and UV-201-A radiotrons is already well known. Here its advantages have been very noticeable, resulting in marked improvements in operating characteristics with very low filament power consumption.

The same advantages appear even more prominently in the power tubes which have been designed with X-L filaments, some of which have been in commercial production for more than two years. The X-L filament is used in radiotrons UV-210, UV-203-A, UV-204-A, and UV-851, which are illustrated in Figure 1, and in a corresponding series of kenotron rectifier tubes. Only the radiotrons will be described in this paper however.

*Received by the Editor, February 14, 1925. Presented before The Institute of Radio Engineers, New York, March 4, 1925.

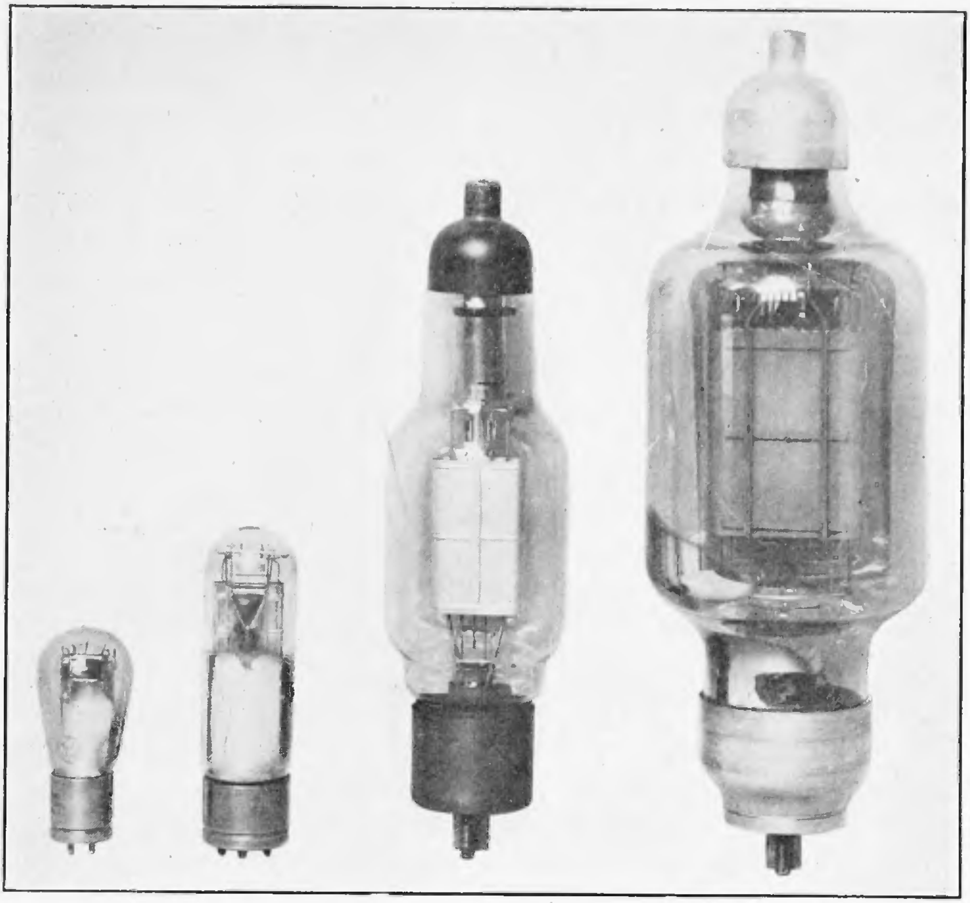


FIGURE 1—X-L Filament Transmitting Tubes

The normal operating temperature of the X-L filament is approximately 2,000° Abs. as compared with about 2,450° to 2,550° for pure tungsten. The emission efficiency of the X-L filament, however, is much higher than that of pure tungsten, as is well illustrated by the accompanying table, Figure 2, in which are shown the filament characteristics of several tubes of both types.

Tube	Type of Filament	Filament				Electron Emission	
		Volts	Amps.	Watts	Temp.	Milli-amps.	m.a. per Watt
UV-203	Tungsten	10	6.5	65	2,635	975	15
UV-204	Tungsten	11	14.75	162.5	2,480	750	4.6
UV-205	Tungsten	20	3.85	77	2,575	975	12.7
UV-210	X-L	7.5	1.25	9.4	2,000	700	74.5
UV-203-A	X-L	10	3.25	32.5	2,000	3,250	100
UV-211							
UV-204-A	X-L	11	3.85	42.5	2,000	4,900	115
UV-851	X-L	11	15.5	170	2,000	20,000	118

FIGURE 2

It will be noticed that the emission electron efficiency is not always the same for either type of filament. In the case of the pure tungsten filament the reason for this is that the choice of the operating temperature is a compromise between life and emission efficiency. For example, the UV-204 and UV-205 tubes are practically identical, except in their filament characteristics. The UV-205 (formerly known as the "Type P pliotron") was designed for war-time service where low filament power consumption was more essential than extremely long life. The UV-204, which was a later design, required 162 watts, but had a life expectation approximately 10 times as long as that of the UV-205.

The X-L filaments all operate at the same nominal temperature, but due to difference in lead losses, the emission efficiency is somewhat different in the various tubes.

In comparison with the UV-204 and UV-205, the UV-204-A gives an excellent example of the improvement effected by the use of the X-L filament. This tube retains the filament voltage of the UV-204 and the current of the UV-205, so that the power consumption is only 42.5 watts, which is only slightly more than one-fourth the filament power of the UV-204. On the other hand the life expectation is somewhat higher than that of the UV-204.

In the UV-204 the filament power is 39 percent of the total power expended in the tube. In the UV-204-A, the internal plate circuit loss being the same as in the UV-204, the filament power is only 14.5 percent of the total. This, of course, results in a lower plate temperature during operation.

There is another advantage gained by the use of the X-L filament, which is not at once apparent, but which is of very great importance. In designing a tube to be used either as an amplifier or as an oscillator, it is always desirable to make the space charge losses as low as possible, consistent with good mechanical clearances. This means that the effective electrode areas must be large and this can be accomplished only by the use of long filaments. Again a direct comparison between an X-L filament and a pure tungsten filament may be of interest.

The UV-203 tube requiring 10 volts and 6.5 amperes has a filament length of approximately 10 cm. The corresponding X-L filament tubes, the UV-211 and UV-203-A, requiring 10 volts and 3.25 amperes, have a filament length of approximately 17 cm. As a result of this increased filament length the mutual conductance of the X-L tubes is increased in about the same ratio.

In the UV-851 tube it was necessary to have a very large cathode area in order to obtain the rated output of the tube at the relatively low plate voltage of 2,000 volts. For this reason the cathode was made up of four "V" filaments connected in parallel. For a given power consumption the total wire length of a filament is increased if two or more parallel branches are used instead of a single filament. This may be understood from a brief consideration of a few of the characteristics of tungsten filaments.

For constant temperature the filament current of a tungsten filament varies with the 3/2 power of the wire diameter.

$$\frac{I_1}{I_2} = \left(\frac{D_1}{D_2}\right)^{\frac{3}{2}}$$

For constant temperature the filament voltage varies inversely as the square root of the wire diameter.

$$\frac{V_1}{V_2} = \left(\frac{D_1}{D_2}\right)^{\frac{1}{2}}$$

For constant temperature and current the filament voltage varies directly as the length,

$$\frac{L_1}{L_2} = \frac{V_1}{V_2}$$

From these three relations it may be seen that the ratio of the lengths of two filaments of different diameter, but operating at the same temperature and at the same voltage, is equal to the cube root of the ratio of the two currents.

$$\frac{L_1}{L_2} = \sqrt[3]{\frac{I_1}{I_2}}$$

Applying this relation to the case of a cathode of constant power consumption, constant temperature and constant voltage, it will be shown that the total *wire length* increases as the cathode is broken up into more and more parallel filaments.

Let V = voltage across ends of cathode (that is, across all parallel branches)

n = number of parallel filaments

I = total current

$\frac{I}{n}$ = current in one filament

L = length of wire when only a single filament is used

L_n = length of single filament when n parallel filaments are used

Then $$\frac{L_n}{L} = \sqrt[3]{\frac{\frac{I}{n}}{I}} \text{ or } L_n = \frac{L}{\sqrt[3]{n}}$$

but since there are n filaments the total wire length becomes

$$L_{\text{total}} = \frac{nL}{\sqrt[3]{n}} = L\sqrt[3]{n^2}$$

For two parallel filaments the total wire length is increased 59 percent and for four the length is increased 152 percent.

There is a practical limitation to this method of increasing cathode area since decreasing the wire diameter too much will reduce the strength of the filament and increase the manufacturing difficulties.

The life of a tube having a pure tungsten filament is at best the burnout life of the filament. The operating temperature of this type of filament is so high that the tungsten evaporates at a fairly rapid rate, eventually resulting in the burnout of the filament. At the operating temperature of the X-L filament the evaporation of the tungsten is negligible and failure of the tube never results from a burnout except accidentally. The electron emission comes from a surface layer of thorium, and while this is constantly evaporating off it is also being renewed by diffusion of thorium from inside the filament. The theoretical life of the filament is ended then only when the supply of thorium inside the filament is completely exhausted. Also, since the electron emission depends only on the surface layer, it should be constant practically to the end of life.

On account of the reduction in diameter of a pure tungsten filament during its life, due to evaporation, it is best to operate at constant voltage and to use a voltmeter for regulation. The same does not apply to an X-L filament since there is no evaporation of tungsten, and either a voltmeter or ammeter may be used, altho a voltmeter is often more convenient particularly when tubes are run in parallel. Filaments should be operated at as near rated voltage as is possible, and, while an oscillator tube will give full output at considerably less than rated filament voltage, such operation is of doubtful advantage.

In order to maintain the active condition of the filament and the resulting uniform electron emission it is necessary to have an exceptionally good vacuum. This is accomplished by a thoro pump exhaust and the use of magnesium "getter" which deposits on the bulb giving the silvered coating characteristic of X-L filament tubes. Good electron emission during operation is an almost certain indication of a good vacuum, and any means taken to improve the vacuum tends to insure constant emission.

On account of the long life of the X-L filament itself, the life of a tube containing this filament is largely dependent on the ability to design and manufacture a tube which will have the necessary vacuum conditions initially and will maintain them thruout life. In practice the failure of a tube often appears to be due to loss of electron emission; that is, the tube fails to operate satisfactorily because the emission has fallen off. Unless the filament has been subjected to excess voltage, loss of emission is seldom the true *cause* of failure, but rather the *result* of failure. That is, due to release of gas from the interior parts of the tube, often caused by overload, or due to leakage of air, the high vacuum is lost and the surface layer of thorium is destroyed, resulting in loss of emission.

In this respect the X-L filament is unique, in that the true filament life is so long that it is not a factor in determining the life of the tube.

In the series of radiotrons to be described later it will be noticed that many of the design features show the influence of this need for maintenance of a good vacuum over a long period of time. One of the commonest causes of air leaks is electrolysis of the glass in the seals which results in a crack in the glass or leakage along the leads. This is greatly accelerated by high temperature and in all of the X-L tubes the plate seal is placed at the coolest part of the bulb and is widely separated from the other leads. Also the distance between the filament and grid seal and the plate is made as large as possible. In the tubes operating at more than 1,000 volts, the so-called double end construction is used and the plate is supported entirely at the opposite end from the other electrodes. Also the grid lead is brought thru another separate seal.

Any power tube is apt to be subjected to short overloads in spite of reasonable care in operation and should be able to stand such conditions without permanent damage. An X-L filament will stand three times its normal voltage without immediate burnout and such treatment if not long continued does not seriously injure the filament as complete activity can be restored by a few minutes under normal conditions. Plate overload usually causes gas to be given off from the overheated plate or other parts of the tube and may cause a decrease in emission. In order to protect the tube against permanent damage from this source the X-L tubes are at present all made with molybdenum plates, which are heated to extremely high temperatures during exhaust and thereby are freed of most of the gas contained in them. The high temperature of the plate also heats the other internal parts of the tube hotter than they should ever become during operation and reduces the chance of their giving off gas later on.

The areas of the plates are relatively large and the surfaces are treated so as to radiate heat easily, so that in operation the plates should never run hotter than a dull cherry red color.

In the case of a very severe plate overload which has liberated considerable gas, the electron emission may be reduced temporarily, but this can almost always be restored by 15 minutes of operation with plate voltage off. This action may be accelerated by raising the filament voltage to about 15 percent above normal. After the filament is reactivated, the tube should be put into operation again under conservative plate load and the gas which has been given off during the overload will usually clean up. This applies only when the gas has been given off internally. An air leak invariably results in complete failure of the tube. If a glow appears in the tube its color will usually show whether the gas has been given off internally or has leaked thru from the outside. A glow which is distinctly blue is usually an indication of gas given off from the electrodes while a purplish or pink glow indicates an air leak. If the leak is sufficient to raise the internal pressure approximately to atmospheric pressure there will be no glow but the filament will give off a white, powdery smoke and will soon burn out. This, of course, is characteristic of both X-L and pure tungsten filaments.

It might seem that the electron emission of an X-L filament, coming as it does from a constantly changing surface of thorium, would be more or less erratic and unstable. This, however, is not the case. In a properly operated tube the emission as well as the other characteristics are perfectly steady. Full emission occurs as soon as the filament comes up to temperature and there is no difficulty whatever in starting oscillations when the tube is used as an oscillator. Also there are no harmful secondary emission effects.

Several of the X-L filament tubes already mentioned will now be described in more detail.

Radiotron, Model UV-210, is the smallest of the group. The external appearance and the internal construction are illustrated in Figure 3. The electrode structure is more rugged than that of some of the earlier transmitting tubes and the electrodes are rigidly supported at each end. The bulb is of the so-called tipless type.

This tube has a nominal output rating of 7.5 watts. The

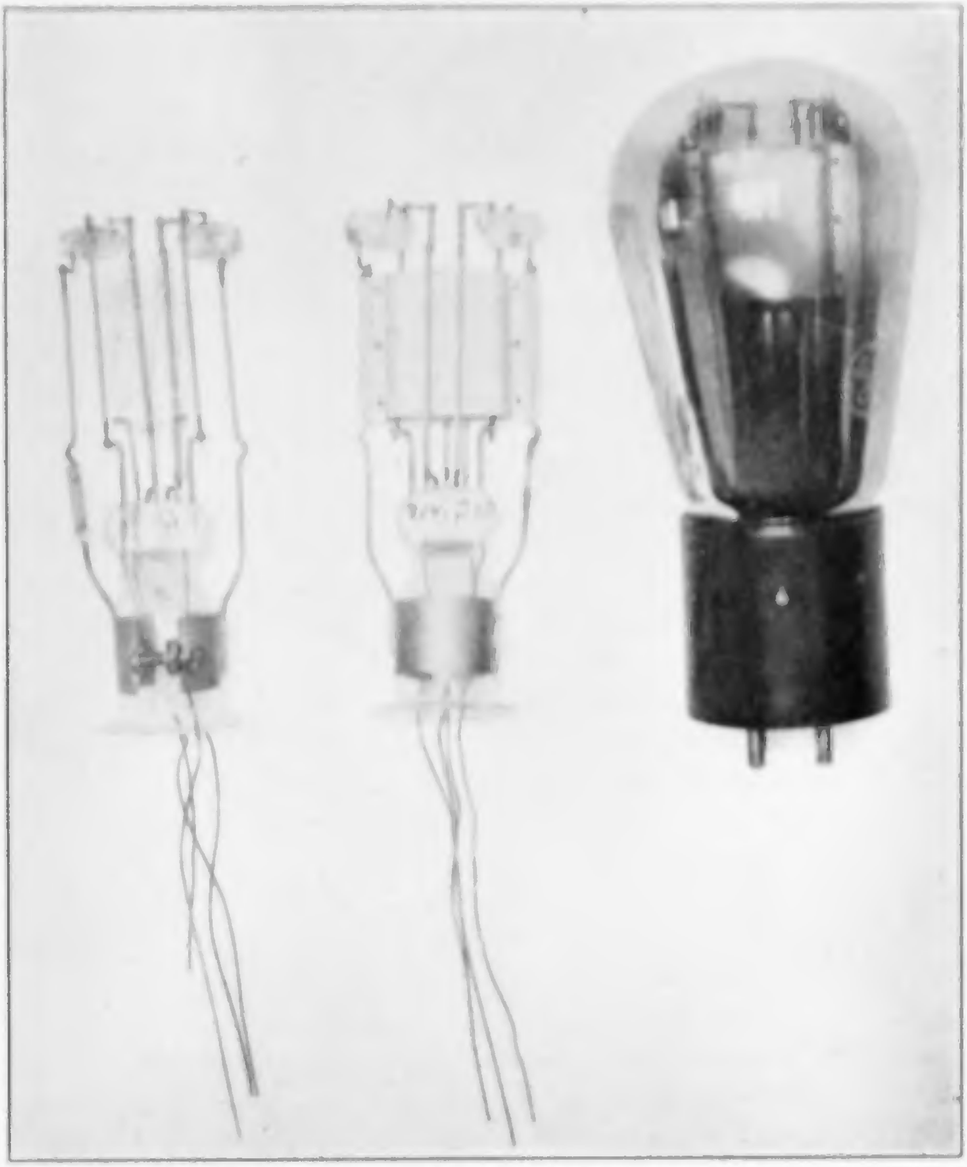


FIGURE 3—XL-7 1/2 Watt Transmitting Tube

normal plate voltage is 350 volts and at this voltage the rated output can be very easily obtained with a plate current of 60 milliamperes. If care is used in the construction and adjustment of the circuit, a much greater output may be obtained with the same input. The grid voltage-plate current and the plate voltage-plate current characteristics are shown in Figures 4 and 5.

The amplification constant of the UV-210 is approximately 7.5 and the internal plate resistance at 350 volts and zero grid is approximately 3,500 ohms. The corresponding mutual conductance value is 2,150 micromhos. It should be understood that these figures are useful for comparison purposes only, since under normal conditions the grid voltage is not zero.

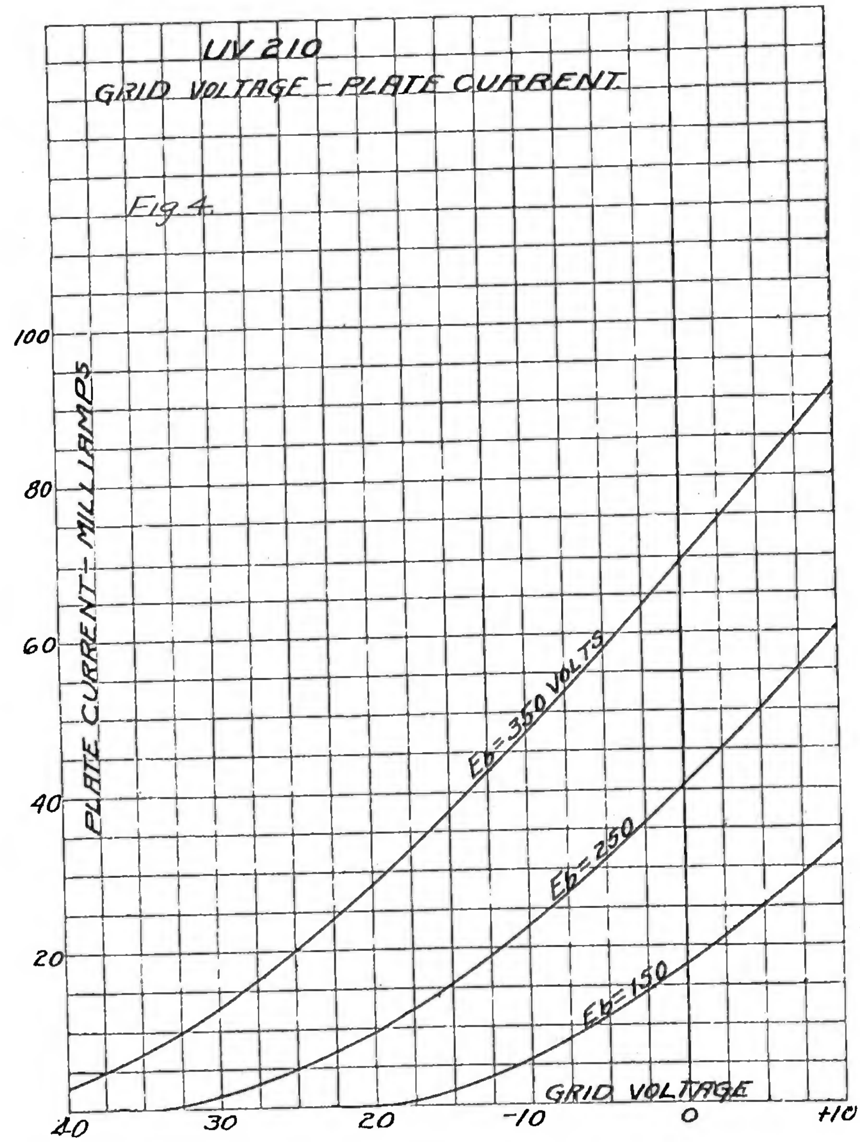


FIGURE 4

In addition to its use in transmitting sets as oscillator, modulator or power amplifier, this tube has been used to some extent in commercial receiving circuits where the service is continuous and where the power output is unusually high, requiring plate voltage and plate current conditions nearly as severe as in transmitting circuits.

The next larger X-L filament power tube is the 50-watt size, shown in Figure 6, which is made in two types, the UV-203-A and the UV-211. These two types differ only in plate impedance and amplification constant, and are exactly the same in external appearance, filament rating, and plate voltage. The UV-203-A is intended for voltage amplification or for amateur and experimental use as an oscil ator, while the UV-211 is designed for oscillator, amplifier and modulator use in commercial sets.

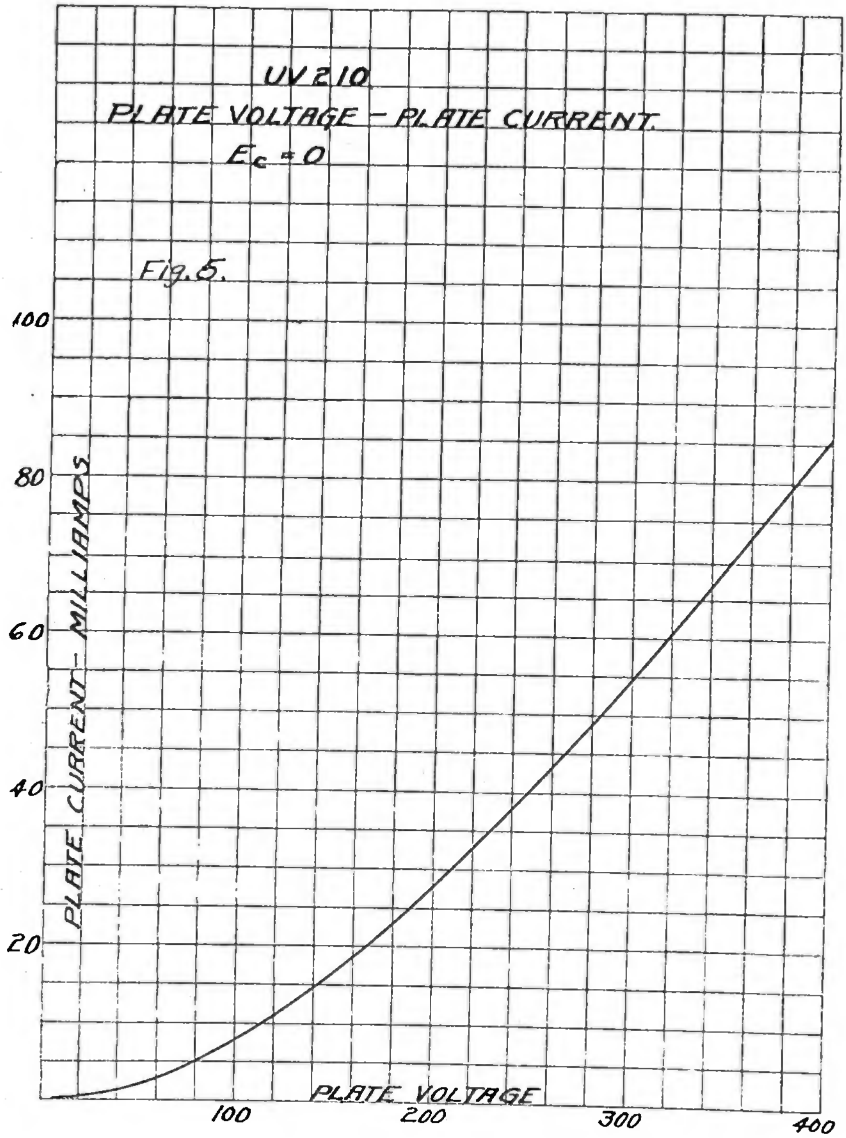


FIGURE 5

Both tubes have a filament rating of 10 volts and 3.25 amperes. The normal plate voltage is 1,000 and the maximum plate power dissipation is 100 watts when a tube is used as an oscillator. When it is used as a modulator or amplifier, the continuous dissipation is limited to 75 watts.

The UV-203-A supersedes the UV-203, and a few comparisons between the two tubes plainly illustrate again the advantages of the X-L filament and the general improvement in the later vacuum tubes of this size. The UV-203 required 10 volts

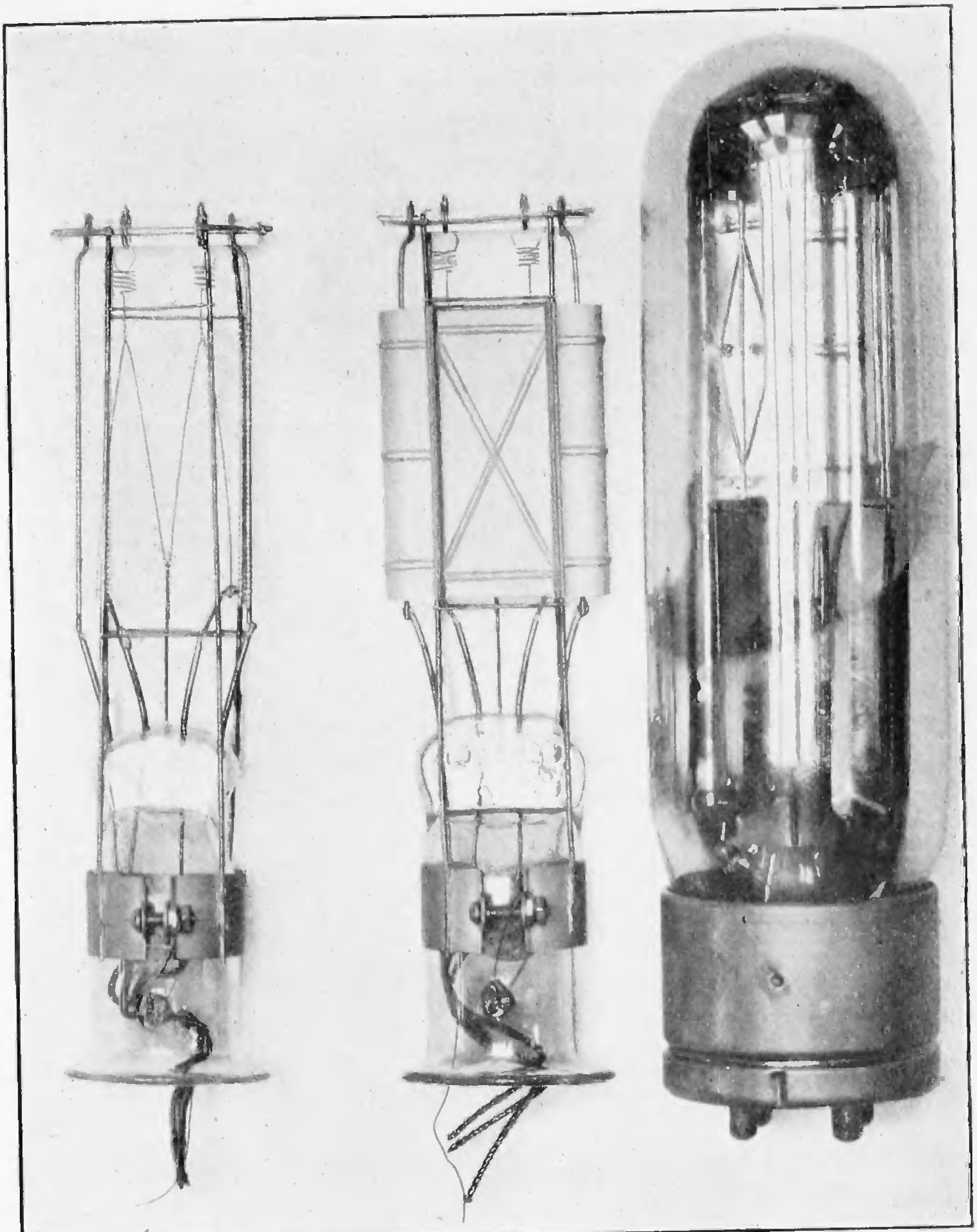


FIGURE 6—XL 50-Watt Transmitting Tube

and 6.5 amperes or 65 watts for filament heating, while the UV-203-A requires only one-half this amount. In spite of this, the electron emission of the UV-203-A is twice as great. The benefit derived from high electron emission and the improvement in characteristics resulting from the large electrode areas are illustrated in Figure 7, which shows the relation between filament voltage and antenna current for the UV-203-A and the UV-203 tubes in a typical transmitting circuit. The filament power is also shown for comparison. It will be noticed that the UV-203-A gives a higher output and that this output is obtained at one-

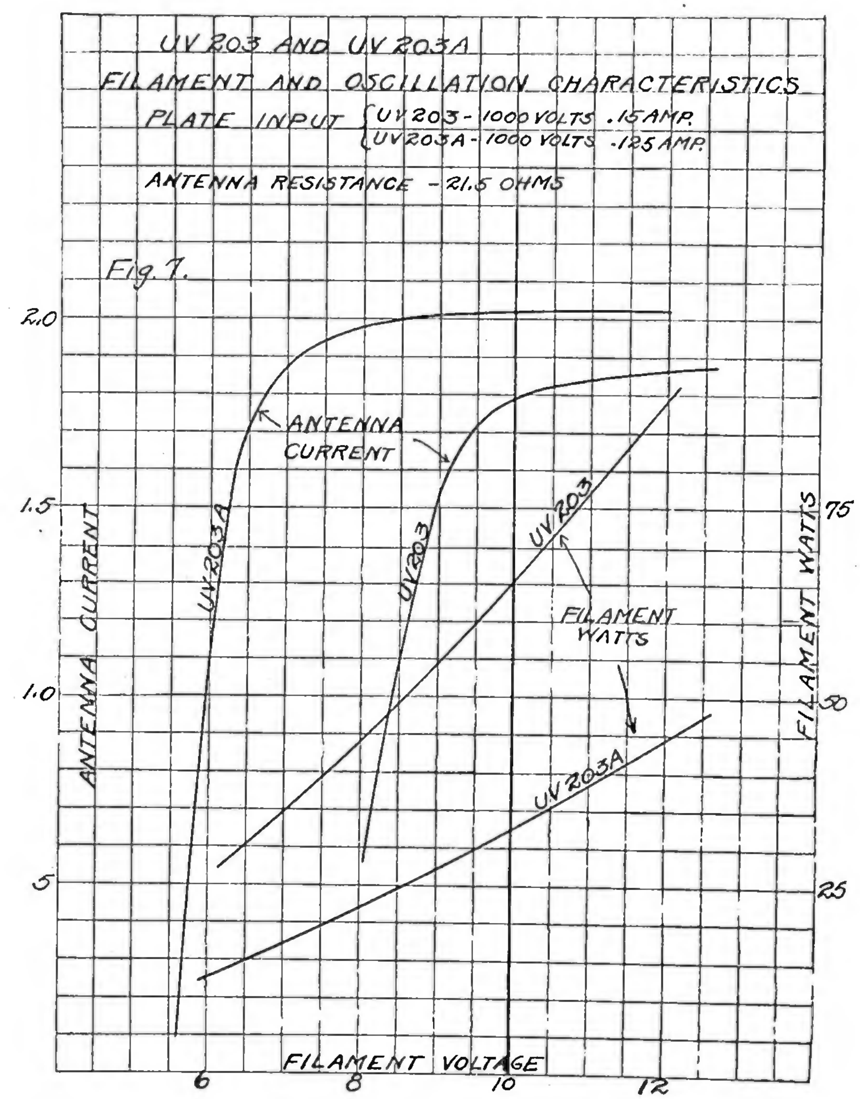


FIGURE 7

half the filament power and at one-sixth less plate current than is taken by the UV-203. At the normal operating point, the UV-203-A gives over 20 percent greater oscillation efficiency than the UV-203.

The UV-211 gives very similar results as an oscillator, but due to lower plate resistance it is much more satisfactory as a modulator or amplifier than is the UV-203-A. The lower impedance is very important where undistorted amplification is desired, as relatively large grid voltage swings may be employed without the grid becoming positive.

Figure 8 shows the plate voltage-plate current characteristics of the UV-203-A and UV-211, and Figure 9 the grid voltage-plate current curves. Also for comparison the UV-203 characteristic has been drawn on Figure 9. The steeper slopes of the

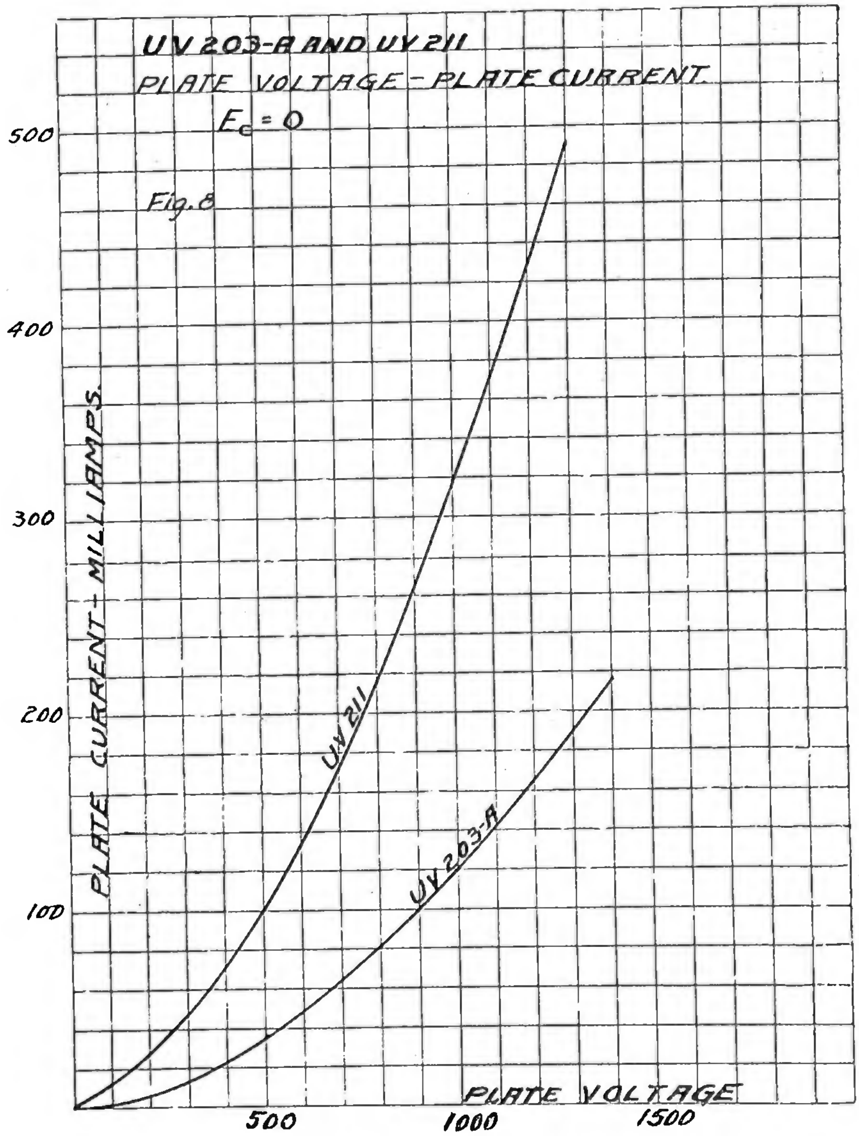


FIGURE 8

UV-203-A and UV-211 curves plainly indicate the superior characteristics of the X-L filament tubes.

The method of safeguarding the UV-203-A and UV-211 tubes from plate current overload may be of interest. The plate resistance of the UV-203-A is so high that if the tube should stop oscillating or lose its negative bias, the plate current would not greatly exceed the normal value when oscillating. Thus, the tube is self-protecting in this respect. On the other hand, the plate resistance of the UV-211 is so low that the plate current at zero grid would soon injure the tube by overheating of the plate. However, here the increase from the normal current during oscillation to the current at zero grid is sufficient to allow

electrodes are fastened together at the upper end. The plate is mounted on four support rods and has four wings which serve not only to make the electrode more rigid but also to dissipate heat. In this tube, helical springs are used to maintain the proper tension on the filament when lighted and also to protect it from shocks. This is necessary for tubes of this size or larger, while for smaller tubes the usual anchor wire has adequate spring qualities.

The next larger X-L filament tube is the UV-204-A radiotron, shown in Figure 10. This tube has an output rating of 250 watts. The normal plate voltage is 2,000 and the filament requires 11 volts and 3.85 amperes or 42.5 watts. The maximum plate power dissipation is 250 watts.

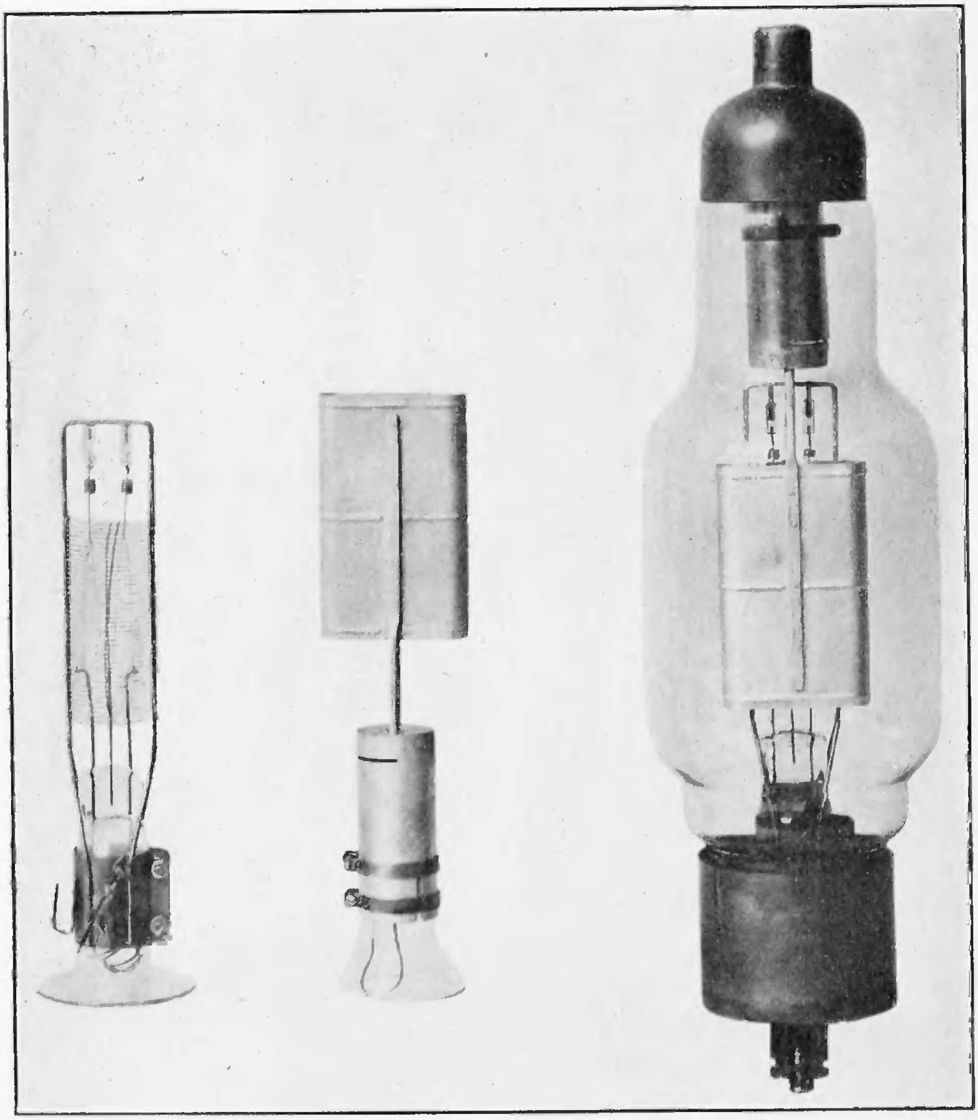


FIGURE 10—Radiotron UV-204-A 250-Watt Output

As already stated, this tube directly supersedes the UV-204, and on account of the interchangeability requirements the plate characteristics are almost identical with those of the UV-204. Consequently, the later tube may be used in sets designed for the UV-204, the only change required being an increase in the rheostat resistance to allow for lower filament current.

The usual static characteristics of the UV-204-A tube are given in Figures 11 and 12. The amplification constant averages approximately 24 and the internal plate resistance at 2,000 volts, and zero grid is approximately 4,700 ohms, giving a mutual conductance, under these conditions, of 5,100 micromhos.

The total electron emission at rated voltage is approximately 5 amperes, which is much higher than the emission of the UV-204

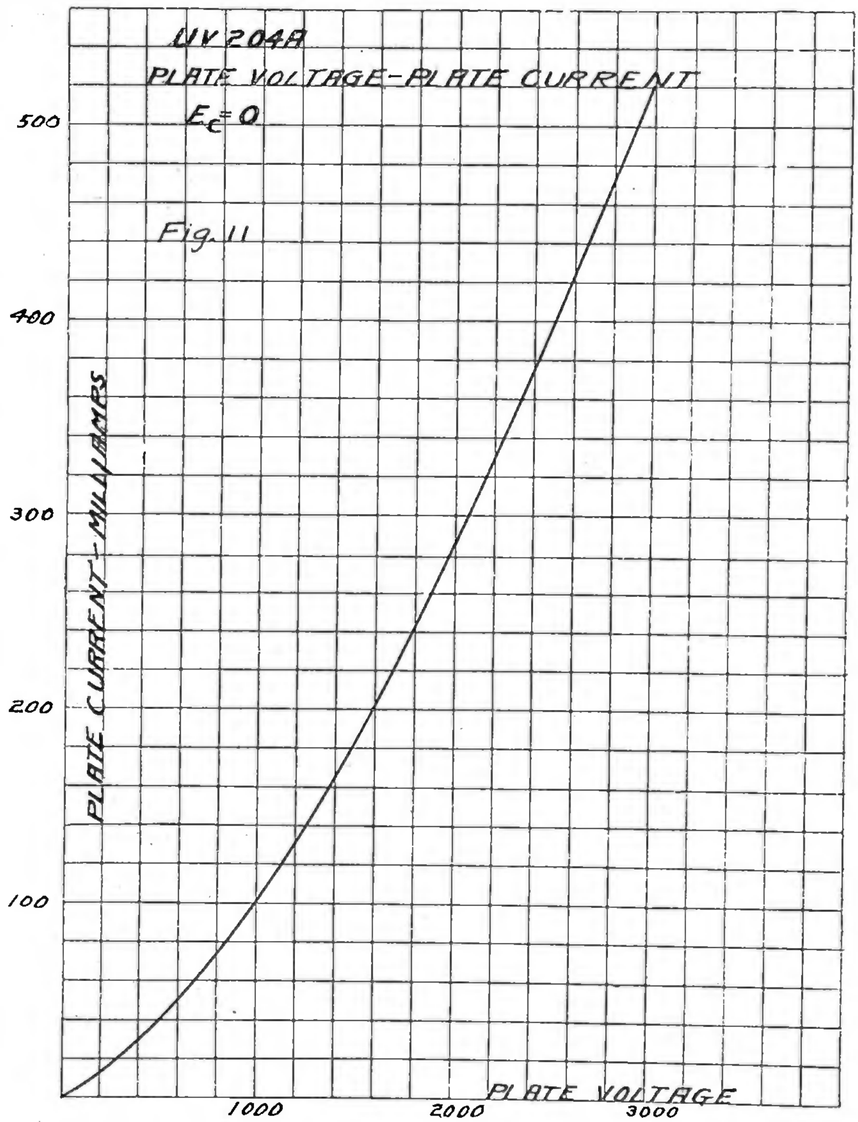


FIGURE 11

filament. This results in somewhat better performance in telephone circuits where the peak values of current are likely to be considerable.

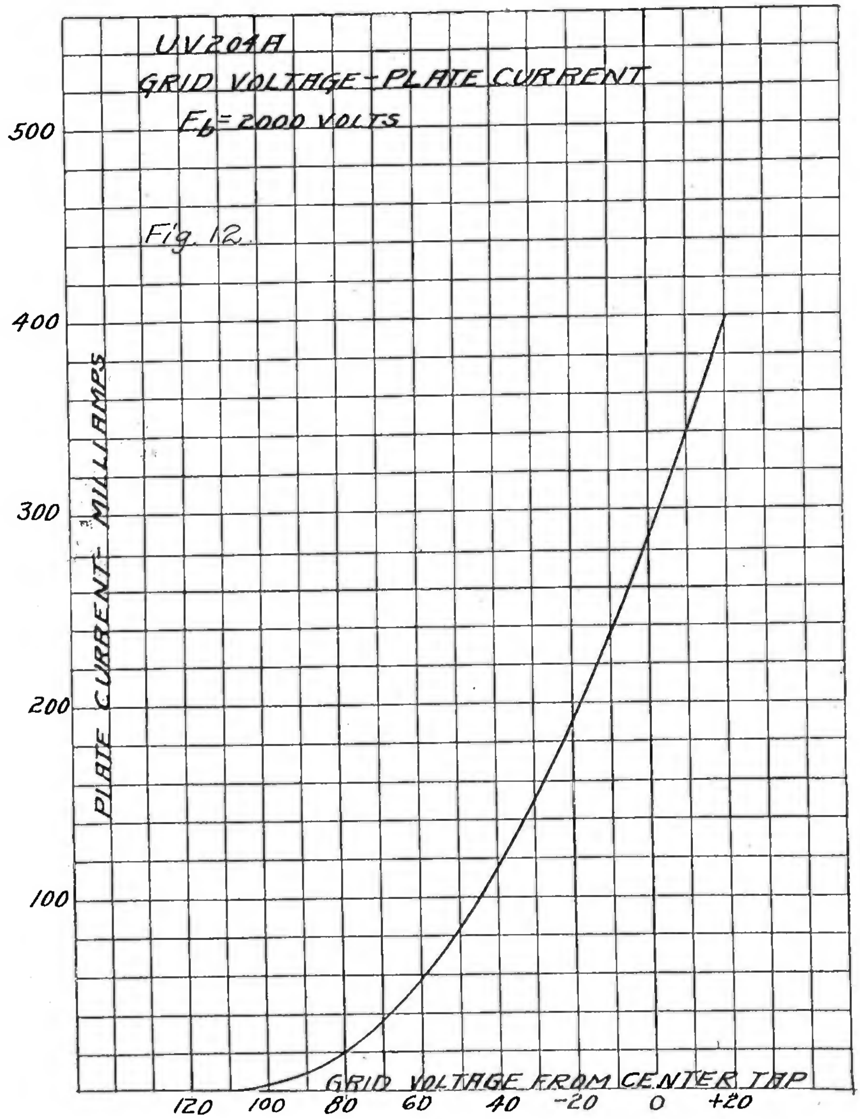


FIGURE 12

For outputs greater than 250 watts, it is quite possible to connect as many as four 250-watt tubes in parallel. However, there are always certain difficulties present in parallel operation of more than two or three tubes, and to supply the demand for a low voltage, high output tube, the UV-851 radiotron has been developed. At present this is the largest power tube utilizing the X-L filament. There is already another one-kilowatt radiotron, the UV-206, but this contains a pure tungsten filament and normally requires a plate voltage of 10,000 volts or higher.

The normal plate voltage of the UV-851 is 2,000 volts, and the maximum plate power dissipation is 750 watts when the tube is used as an oscillator. Under these conditions, the tube is capable of giving a radio frequency output of one kilowatt or more. The filament requires 15.5 amperes at 11 volts, or a power consumption of 170 watts. The total electron emission is about 20 amperes.

FIGURE 13—Radiotron UV-851 1 KW Output

Figure 13 shows the external appearance of the tube and the anode, cathode and grid structures.

The X-L filament, while bringing about marked improvements in all of the tubes in which it has superseded the pure tungsten filament, has been of even greater importance in the design of the UV-851. A tube of this type and size would have been almost impossible to build with a pure tungsten filament. This is evident when it is realized that a pure tungsten filament would have required at least 600 to 700 watts to obtain the necessary electron emission. This power would have been dissipated almost entirely inside the plate and would have resulted in considerable over-heating when added to the normal dissipation due to internal plate circuit losses. Furthermore, the plate char-

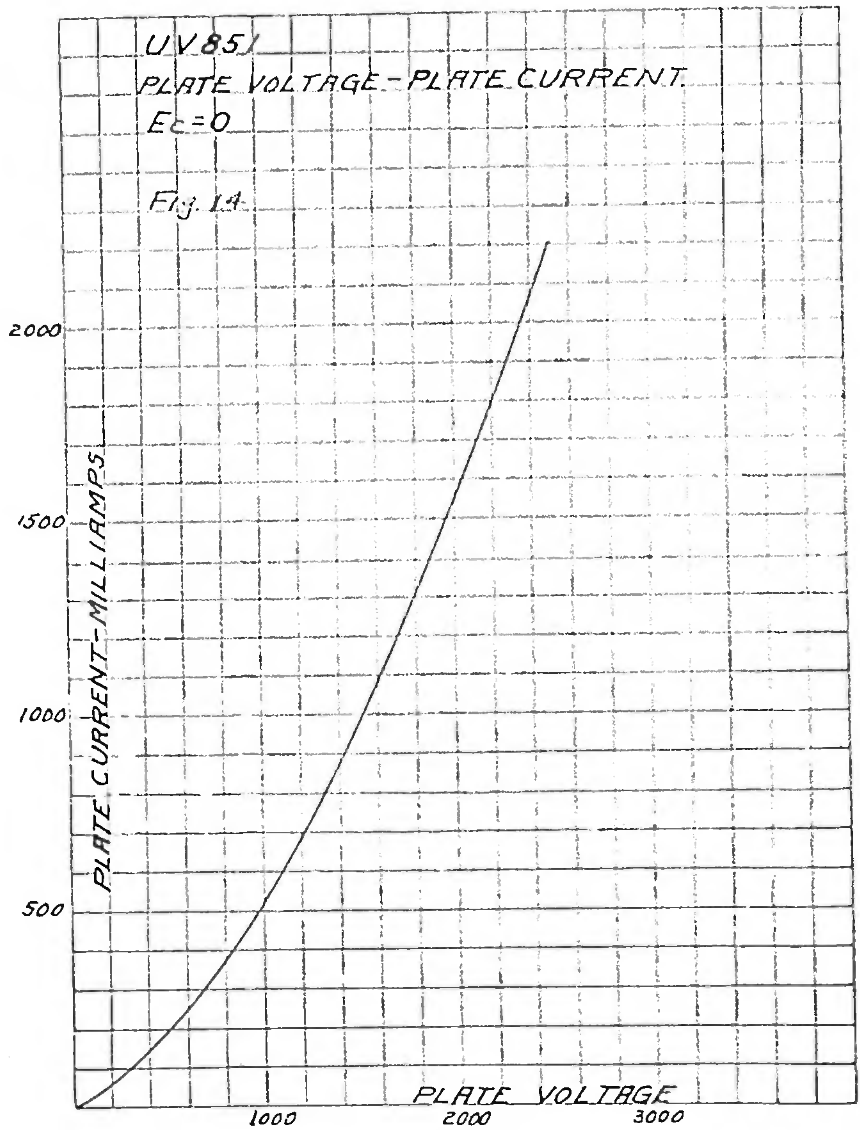


FIGURE 14

acteristics required to give one-kilowatt output with reasonable efficiency at the relatively low plate voltage of 2,000 volts would have been unattainable with a tungsten filament.

The amplification constant of the UV-851 is approximately 20 and with 2,000 volts on the plate and zero grid the internal plate resistance is approximately 850 ohms and the mutual con-

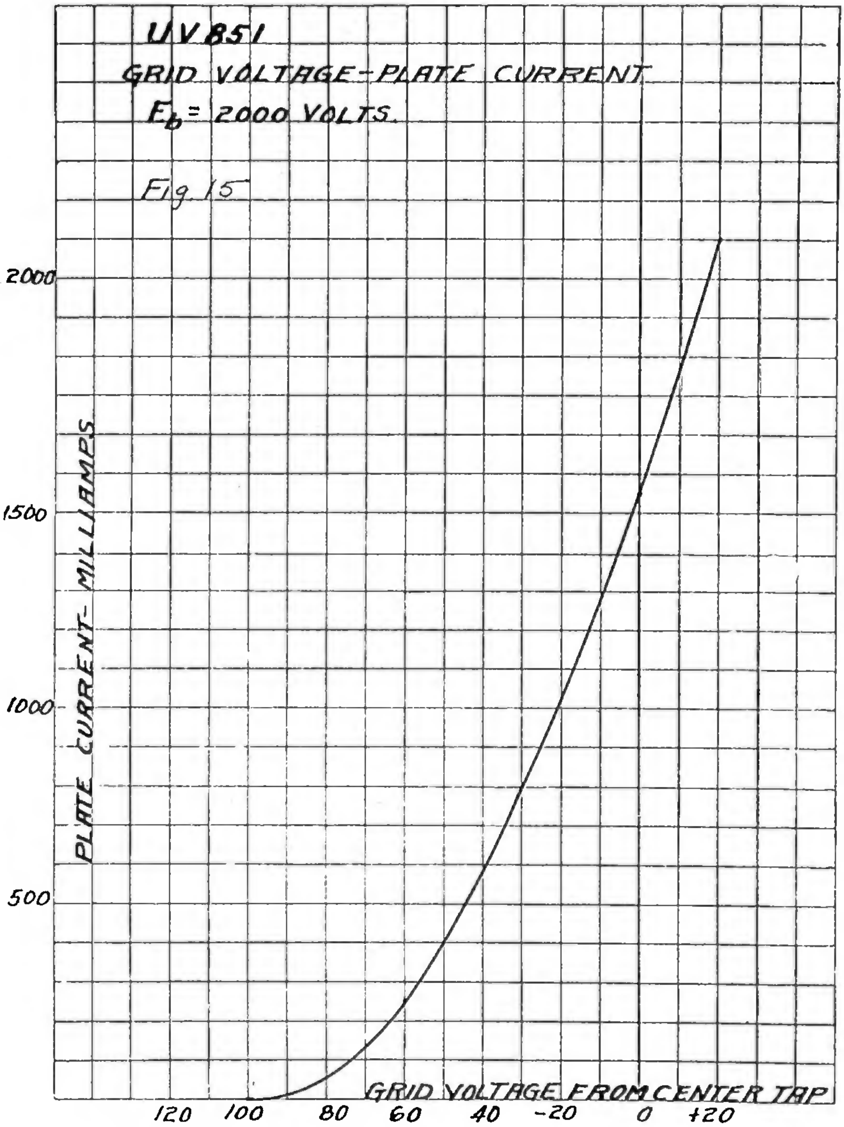


FIGURE 15

ductance, therefore, is 23.5 milliamperes per volt or 23,500 micromhos.

The static characteristics of the tube are shown in Figures 14 and 15.

The mechanical construction is of some interest on account of the large size of anode and grid structures and also due to the fact that four parallel filaments are used. The advantage of the parallel type of filament has already been explained. It is particularly important in a tube of this size, because of the necessity of reducing as much as possible the plate losses inside the tube. The grid also is somewhat different from that ordinarily used, being made of a heavy square mesh of molybdenum wire.

The grid frame is anchored to the plate structure with an insulator so as to maintain the proper position of the grid inside the anode. The plate is of exceptionally heavy construction and its surface is so treated as to give good radiating properties. Proper filament tension is maintained, as in the UV-203-A and UV-204-A, by helical springs, which are protected by small metal discs from excessive heat.

The tubes described above, while not including all that have been designed with X-L filaments, serve to illustrate the most important advantages of this type of filament over the older pure tungsten type, resulting in improved operating characteristics in tubes of such sizes as were already in existence, and permitting the design of a new class of tube, the manufacture of which otherwise would have been impractical if not impossible.

For reference a table of the electrical constants of the X-L filament tubes is given in Figure 16.

Radiotrons	UV-210	UV-203-A	UV-211	UV-204-A	UV-851
Rated Output (Watts)	7.5	50	50	250	1,000
Max. Plate Dissipation	15	100	100	200	750
Filament Voltage	7.5	10	10	11	11
Filament Amperes	1.25	3.25	3.25	3.85	15.5
Plate Voltage	350	1,000	1,000	2,000	2,000
Plate Current Oscillating (m.a.)	60	125	125	200	875
Amp. Constant (Approx.)	7.5	25	12	24	20
Plate Impedance (Approx. ohms) at zero grid and rated plate voltage (See Note)	3,500	5,000	1,900	4,700	850
Mutual Conductance (Micromhos) at zero grid and rated plate voltage (See Note)	2,150	5,000	6,300	5,100	23,500
Plate Current (m.a.) at zero grid and rated plate voltage (See Note)	70	120	320	275	1,550
Dimensions Over-all (inches)	5¼	7⅞	7⅞	14¼	17½

NOTE: These figures are given for comparison only and do not necessarily apply to all conditions of normal operation.

FIGURE 16—Characteristics of X-L Filament Transmitting Radiotrons

SUMMARY: The properties of the X-L or thoriated tungsten filament are discussed with particular reference to the suitability of this material for use in power tubes and its advantages over other materials. Comparisons are given between pure tungsten and thoriated tungsten filaments in electron emission characteristics and effect on tube design and performance.

Several power tubes containing X-L filaments are described in detail. The improvements due to the use of the X-L filament are illustrated by comparison of these tubes with older types of tubes containing pure tungsten filaments.

DETECTING CHARACTERISTICS OF ELECTRON TUBES*

By

H. M. Freeman

(Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania)

For a number of years the electron tube has been regarded as the nearest approach to an ideal detector of radio power that has yet been devised. Its chief advantage over the simple contact rectifier lies in its stability and ease of control, and in its amplifying property, particularly that factor which permits the building up of the input voltage by means of regeneration. In fact, this regenerative faculty has provided such a simple and easily controllable means for increasing the detector efficiency that the minor factors controlling the performance of the tube as a detector have been rather overlooked, and very little attempt has been made to develop the possibilities of controlling these minor factors in such a way as to increase the efficiency of the tube as a non-regenerative detector. However, the well-known disadvantages of the use of regeneration in its simplest form are becoming of greater and greater importance with the continually increasing number of listeners in radio; and the use of the tube as a detector is being more and more restricted to the simple rectifying function.

This being the condition now in existence, it becomes of more importance than ever before to examine carefully the operation of the tube as a non-regenerative detector; and to determine more thoroly than has yet been done the importance of the various characteristics which enter into the operation of the tube as a detector, and the factors which control these characteristics. Up to the present time the practice among the manufacturers has been to work toward a general purpose tube, on the theory that almost any kind of a tube is good enough as a detector if the characteristics which determine its efficiency as an amplifier are sufficiently emphasized. With the development of the art, the advantage of using one type of tube for all purposes is decreasing

*Received by the Editor January 26, 1925. Presented before The Institute of Radio Engineers, New York, February 4, 1925.

in importance, and an increasing appreciation of the large part played in set performance by the efficiency of the detector is bringing out to an ever increasing degree the need of emphasizing the characteristics of a tube which are of primary effect in ts performance as a detector.

The present paper is a report of some preliminary studies of the tubes now in existence, with the object of opening up the field for the development and control of the operational factors of the detector tube; and while the work has not yet progressed far enough to venture any predictions as to what may eventually develop along these lines, it offers some interest as evidence of the improvement that is possible even in existing tubes over the commonly used conditions of operation.

As a preliminary to developing criteria which will enable the performance of a tube as a detector to be easily and accurately predicted and as a check on the proposed method of measurement, a study was made of a normal tube of a type much used at the present time for either detector or amplifier. In this particular tube, the filament is designed to operare at 1.1 volts and 0.25 amperes for general service, and it has a plate impedance of 14,000 ohms, an amplification factor of 5.6, and a mutual conductance of 400 microamperes per volt when measured with a plate voltage of 45 volts with the grid tied to the negative end of the filament. Following the well-known development for the performance of a tube as a detector when used in the circuit shown in Figure 1, the expression for the change in plate current produced by impressing a signal voltage E in the grid circuit is as follows:[1]

$$\Delta I_P = \frac{E^2}{2} \frac{\dfrac{d^2 I_G}{d E_G^2}}{\dfrac{d I_G}{d E_G}} \frac{d I_P}{d E_G} \qquad (1)$$

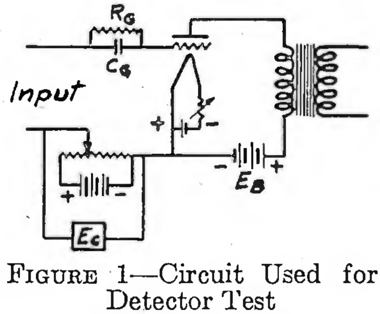


FIGURE 1—Circuit Used for Detector Test

[1] J. H. Morecroft, "Principles of Radio Communication," page 456.

From this expression it appears that the output obtained from a given incoming signal is proportional to the product of the rate of change of the slope of the grid characteristic by the slope of the mutual characteristic, and inversely proportional to the slope of the grid characteristic.

From an analysis[2] of the action taking place in a detector circuit comprising a grid condenser and grid leak, it is at once apparent that certain conditions must be met in order to obtain efficient operation, before the characteristics of the tube itself become effective. The condenser must be of such a value that it will be fully charged up to the maximum voltage of the incoming signal during the time in which the signal is impressed. For example, if we assume a signal frequency of 1,000,000 cycles per second, modulated at a frequency of 10,000 cycles (which is well within the conditions of ordinary telephony) we find that a tube having a grid conductance of 5 microamperes per volt will allow a condenser of 0.00025 microfarad capacity to become charged up to the peak voltage in one half the time of a complete cycle of modulation. Such a condenser will require a leak of 400,000 ohms in order to discharge completely in the same length of time. This rough estimate gives us semi-arbitrary values of grid condenser and leak which should give good operation with a normal tube of the type under discussion, and these values are used for the purpose of this experimental check.

Confining the experiment for the present to conditions such as are often met in practice, characteristic curves have been drawn for plate voltages of 10, 20, 30, and 40; the filament being maintained constant at 1.0 volt. In drawing these curves, the grid return was connected in each case to the positive end of the filament, making a constant positive potential of 1.0 volt on the grid referred to the negative end of the filament.

Figure 2 shows the variation of grid current with grid voltage for the values of plate voltage shown above. Figure 3 shows variation of plate current with grid voltage over the same range. These curves were obtained experimentally in the customary way, and were used as the basis for deriving curves from which the values of the factors in the expression for output could be obtained.

The first of these derived curves shows the variation with grid voltage of the slope of the grid current-grid voltage curve. This value, $\frac{dI_G}{dE_G}$, is plotted against E_G in Figure 4. The initial

[2] J. H. Morecroft, "Principles of Radio Communication," page 461.

conditions under which the experiment was carried out demanded a value of $\frac{dI_G}{dE_G}$ of at least 5 microamperes per volt. Consequently, further discussion is confined to those portions of the curves above the horizontal line representing this limiting value.

Figure 5 shows the values of the second derivative, $\frac{d^2 I_G}{dE_G{}^2}$, as as obtained from the curves of Figure 4. Figure 6 shows the curves of $\frac{dI_P}{dE_G}$ plotted against E_G, as derived from the mutual characteristic curves of Figure 3.

From the three derived curves of Figures 4, 5, and 6 the values of ΔI_P for various settings of E_G are calculated from the equation given above; and the resulting curves are plotted in

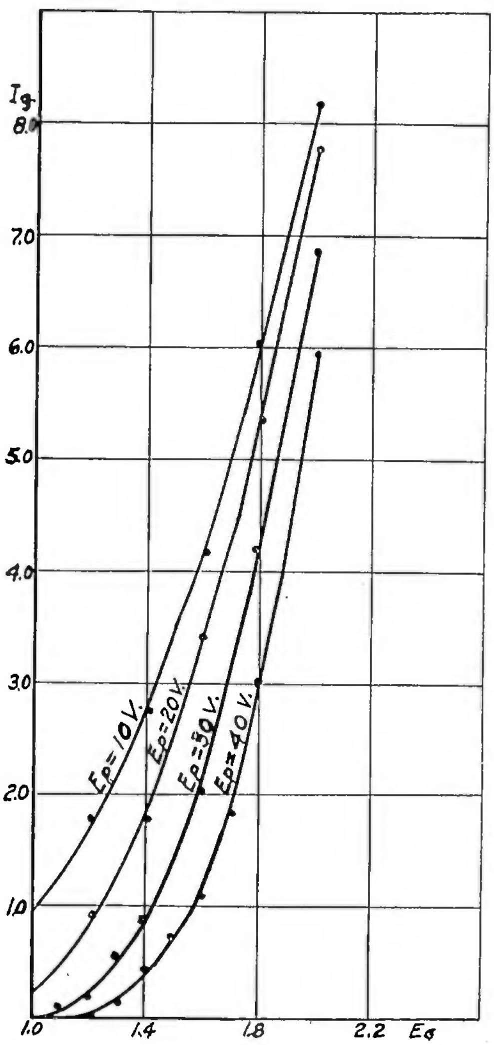


FIGURE 2—Tube DT-1, Grid Characteristics

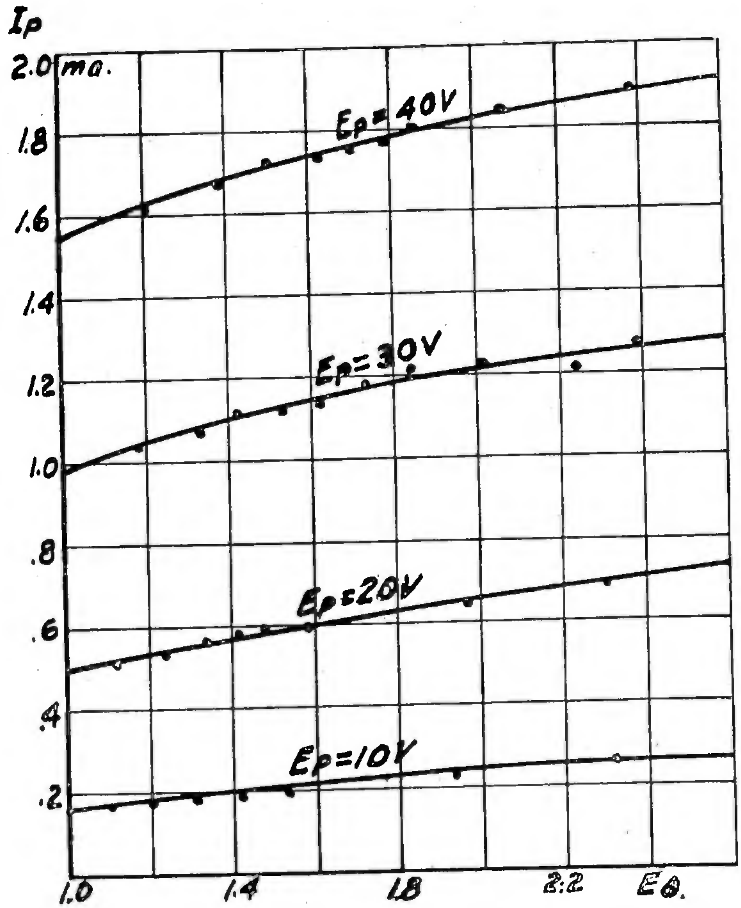


FIGURE 3—Tube DT-1, Mutual Characteristics

Figure 7. All of these curves show maximum signal strength at the lower limit of the region explored. The sharp falling off of signal strength, as $\frac{dI_G}{dE_G}$ increases because of increased E_G, shows plainly the danger in using too high a positive voltage on the grid.

In order to check experimentally the findings predicted from theoretical considerations and plotted in Figure 7, the strength of the output obtained from a standard signal voltage impressed in the circuit of Figure 1 was measured for a number of values of grid voltage and plate voltage within the region covered by the curves of Figure 7. The arrangement of circuits used is diagrammed in Figure 8. The source supplying a modulated radio frequency signal of constant strength was coupled loosely to the dummy antenna used in connection with a tuner and the circuit of Figure 1 in the detector *D*. The output of the detector was amplified by a shielded two-stage audio frequency amplifier *A*, and the peak voltage on the secondary terminals of a transformer in the plate circuit of the last tube was measured by means of an electron tube voltmeter of the type described by R. A. Heising.[3] This circuit (Figure 9) is used as follows: The tube is set at a certain grid bias sufficient to bring the plate current at normal filament operation, nearly to zero. This bias is determined by the point on the potentiometer P to which the positive terminal of direct current voltmeter V is connected.

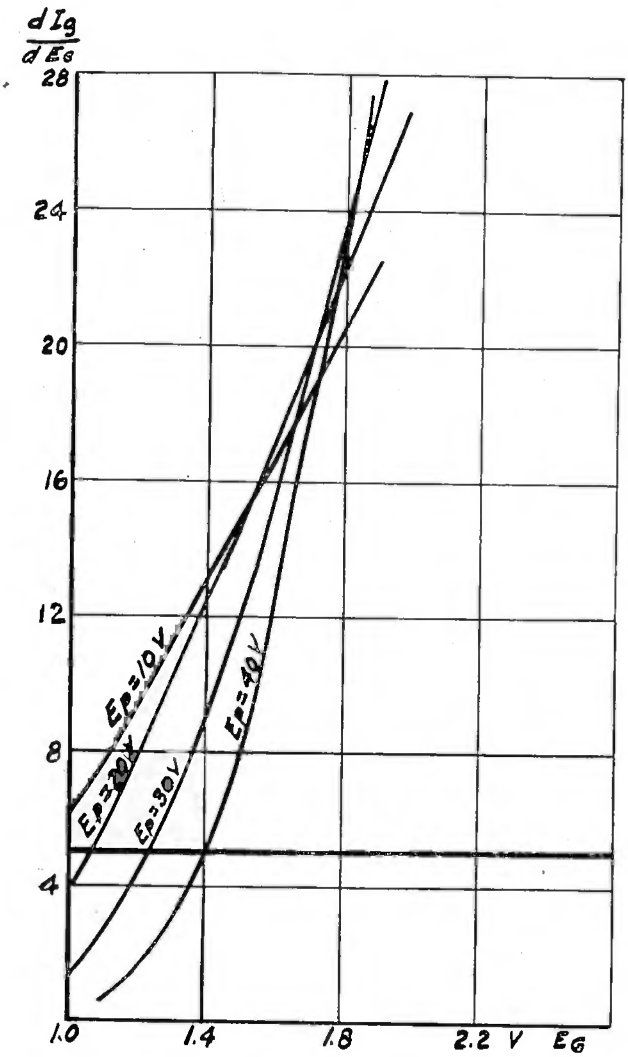


FIGURE 4—Tube DT-1

With no signal applied to the terminals of the transformer T, the filament is adjusted until the microammeter M shows a definite very small reading. When an alternating voltage is applied to the terminals of T, a reading is obtained on M because of the rectifying property of the tube as operated at the lower end of its mutual characteristic. The slider on P is now moved in such a way as to make the grid more negative, until the read-

[3] J. H. van der Bijl, "The Thermionic Vacuum Tube," page 367.

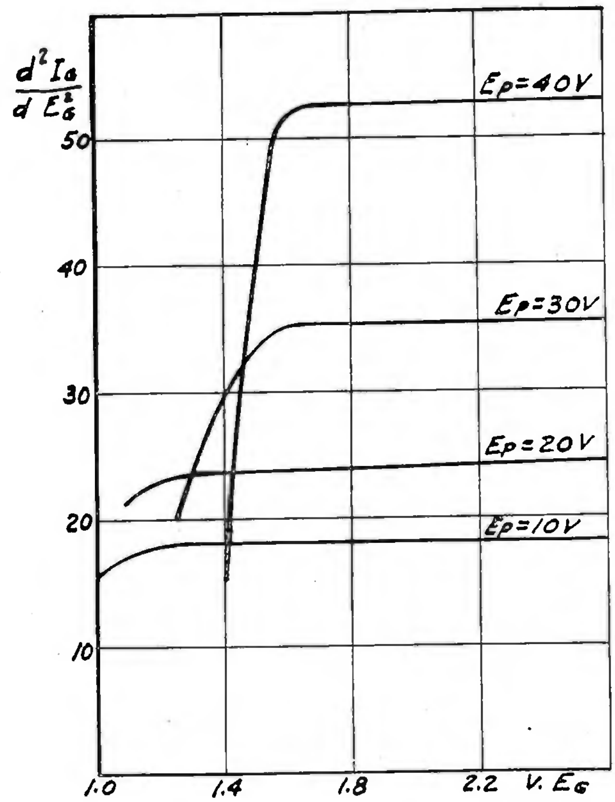


FIGURE 5—Tube DT-1

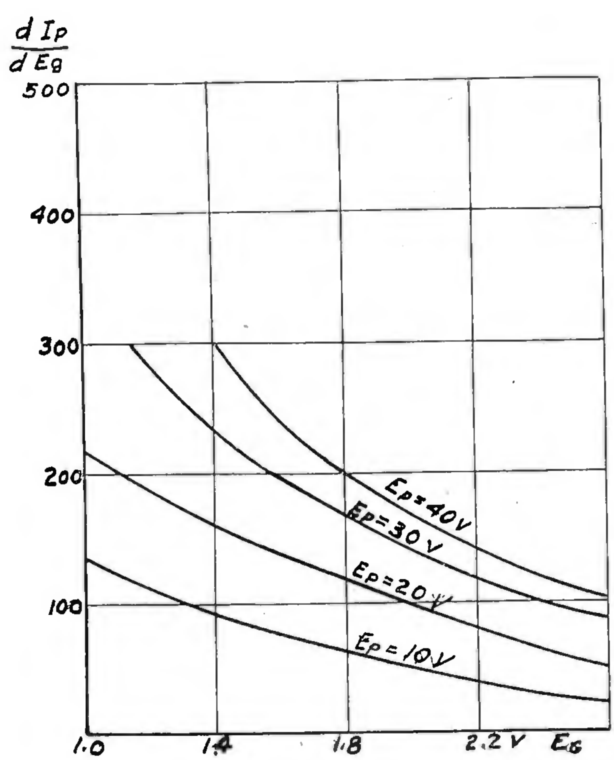


FIGURE 6—Tube DT-1

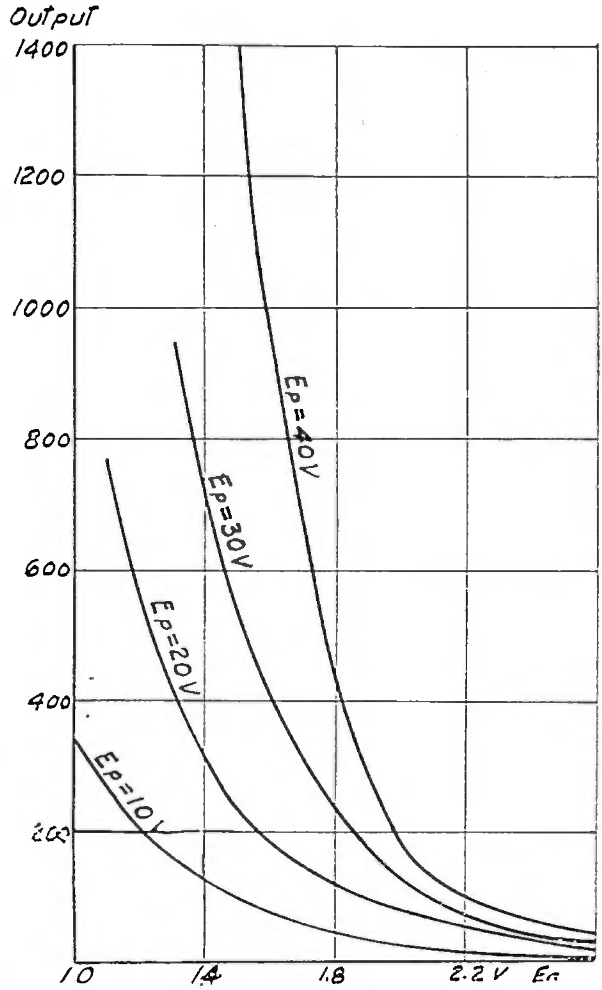


FIGURE 7—Tube DT-1, Derived Curves. Detector Output

ing of M is the same as it was when no signal was coming in. The amount of additional grid bias necessary to bring about this result, as measured on the voltmeter V, is equal to the peak voltage of the signal in the secondary of the transformer T, and, therefore, proportional to the change in plate current in the detector tube, within reasonable limits of operation.

It has always been a matter of extreme difficulty to obtain satisfactory measurements of this kind, particularly in a building subject to disturbances from other radio sets, electric motors, and other sources of electrical disturbance. This difficulty was overcome to a considerable degree in the present case by performing the whole experiment inside of the cage shown in Figure 10. This cage is made of expanded metal screen, having a diamond mesh of approximately 1 inch by 1½ inches, the metal strands being roughly the size of number 8 gauge wire. All

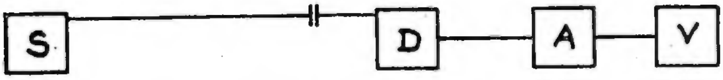


FIGURE 8—Diagram Showing Arrangement of Apparatus for Testing Detector Output

seams were carefully covered with metal straps bolted to the supporting steel framework of the cage, and the door was supplied on all its edges with copper lining strips which formed a close electrical contact with the door frame when the door was closed. The cage was thus completely a series of closed circuits, and proved very effective in screening out radio frequency disturbance of all kinds. For example, a receiving set comprising two stages of tuned radio frequency amplification, detector, and two stages of audio amplification gave an interference output that was barely audible in head phones inside of the cage, altho outside in the room the noise from commutators and other electrical equipment in the building furnished a continual roar in the loud speaker of such volume as to make it a matter of extreme difficulty to talk against it. Station KDKA, at a distance of approximately one-quarter of a mile, could be heard with the head telephones on the same set inside of the cage, but was easily eliminated by tuning. The cage was insulated from the floor (which is of a highly conducting material) and there were no leads running into the cage from the outside.

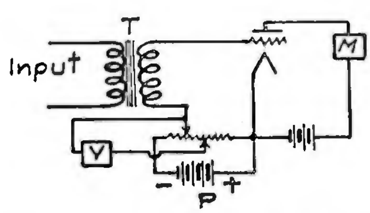


FIGURE 9—Circuit of Tube Voltmeter

By the use of this cage, and by observing all possible precautions to insure the constancy of operation of the component parts of the set-up, particularly of the source of signal and of the shielded amplifier A, it was found possible to obtain easily reproducible results in the determinations of the relative output obtained for various operating conditions of the detector tube D.

A correction which it was found necessary to make in assigning values of the grid voltage E_G occurred because of the change in resistance of the grid leak with the amount of current passing thru it. The reason for this change is not apparent, but since it seemed to be constant and reproducible it was merely taken account of as a correction in determining the value of grid battery E_C necessary to provide the desired grid voltage E_G.

The curves of Figure 11 show the variation of signal output with voltage of grid battery, and are of the same general form as the curves of Figure 7, derived from the static characteristics of the tube. As a check on the closeness of agreement, the curves

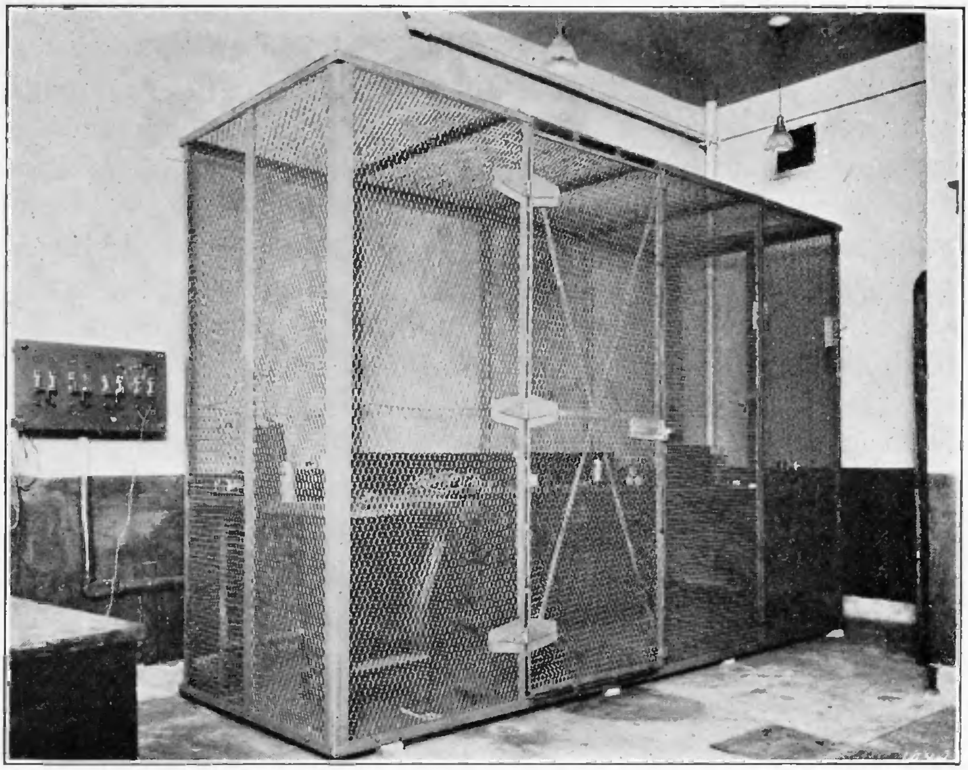


FIGURE 10

of Figure 7 were re-drawn, assigning the arbitrary value of 100 units to the maximum point shown and calculating other points on the curves on this basis. Translating the value of grid battery in the curve, Figure 11, into the corresponding voltages on the grid by subtracting the drop due to the resistance of the grid leak and referring to the maximum reading as 100 units, the experimental values of output are plotted as crosses on the same sheet. Figure 12 shows the closeness of agreement between the calculated curves and the experimental points.

It is apparent that this method of measuring the output from the detector tube gives results which agree satisfactorily with the theoretical values obtained from the static characteristics, and therefore furnishes a quite accurate means of making quick determinations of the effect upon detector efficiency of changing the operating conditions of the tube.

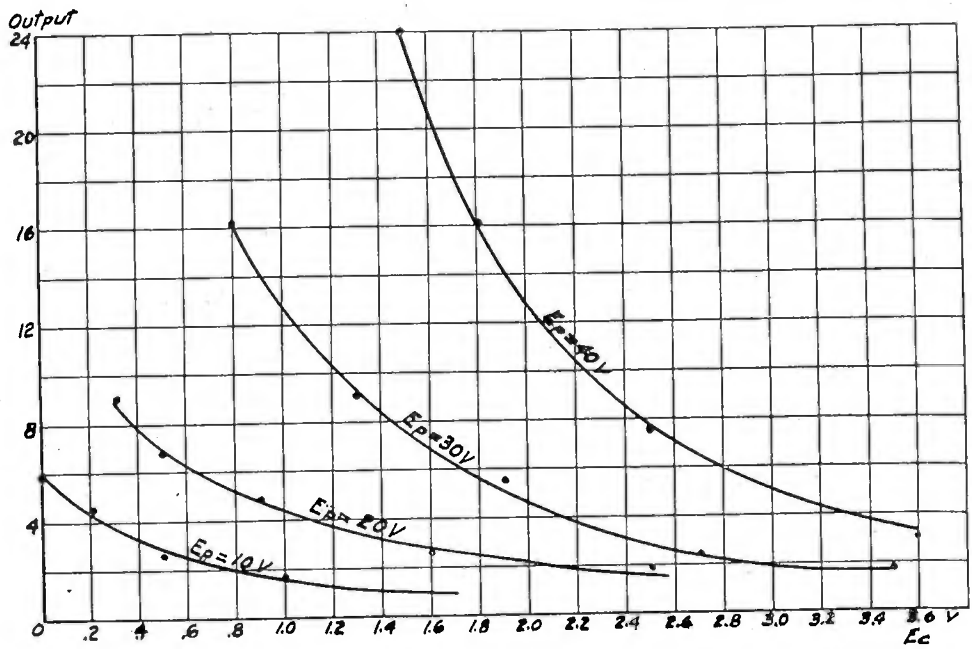


FIGURE 11—Tube DT-1, Experimental Curves, Detector Output

The curve of Figure 13 shows the results obtained with tubes of three well-known commercial types, the grid return being to the negative end of the filament in each case. In this test the

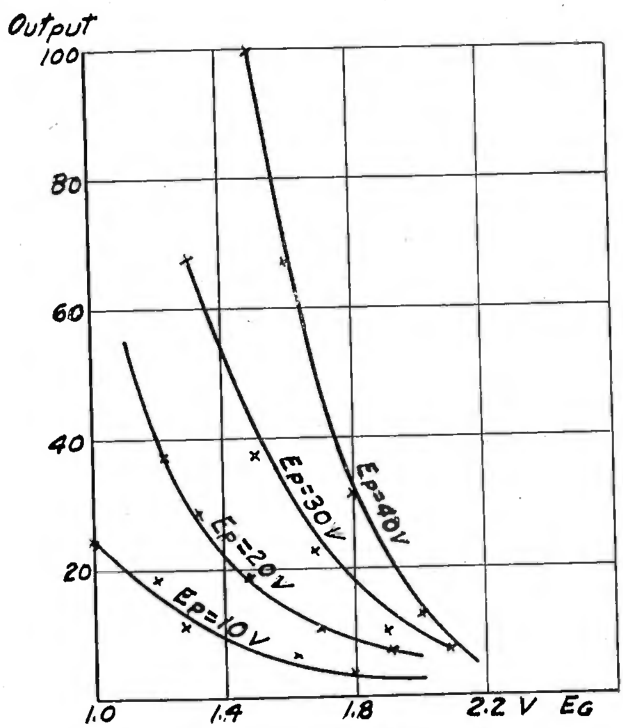


FIGURE 12—Tube DT-1, Comparison Experimental and Derived Curve. Detector Output

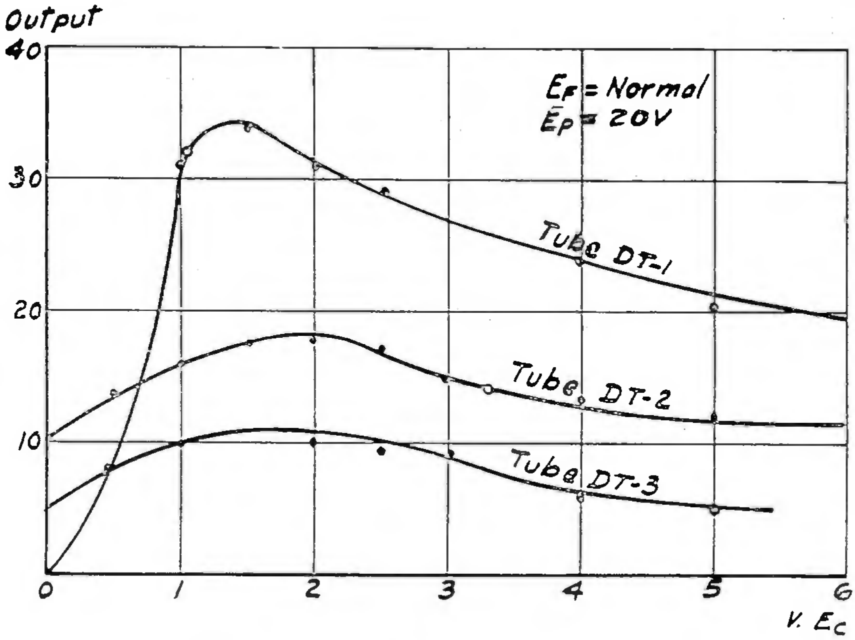


FIGURE 13—Variation of Detector Output with Grid Voltage

grid condenser and leak were of values customarily used, and the filaments were operated at rated supply voltage. The plate voltage was 22½ volts. The circles on the curves indicate the value of filament voltage drop and show what may be expected of these tubes when operated with zero grid bias but connected to the positive end of the filament. In the case of these individual

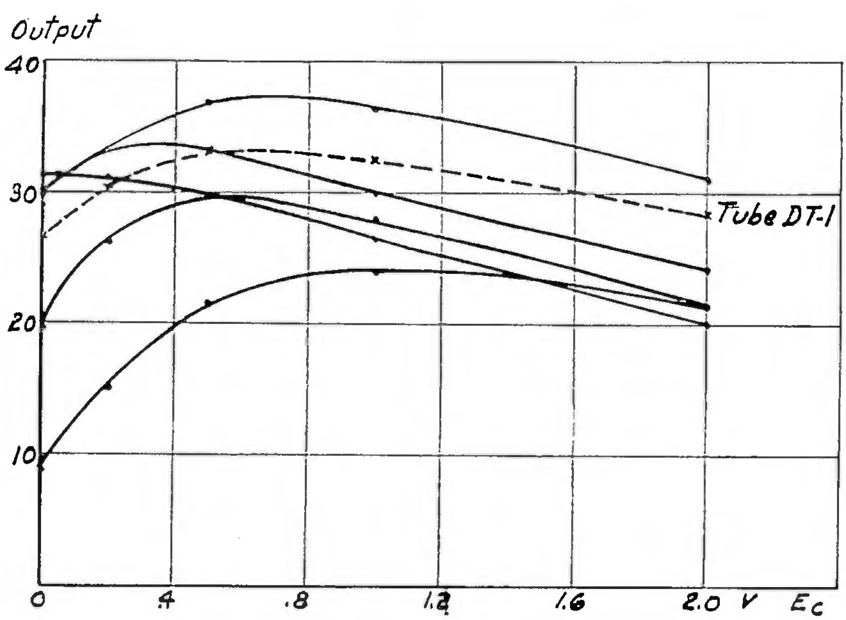


FIGURE 14—Output from Various Tubes of 1 Type
E_F = Normal E_P = 20 V.
Grid to Positive Filament

tubes it appears that the one having the 1.1-volt filament happens to approach the required grid bias conditions most closely when connected in this way.

The curves of Figure 14 were drawn for six tubes of this type with the grid connected to the positive end of the filament, normal filament voltage and a plate supply of 22½ volts being used. Altho these tubes showed approximately the same values of the plate and mutual characteristics ordinarily used to describe tube performance, their operation as detectors showed a wide range of values under any single fixed operating condition. It will be noted that all of these tubes show the normal operation for this type as given in the curve of Figure 13, at some particular operating point, but that in some cases the proper grid bias is quite different from that obtained in the customary connection in the set. This result explains many of the phenomena that have been observed regarding the improvement which may be obtained in the operation of a set by juggling the tubes around and emphasizes the importance of the problem outlined in this paper.

Research Laboratory, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

January 19, 1925.

SUMMARY: It is pointed out that owing to the progress of the radio art the opinions heretofore held as to the importance of the part played by detector efficiency in a receiving set are in need of revision.

Taking the well-known analysis of the operation of a detector tube with condenser and grid leak, curves are derived from the static characteristics of a typical general purpose tube showing the performance of the tube as a detector under certain conditions of operation.

A method is described of measuring the output of a detector tube with a standard incoming signal, and experimental results obtained with the tube used for deriving the curves are compared with those obtained from theoretical considerations, showing that the method can be used to give a true picture of the effect on detector efficiency of variations in operating conditions.

Sample curves are given, showing the wide variations obtained in the efficiency of certain types of standard tubes by relatively slight changes from the customary operating conditions, and also the variations in efficiency of a number of similar tubes under normal operating conditions.

LIFE TESTING OF TUNGSTEN FILAMENT TRIODES*

By

William C. White

(Research Laboratory, General Electric Company, Schenectady, New York)

General

Very little has been published on triode life, a most important subject, and probably for this reason very few of those interested in radio have any reliable information regarding it.

The most common opinion is that the life of a certain type or make of triode is a sort of constant, like the amplification constant. This viewpoint is entirely incorrect and it is the object of this paper to show what a variable factor triode life really is.

It is not uncommon to hear of a life test being made on a few triodes of one type under conditions of doubtful constancy and the result used to indicate the life of that type under all conditions over a long period of time.

This subject has in many ways marked similarities to the study of vital statistics in the field of medicine.

The gathering, compiling, and studying of vital statistics is not made so that any individual may estimate how long he is going to live, but in order to furnish information to help prevent or combat the various diseases and causes of death.

In a similar way the manufacturer of triodes obtains great advantage in observing the behavior during life of his product and length of its life with operating conditions accurately controlled.

A great deal of data is continually being published on the constants and characteristics of triodes. In practically all of these cases the triodes are comparatively new. The user is primarily interested in their performance thru at least several hundred hours of use. Therefore, initial constants and characteristics are only a small part of the performance rating of the tube.

Without going thoroly into the subject, one might think that

*Presented before The Institute of Radio Engineers, New York, March 4, 1925. Received by the Editor, March 14, 1925.

it is a simple matter to set up and operate a triode life test, but experience has shown that unless great care is continually taken on many details the results are worse than useless, because they may be so misleading.

Some of these details are such things as, what constitutes end of life, electrical conditions of operation so results are comparable to practice, and obtaining accurately the desired information on a large number of tubes with a reasonable cost.

The subject is a complex one because the effect of some particular variation of design or manufacturing process may give a resultant change in life on one test, whereas, the same test conducted a year later, may give an opposite result, due to still another slight change which has occurred in the meantime.

To be of real value, life testing must be kept up continuously with triode production. In general, to check up a regularly manufactured product, it has been found more satisfactory to put a few samples on life test at regular brief intervals, rather than relatively larger quantities at less frequent intervals.

Even with great care in all respects some life test results are difficult to understand or analyze.

Reasons for Life Test

The most important reasons for the life testing of triodes are as follows:

(1) To life test new types before their regular use has begun, so as to be certain that no details have been overlooked which would prevent the realization of a satisfactory operating life.

(2) To enable the best choice to be made between several different proposed details of design. As will be pointed out later, very often some little, apparently insignificant, detail will have a pronounced effect upon life.

(3) To detect marked changes in the life quality of the triodes as regularly produced.

(4) To aid in the choice of the best raw materials conducive to long life.

(5) To determine the most satisfactory exhaust method.

(6) To learn if any of the characteristics change during the operating life and, if so, to what extent.

(7) To learn the effect on life of different combinations of operating conditions such as:

(a) position of mounting
(b) room temperature
(c) filament voltage

(d) plate voltage
(e) plate current
(f) grid bias voltage
(g) intermittent operation

APPARATUS USED

The apparatus to be described is located in the Research Laboratory of the General Electric Company at Schenectady, New York.

(1) *For Receiving Triodes*

The general arrangement of life testing racks for receiving triodes is shown in Figure 1. Each of these large racks is divided into a number of smaller sections and on each of these sections the filament, plate, and grid voltages can be adjusted to any desired value within certain ranges. This is accomplished by means of small control panels, as shown in Figure 2, which is a close-up view of four of the sections.

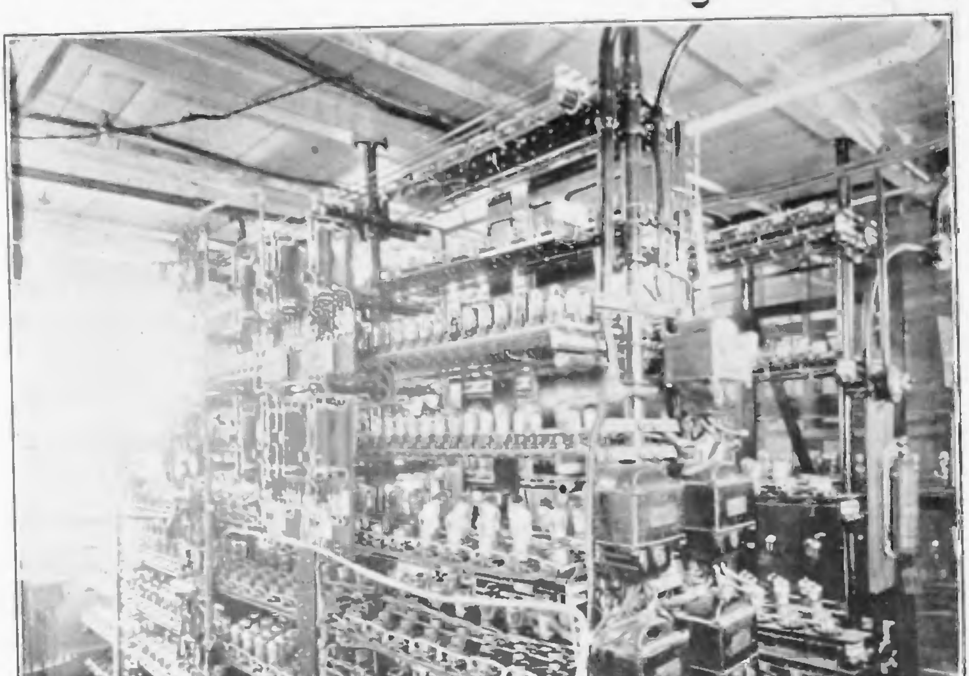


FIGURE 1

Plate voltage is supplied at 125 volts from the building direct current power lines, as it has been found that the regulation of these lines is close enough so as not to affect the results. This voltage is adjusted by means of a slide wire rheostat in a potentiometer connection, and the plate voltage on the triodes is indicated by a small voltmeter.

The grid voltage is supplied from a small low voltage direct current generator, and it is adjusted by a small circular potentiometer rheostat, and the actual bias voltage indicated by a small voltmeter.

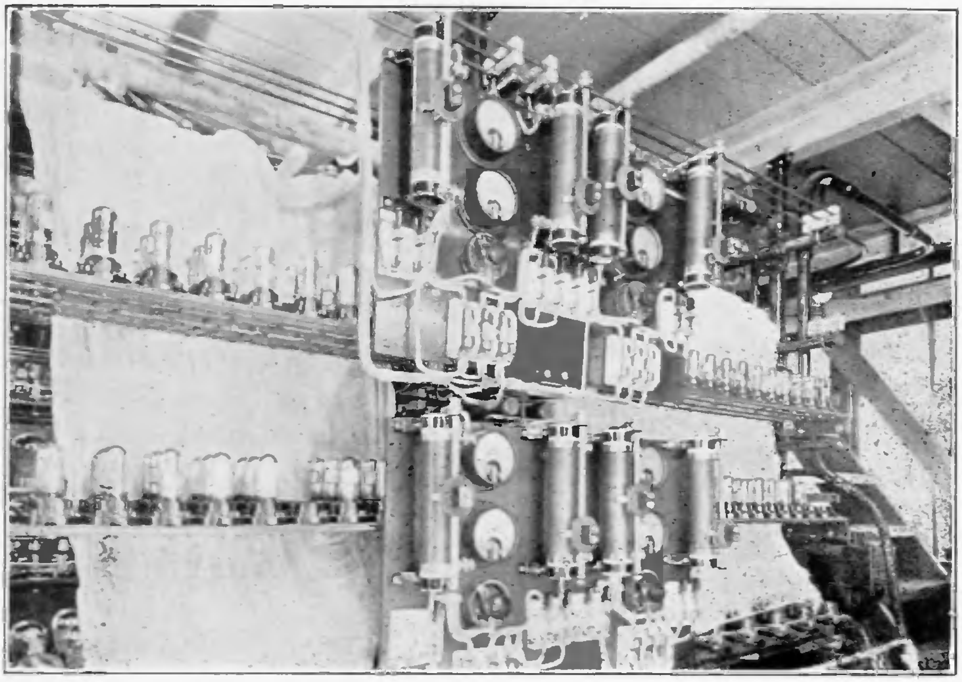


FIGURE 2

The filament voltage is supplied thru special motor generator sets equipped with voltage regulating devices so that the voltage is held well within plus or minus one percent. Owing to the fact that many different voltages are employed, alternating current has been found most practical. This low voltage alternating current is supplied by a transformer on each small section and controlled by a third slide wire resistance. The filament voltage is measured by a high grade and frequently calibrated portable alternating current voltmeter, especially designed to require less current for operation than the usual instruments. When making a filament voltage measurement, leads from this voltmeter are clipped to the filament terminals of one of the sockets of the section.

It is true, of course, that practically no receiving triodes are actually operated on alternating current. We know from experience, however, that there is no very great difference between alternating current and direct current for filament operation, and, as these life tests are conducted from the viewpoint of obtaining comparative results, rather than results to show the highest possible life figures, it is believed that alternating current is preferable for filament operation in life tests where a great number of different values of filament voltage must be used.

The main generator for supplying the filaments delivers power at a thousand volts and this is stepped down to approximately 115 volts for the small section transformers behind the main life test distributing panel. The individual transformers for supplying the small sections are located so that the low voltage leads are only a few inches long. By this method of distribution, no heavy currents are carried thru any great distance and voltage variation, due to change of load, is minimized. Also, variations of load on one section do not appreciably affect the voltage on other sections.

A large number of the triodes life tested are run under certain standardized conditions, and it might seem best, therefore, to have one large section devoted to each type. It has been found, however, that sections containing a very large number of triodes give a great deal of trouble from high frequency oscillations set up in the leads and wires connected with the triodes. These oscillations may seriously change the bias voltage conditions, and even have been found in some cases to vary the filament voltage considerably. They are often of such an extremely high frequency that it is difficult to prevent their occurrence in all parts of a section, and for this reason experience would indicate that sections containing not more than fifty to one hundred tubes are preferable.

(2) *For Transmitting Triodes*

A view of one portion of the transmitting rack devoted to the small power triodes is shown in Figure 3. A wire screen protective covering is used over the racks and at intervals gates are provided to gain access to the triodes. This protection is advisable, as the plate voltages used are from 500 to 2,000. The gates are provided with contacts so that this high voltage is automatically disconnected when a gate is opened.

Transmitting triodes are, in general, tested non-oscillating; that is, they are tested at rated filament and plate voltage with the plate current adjusted to give a certain power dissipation from the plate by means of a proper grid bias voltage. This condition of operation is similar to that obtained in the use of the triode as a modulator, or power amplifier, when no alternating voltage for amplification is applied to the grid.

Because of the high plate voltages used, three fixed values of direct current plate voltage are supplied to this life testing rack. These are 2,000, 1,000, and 500 volts. A number of separate sections, however, are available for each type of triode and these sections are provided with independent control of filament voltage and grid bias voltage.

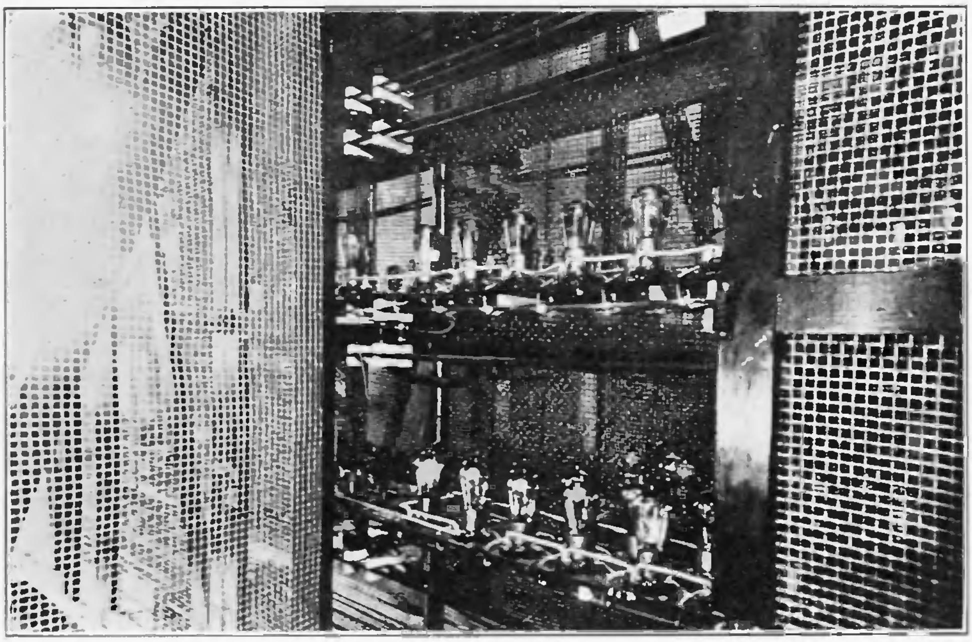


FIGURE 3

In the case of transmitting triodes, alternating current is also used for filament operation, but this is entirely logical as most of the power triodes are used in this way.

Great care must also be taken to prevent very high frequency oscillations in these life testing sections. In general, a high resistance in the grid lead of each tube is employed, and the number of tubes per section is also limited.

The power triode rack, which has just been described, is used for testing triodes of the five-watt to the one-kilowatt, 2,000 volt, types inclusive.

Some life tests are also run on the high voltage higher power triodes, but in this case the numbers tested are so small relatively and the tests are of such a special nature, that they will not be included in this paper.

(3) *Miscellaneous*

Relays are provided, operated from the grid bias voltage, so that in case this voltage fails, the filament voltage or plate voltage, as is most convenient in any particular case, is disconnected from the triodes. This is a necessary precaution because many types of tubes would be ruined very quickly by overloading if the grid bias voltage failed for any considerable length of time.

A recording voltmeter, with charts changed daily, is used in connection with the main filament voltage generator. This instrument shows the voltage regulation attained, and indicates any failure of this supply for even a short period of time. During the night hours the life test runs with only such attention as can be given it by a night watchman making his rounds about once an hour, so that these features are necessary.

Figure 4 shows an electrically driven commutator having two large drums. One of these drums makes a revolution once every twenty-four hours and the other once every hour. On the

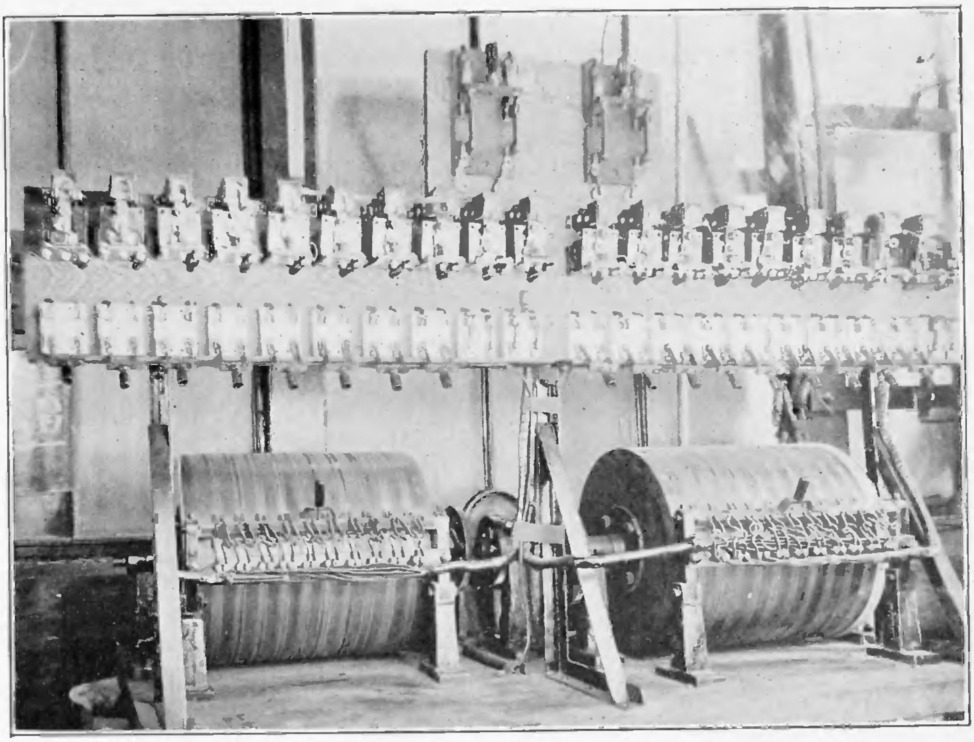


FIGURE 4

surface of these wooden drums can be easily fastened thin strips of copper which can be attached in such sequence as to give any desired time control. Pairs of light brushes press against these copper strips on the drums and in circuit with them are included relays so that plate, grid, and filament voltages on any section of the life test can be thrown on or off or varied by certain definite steps on any desired time schedule.

METHOD OF TESTS

All triodes to be life tested are labeled and each lot is given a designation, which is coded to some extent, to indicate briefly the identity and classification of the triode.

For each lot of triodes to be tested a "work sheet" is made out, giving all the information about the identity of the triodes, such as the purpose for which the test is being run; the conditions under which these triodes are to be life tested; the readings to be taken initially and during life, and the person or persons to whom the results are to be reported. When the life testing has been completed, a summary form is filled in, giving as briefly as possible the result and desired information. An extra copy of this summary is filed under the type of triode tested, so that all life information on a certain type of tube can be found in one place.

Usually, the electrical conditions of test are chosen to represent at least the most severe conditions given by the rating of or instruction sheets accompanying the triode. Very often the conditions are made even more severe than this. This is done, first, to give a factor of safety beyond normal operating conditions and, second, to give the results desired as quickly as possible. Again, it should be pointed out that the important reason for conducting life tests is to obtain relative values and the actual figure obtained for a given lot of tubes taken by itself is not usually of great interest or value.

From time to time these life test conditions for each type of triode are changed to take account of changing radio practices. In so far as possible, the number and frequency of these changes are kept to a minimum so that the results obtained on a given type of triode are comparable over a considerable period of time.

In general, for each type of triode, a standardized schedule is followed, giving the hours at which triodes are removed from life test to be given electrical characteristic tests. Such a schedule generally includes electrical characteristic tests initially and as an example at the end of 25, 50, 100, 250, 500, 750, 1,000, 1,500 2,000 hours, and so on if necessary. Usually tubes having abnormally long lives are removed from test, as waiting for their failure greatly delays the final results, and the including of a very few abnormally long life figures renders less valuable the average figure obtained.

When only a very few triodes are life tested the average figure obtained may not accurately represent the average life of a very large number. The Bureau of Standards in its Circular Number 13, covering "United States Government Specifications for Large Tungsten Filament Incandescent Lamps," gives the following tabulation to indicate what they consider an allowable variation from specified life, due to the relatively small number of samples tested:

Number of lamps averaged	Allowable % variation from guaranteed life	Number lamps averaged	Allowable % variation from guaranteed life	Number of lamps averaged	Allowable % variation from guaranteed life
250 and above	5	24–20	12	9	19
249–100	6	19–18	13	8	20
99–55	7	17–16	14	7	21
54–45	8	15–14	15	6	23
44–35	9	13–12	16	5	25
34–30	10	11	17		
29–25	11	10	18		

For each type of triode there is chosen some value for each of the different factors of tube performance which is considered the end of useful operating life. For instance, in the case of Radiotron UV-201-A, the life is usually considered ended when the electron emission has dropped to below 20 milliamperes. Of course, in many circuits the Radiotron is still satisfactory when the emission has dropped to much lower values, but here, again, from the viewpoint of the manufacturer, relative results quickly obtained are of first importance.

In some of the tabulations given in the latter part of the paper it will be noticed that often the life figures for individual tubes are given to an even twenty-five hours. This is owing to the fact that very often between two successive electrical tests some factor such as the emission drops below the prescribed limit and the time at which it passed below this limit must be roughly estimated from the two readings.

Of course, in a certain number of triodes, failure occurs, due to some definite cause, such as filament breakage, air leakage, short circuit of the electrodes, and so on, defects which render them entirely inoperative. In such a case, if the approximate time of this failure has not been noted, a life figure is arbitrarily assigned which represents a time halfway between the last electrical test at which the triode was satisfactory and the test when the defect was discovered.

In general, a complete set of initial readings is taken on all triodes placed on life test so that if during the test some unforseen

After this filament breakage difficulty has been eliminated another lot may last slightly longer and then develop difficulty from continued overheating of some part. This is just an imaginary case, illustrating the sort of thing which is quite common in a new development in its early stages.

(c) Seemingly unimportant, or very minute, details of design or manufacture may have a very pronounced effect on life. Sometimes different lots of triodes have surprisingly large life variations and it is often extremely difficult to learn the cause of these differences.

(d) Up to the present time no thoroly satisfactory method for the forced life testing of triodes has been developed which allows the life quality to be judged by a life test covering only a few days. It is believed such a forced life test, that is reliable, can be developed, but a great deal more experimental work will have to be done before it can be used to displace life testing under normal conditions.

(e) To be of value in judging the quality of a product, life testing must be carried on at regular and frequent intervals. Even under these conditions, individual results occasionally will vary widely, due probably to slight variations in the product or method of testing, which have escaped detection, or owing to the fact that the small number of samples chosen for testing happened to be far from representative of the product as a whole.

(f) It is not possible in the present stage of this work to get exact quantitative relations between such factors as life and plate voltage, or some of the varying conditions of use. The best that can be done is to get the general trend of these variations and relative values.

(2) *Specific Results*

Using the life test equipment, which has been briefly described, there have been life tested during the past eighteen months about one thousand lots, comprising nearly 10,000 triodes. Some of these are still on test. In giving some of the actual results obtained the life test summary sheets and work sheets were examined to pick out cases which were typical of clean cut results, indicating certain relations that are of interest. One of the great difficulties of triode life testing is the occasional seemingly contradictory results and the difficulty of analyzing them.

Therefore, in connection with the results given, it must be remembered that these are special cases picked out specifically to illustrate some point and in most cases are special lots of triodes, representing experimental variations in the standard product.

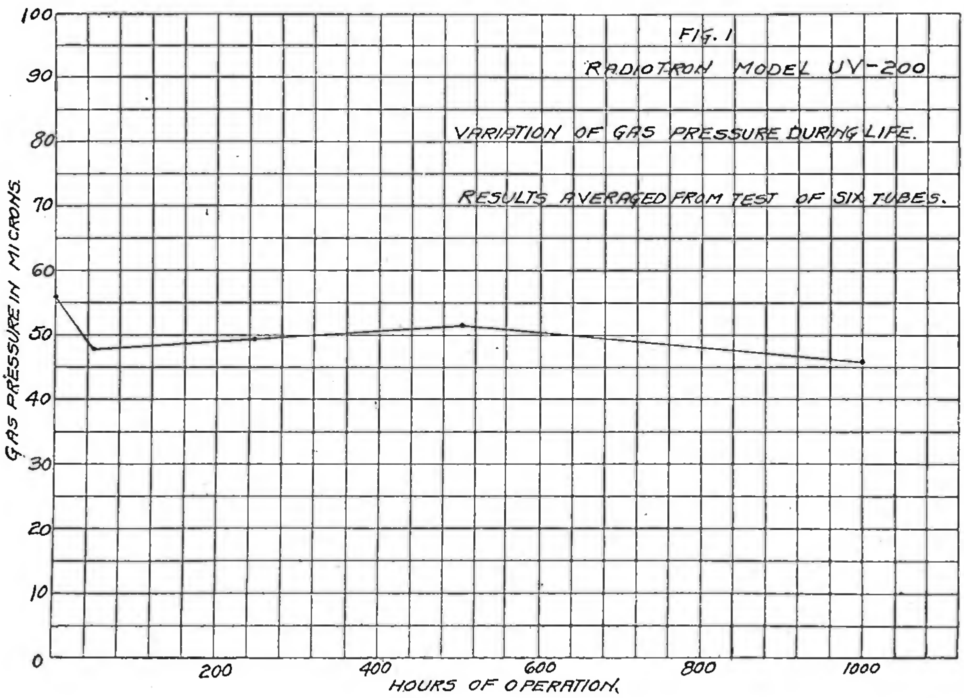
TABLE I

Type of tube tested........................Radiotron UV-200
Lot Number J-M-403
Number of tubes tested................6
Life test conditions:

Filament volts................5.0 A. C.
Plate volts....................20 D. C.
Grid connected to one end of filament.

Tube Number	Hours Life	Failure due to
4	1300	Filament burn out.
6	1200	Filament burn out.
8	1200	Loss of detector action.
10	1800	Filament burn out.
12	1900	Filament burn out.
15	700	Broken Filament

Average life 1,350 hours. Max. 1,900. Min. 700.



CURVE 1

These illustrate the results of a test run to learn whether the gas pressure in this lot of UV-200 Radiotrons varied during life, and if so in what way.

The gas pressure in these different triodes was initially nearly alike and varied quite similarly during life, so that the average, as plotted, gives a good idea of the result obtained. The curve indicates that the gas pressure during life remains almost constant, with the exception of a rather decided drop near the beginning. The other variations are hardly more than the experimental error in determining the pressure.

TABLE IIA

Type of tube.................. Radiotron Model UV-201-A
Lot Number T-S-1
Number of tubes tested................7
Life test conditions:

Filament voltage................5 A. C.
Plate voltage..................60 D. C.
Grid voltage..............5 volts D. C.

Tube Number	Hours life	Cause of failure
*1a	10,000	Base defect
*2a	10,500	Low emission
3a	11,500+	No failure removed from test
*4a	8,300	Low emission
1b	3,800	Low emission
*2b	9,000	
3b	1,000	Accidentally broken

Average life 7,729+. Max. 11,500+. Min. 3,800.

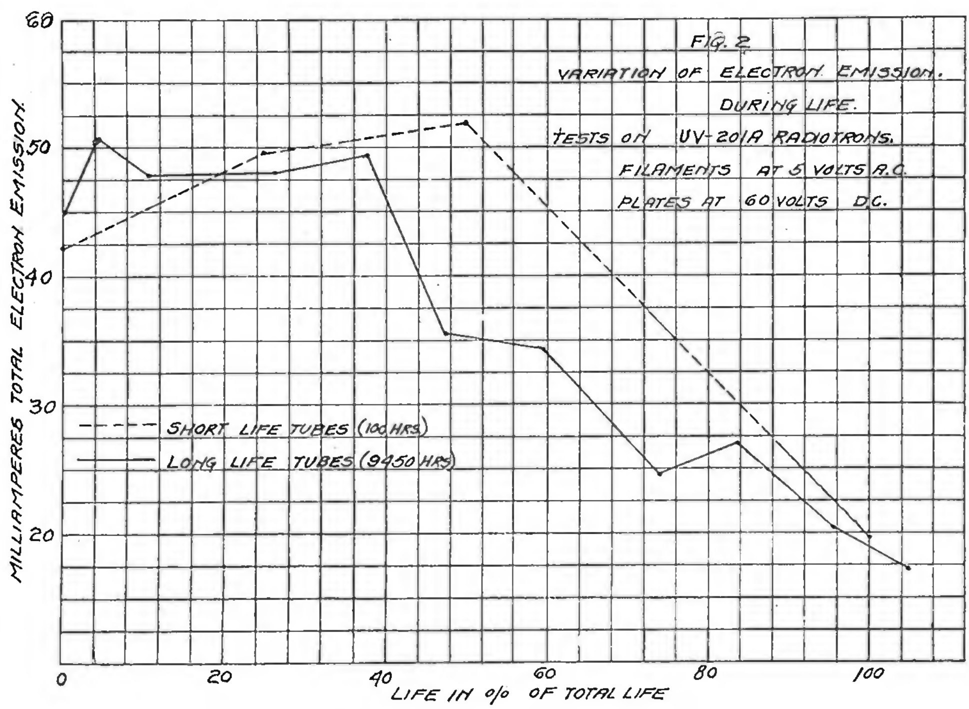
These results were chosen to indicate a rather usual form of variation of electron emission with life on such triodes as the UV-201-A.

As a matter of interest, two different lots were combined; one lot IIA, having exceptionally long life; the other lot IIB, being defective tubes having exceptionally short life. Curve 2 was plotted using the triodes marked with an asterisk on Tables IIA and IIB. Four tubes were picked from each lot that had roughly the same length of life. This was done so that values could be conveniently combined on a percentage basis. The curve shows that there is somewhat of an increase in emission during the first half of life, the latter half of life showing a decrease. In this test the life of the triode was considered as being terminated when the emission dropped below 20 milliamperes.

TABLE IIB

Type of tube....................Radiotron Model UV-201-A
Lot Number M-W-1 (Defective exhaust)
Number of tubes tested................6
Life test conditions:
Filament voltage................5 A. C.
Plate voltage..................60 D. C.
Grid..Connected to one filament terminal

Tube Number	Hours life	Cause of failure
*1	75	Low emission
*2	125	Low emission
*3	100	Low emission
*4	100	Low emission
5	75	Low emission
6	75	Low emission



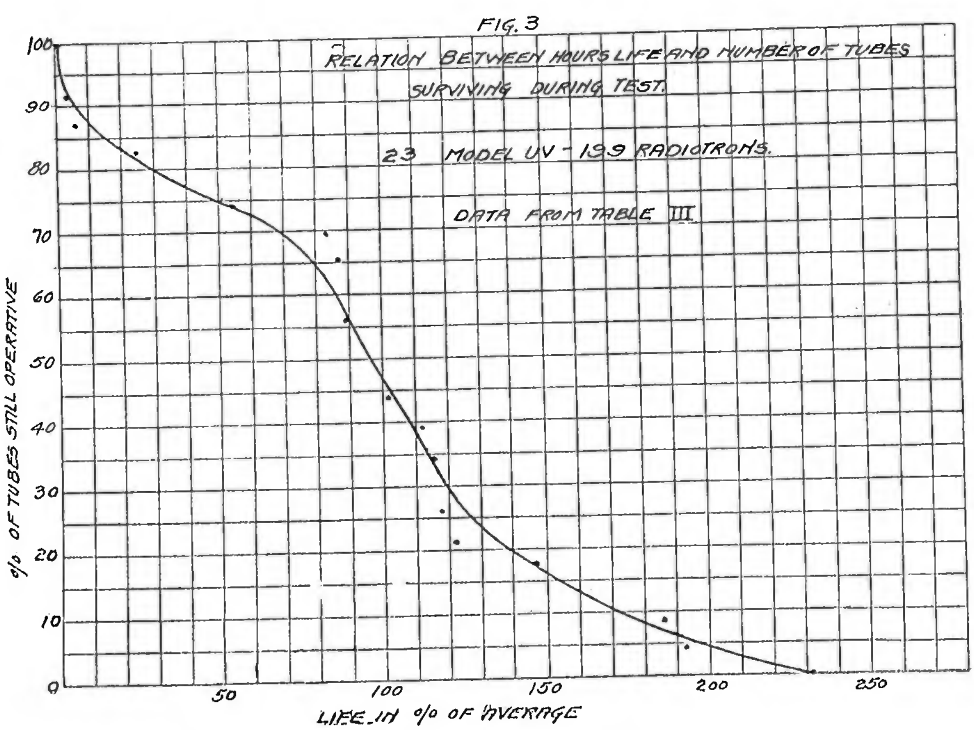
CURVE 2

TABLE III

Type of tube....................Radiotron Model UV-199
Lot designation....................N-S-1
Number of tubes tested..............23
Life test conditions: (Electrical)
Filament................3.0 volts A. C.
Plate....................60 volts D. C.
Grid......Connected to one filament end

Tube Number	Hours life	Cause of failure	Tube Number	Hours life	Cause of failure
4	915	Low emission	32	25	Base defect
8	915	Low emission	33	650	Low emission
21	800	Low emission	34	700	Low emission
22	1,800	Low emission	35	200	Base defect
23	425	Low emission	36	800	Low emission
24	675	Low emission	38	1,250	Low emission
25	1,150	Low emission	39	1,500	Low emission
26	425	Fil burn out	40	700	Low emission
27	25	Short circuit	41	900	Fil. burn out
29	800	Low emission	42	950	Low emission
30	1,450	Low emission	43	875	Low emission
31	35	Broken filament			

Average life 781 hours. Max. 1,800. Min. 25.



CURVE 3

These give the results on a test of twenty-three Radiotrons, Model UV-199. Curve 3 is plotted between life in percentage of average and the percent of triodes still operative. The object of giving the results of this test and plotting this curve is to show that on a relatively large number of tubes the average life is indicated with an approximate degree of accuracy by the number of hours that have elapsed when half of the triodes started on test have failed. The less developed the product the nearer this curve approaches a straight line drawn between the beginning and end of the curve shown. In other words, the more highly developed product shows fewer early failures and fewer exceptionally long lives, the majority failing around average life for the lot.

Table IV is given to illustrate how some very slight detail of manufacture or design will greatly affect the life of the triodes. These four lots were identical, except that the two lots had a very slight difference in the nature of the grid; a difference that would entirely escape ordinary inspection, but happened to be noted in these experimental lots of Radiotrons, Model UV-201-A. All of the life failures on these lots were due to loss of emission, which in connection with the fact that the only difference between the lots was a detail relative to the grids still further emphasises what great care must be employed in Radiotron manufacture and design. All four lots were life tested in identically the same way. In the two lots A and C there were no failures up to 2,000 hours; whereas, in the other two lots, B and D, the average life was low and only one tube lasted a thousand hours.

TABLE IV

Type of tube life tested..........Radiotron Model UV-201-A
Lot Numbers..........R64-A, B, C, D
Number of tubes tested...............36
Life test conditions:

Filament voltage...............5.0 A. C.
Plate voltage.................120 D. C.
Grid voltage..................−6 D. C.

Lots A and C.

All good at the end of 2,000 hours with average emission more than double the lower limit of 20 milliamperes considered the end of life.

Lot B		Lot D	
Tube Number	Hours life	Tube Number	Hours life
1	500	1	175
2	300	2	100
3	300	3	300
4	250	4	275
5	490	5	175
6	350	6	175
7	1050	7	275
8	750	8	200
9	300	All failures low emission. Aver. life 209. Max. 300. Min. 100.	
10	250		

All failures low emission.
Average life 354. Max. 1,050. Min. 250.

In this test, also, end of life was considered as having been reached when the electron emission dropped below 20 milliamperes.

Table V shows the results of a life test conducted on ten Radiotrons, Model UV-204-A, which is a power triode having a rated output of 250 watts.

TABLE V

Type of tube.................Radiotron Model UV-204-A
Number of tubes life tested............10
Life test conditions: (Electrical)
Plate voltage...........2,000 volts D. C.
Plate current..........0.125 amps. D. C.
Filament..................11 volts A. C.

Object of test—To determine if intermittent filament operation (½ hour on and ½ hour off) was detrimental to life of this particular type of tube.

Lot A—Intermittent operation

Tube Number	Hours life
7,569	1,577
7,572	1,000
7,579	2,500+
7,590	691
7,598	960

Average life 1,346+ hours. Max. 2,500+ hours. Min. 691 hours.

Lot B—Continuous Operation

Tube Number	Hours life
4,137	1,500
7,004	445
7,561	1,370
7,580	291
7,582	1,718

Average life 1,065 hours. Max. 1,718 hours. Min. 291 hours

The object of this test was to determine whether intermittent operation of the filaments greatly shortened the life of this type of triodes. Five of them were operated with the filaments intermittently on one-half hour and off one-half hour. The other five were operated continuously. All other life test conditions were the same. The results indicate that there is certainly in this particular lot of tubes no detrimental effect incidental to intermittent filament operation. The slightly longer life on intermitte nt operation is not noteworthy, because the percentage difference between the lives of the two lots is not greater than would be expected, due to the small number of samples tested.

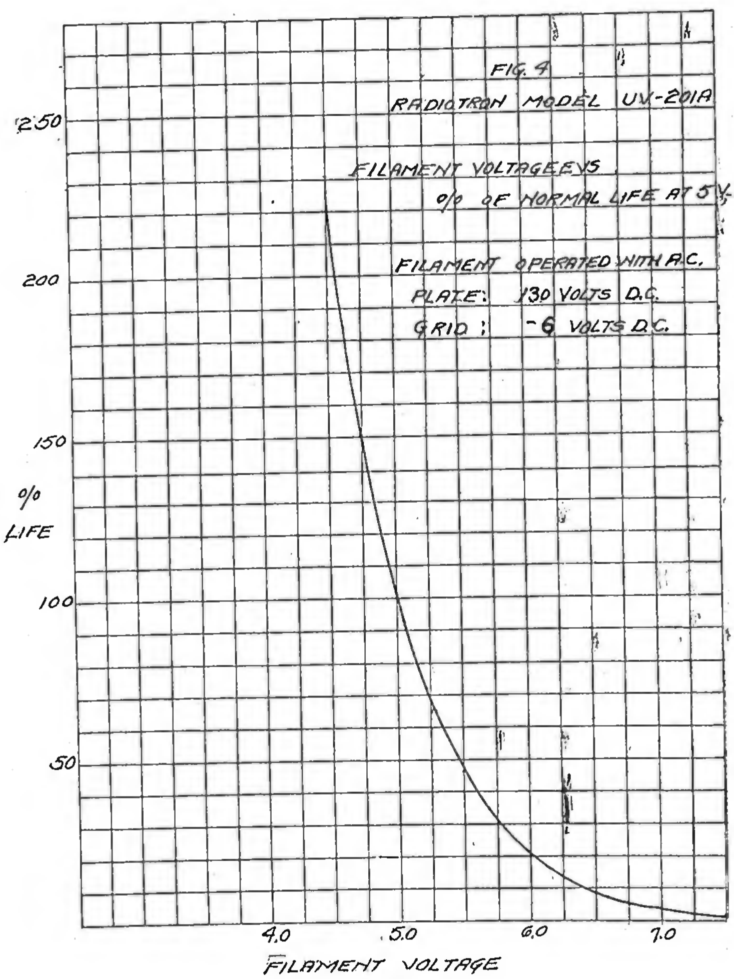
The commutator described in a previous paragraph was used for automatically turning the filaments on and off during test. In this test the conditions of operations were severe; again, in order to get the answer quickly.

It is believed from some tests made on the filaments of receiving Radiotrons that intermittent operation has no injurious effect. On some of the high power high voltage triodes, however, there is some reason to believe that intermittent operation does have a bad effect on life.

Curve 4 gives the result of a test made on a few Radiotrons, Model UV-201-A, to determine in what way life was affected by variation of filament voltage. The curve indicates that in the range tested the life of this particular lot of tubes was halved or doubled when the filament voltage was increased or decreased ten percent, respectively. Tests have not been run on a sufficient number of tubes to indicate the accuracy of these results, and they are merely given as an example of results obtained from one particular lot.

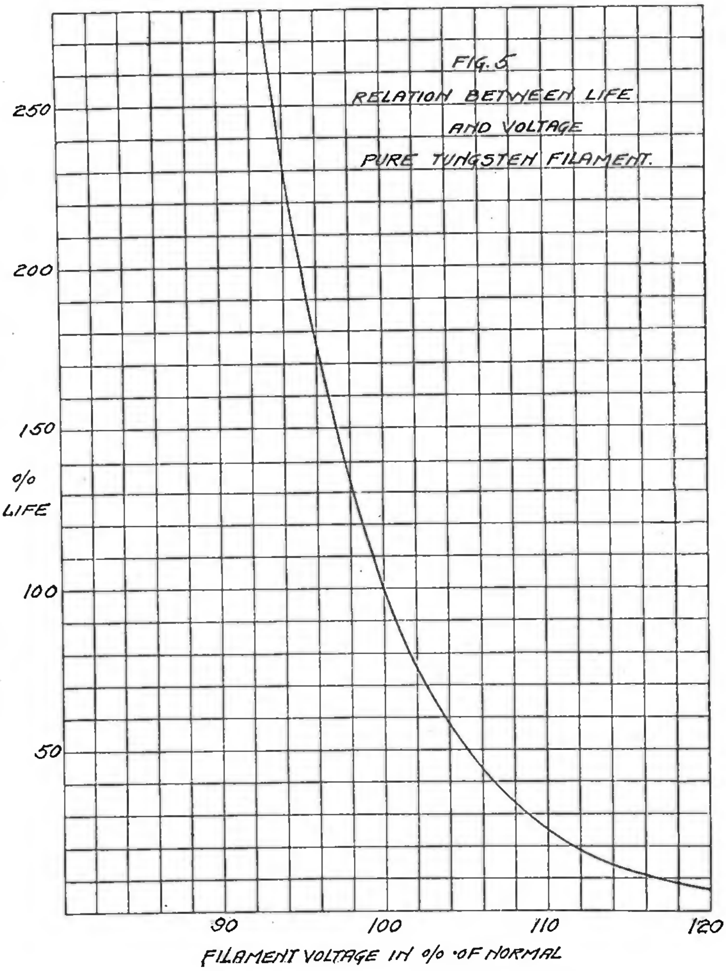
In making this curve the actual figures were plotted on a separate curve sheet of the semi-log type. A smooth line was drawn to give the best interpretation of the results and Curve 4 was plotted from this line.

The calculated rate of evaporation of tungsten, confirmed by test experience, indicates that the life of a pure tungsten filament triode, other factors being the same, will be halved or doubled with a five percent increase or decrease, respectively, of filament voltage. This relationship is shown in Curve 5 plotted on a percentage basis.



CURVE 4

In the case of a pure tungsten filament triode the filament temperature is so high that the life is usually terminated by actual burnout and during life there is a slight evaporation of tungsten from the surface so that its diameter is slightly decreased. Experience in the life testing of tungsten filament lamps indicates that on the average the life of a tungsten filament is ended when the evaporation has reached such a point that the diameter has been decreased by about three percent to ten percent, depending upon the diameter of the filament. The larger the diameter of the filament the greater the percentage of evaporation before failure occurs.

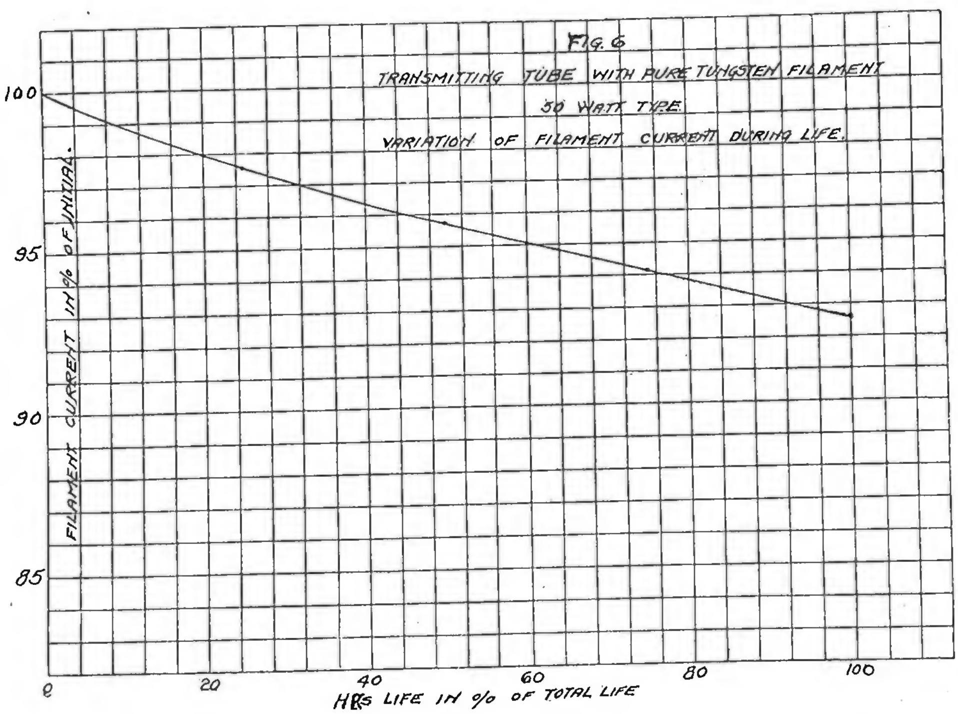


CURVE 5

This decrease in filament diameter during life causes an increase in filament resistance and when the filament is operated at constant voltage there is, therefore, a decrease in filament current.

Curve 6 shows such a filament current decrease, plotted in percent, for a fifty-watt type of triode having a pure tungsten filament.

It might be supposed that this drop of current would cause a drop in electron emission, but this is not always the case, and when it does occur it is often only very slight in amount. The reason for this is that as the current goes down, due to the decrease of filament diameter, so also does the heat radiating surface decrease, and, therefore, the temperature is maintained at nearly constant value. Also, experience has shown that in many cases this evaporation gives a purer tungsten surface which emits electrons at a considerably higher rate per unit of area than the initial surface which might have been somewhat contaminated.



CURVE 6

In conclusion, it is again to be emphasized that these specific results have been selected to illustrate some of the results obtained from the life testing of triodes, but by the very nature of the tests and the way triodes are used, they cannot in any way represent the life to be expected in any individual case of operation.

As explained at the beginning of the paper, the life of a triode is not a constant for any particular type, but is variable as are most of the other characteristics, depending upon many factors.

SUMMARY: It is first pointed out that triodes are life tested primarily as an aid to the manufacturers in proving their performance and useful length of service rather than to obtain any average life figure. The apparatus employed and its method of operation, together with the procedure in handling the data, is next described.

Some actual results obtained are then given to illustrate the methods employed and results obtained. These results are given in the form of tables and curves.

One point emphasized thruout the paper is that triode life is just as much a variable as other factors such as electron emission or impedance.

FURTHER DISCUSSION ON "A METHOD OF MEASURING VERY SHORT RADIO WAVE LENGTHS AND THEIR USE IN FREQUENCY STANDARDIZATION," BY F. W. DUNMORE AND F. H. ENGEL

S. R. Kantebet (by letter): The discussion on the above paper raised by Messrs. Takagishi and Kawazoe has brought out an important point in the distribution of current along a pair of parallel wires carrying stationery waves. The writer himself, in making certain measurements on wave lengths of the order of six meters, has found that wave shapes like the ones experienced by Takagishi and Kawazoe exist even under conditions entirely different from theirs.

In these experiments a 50-watt Mullard valve was used as the source of short radio waves. The oscillatory circuit was of the Hartley type. A single turn of number 14 standard wire gauge 3 cm. in diameter formed the plate circuit coil. In the grid circuit there was a coil of 3 turns of 1 cm. diameter, mounted at a distance of about 6 cm. from the plate coil. The parallel wires were bent at the input and into a loop of about 20 cm. diameter. The loop was nowhere nearer the oscillatory circuit than about 30 cm. Finally, instead of a heavily shunted thermal instrument, a selected carborundam crystal connected onto a galvanometer was used for measuring the current distribution.

It will be seen from this that the coupling between the wires and the valve circuit could not be called tight, especially having regard to the fact that the oscillatory circuit was so small, the parallel wires so far off, and the the input to the valve never more than about 25 watts. Still when current measurements were made with the crystal and galvanometer for a distance covering over three half-waves along the wires, and the results plotted to a distance base, it was found that each half-wave had two maxima with a central depression. And this distribution of current persisted even when the coupling loop was distorted into a thin rectangle. Hence the objection of tight coupling, as suggested by Dunmore and Engel, does not seem to answer the point.

It will be interesting to note here that whereas this distribution was got by chance, Messrs. G. Lamm and E. Graham have obtained similar curves in an entirely different way ("Wireless World and Radio Review,"—December 31, 1924 and January 7, 1925.) Their parallel wires were 16 meters long, 2 mm. in diameter with a clearance of 5 cm. Measurements were made with a thermo-ammeter of 60 ohms resistance. However, in contrast with other experiments, they short-circuited the wires at one end and induced the radio frequency currents nearer the other end of the wires which were here joined together thru an electrolytic resistance the value of which (117.5 ohms) was got at experimentally so as to give a very pronounced central depression for every half wave. They give 500 ohms as the surge impedance of these wires.

In explanation of these curves, they say: "It will, of course, be understood that the influence of the measuring instrument (on the shape of the wave) will increase as its impedance becomes smaller compared with the characteristics of the parallel wires, their characteristics being 500 ohms for these frequencies (30 thousand kilocycles). We can connect a resistance between the terminals at end B and carry out similar calculations. The result will be that we can obtain any form of curve from a pure sine wave.

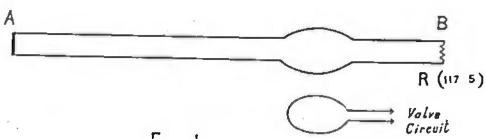


Fig 1

"If we want to get the original curve, the impedance of the measuring instruments should be great compared with the characteristic of the wires." They also prefer measurements being made with nodes instead of loops for reference points, as they say high accuracy is possible there.

The central depression in the INSTITUTE experiments was attributed to the presence of the 3rd harmonic component in the fundamental wave, without experimental verification. So much for the central dip in the distribution curves.

A word may here be said about the different means available for measurement, some of these being a thermal instrument, with or without a shunt, a crystal rectifier and a valve detector. The latter two seem to be specially suitable from the point of view of reflection. Pronounced current loops exist on a pair of wires only when the co-efficient of reflection,

$$K=\frac{R-Z_o}{R+Z_o}$$

is unity. The resistance of crystals and thermionic valves is several thousand ohms, whereas the surge impedance of parallel wires is usually a few hundred ohms. Consequently the reflection factor becomes practically unity (+1) and not very different from that of the method under review which works with $K = -1$.

Coming to the thermal instruments, the following doubt arises. Firstly, they are not very sensitive for small currents and their scales are crowded near the zero point. So one has only to work at the current loops. In the INSTITUTE experiments, as also those referred to above, it has been found preferable to work at the node. In the former case, the thermal instrument gave a much flatter curve with not very definite maxima and minima. The crystal, on the other hand, showed capacity for considerable precision, the node having been traced down to a few micro-amperes.

Secondly, the use of a shunt across the thermo-ammeter seems to be open to the following objection. As has been admitted ("Scientific Papers of the Bureau of Standards," number 491), almost all the current passes thru the shunt and only about a four-hundredth part goes to the heater of the instrument. Suppose that, for example, for a certain position 100 microamperes flow thru the heater, then 40,000 flow through the shunt. Suppose next that, due to a certain shifting, 1 percent change takes place in the current. Out of a total change of 401 microamperes, the current change in the heater will be only 1 microampere in the hundred already flowing thru it. Consequently the change in the heating effect is in the proportion of 10^{-4}, which should be very difficult indeed to perceive. With the shunt removed, all the change would affect the heater and, as such, would be easily perceivable. So the heavy shunt seems to reduce the sensitivity of the instrument very considerably.

As regards reducing the effective resistance of the wire system thru the use of the shunt, perhaps the object could be achieved by using a thicker wire without losing the sensitivity of the instrument.

Department of Electrical Technology,
Indian Institute of Science,
Bangalore, India.

F. W. Dunmore, F. H Engel, and A. Hund (by letter): In reply to Mr. S. R. Kantebet's remarks, the parallel wire method of measuring very short wave lengths described by F. W. Dunmore and F. H. Engel in the PROCEEDINGS OF THE INSTITUTE OF

Radio Engineers, volume 11, number 5, article 23, page 407, and discussed theoretically by Dr. A. Hund in "Bureau of Standards Scientific Paper" number 491, "Theory of Determination of Ultra-radio Frequencies by Standing Waves on Wires," has since been further investigated experimentally by other members of the Bureau of Standards radio laboratory staff. With the conditions as described in detail in the above papers, it was never possible to obtain two maxima as obtained by Mr. K:antebet. The resonance settings were always decidedly sharp. The resonance settings were not nearly so sharp when no shunt was used on the indicating instruments. With the shunt, check settings could be made within 1 mm., whereas without the shunt it was impossible to duplicate settings within 2 mm. Resonance curves taken with and without the shunt showed much sharper resonance with the shunt. The experiments here agree with Mr. Kantebet's suggestion that a crystal detector would be a good means of indication. A crystal detector in series with a portable galvanometer (full-scale deflection = 1 milliampere) as the indicating device was found quite satisfactory. A shunt was used across this combination. The use of this combination increased the sensitivity. As brought out in the above paper, the indicating instrument bridging across the parallel wire system should be as compact as possible. It is doubtful whether reliable results can be obtained when long leads run to a tube or any other indicator. The parallel wire system should be suspended freely as far away as possible from other apparatus.

Radio Laboratory of Standards,
Department of Commerce,
Washington, D. C.

DIGESTS OF UNITED STATES PATENTS RELATING TO RADIO TELEGRAPHY AND TELEPHONY*

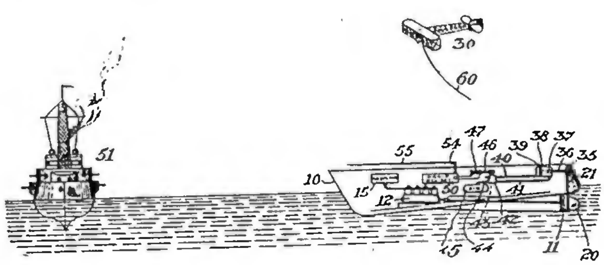
ISSUED JULY 7, 1925—AUGUST 25, 1925

BY

JOHN B. BRADY

(PATENT LAWYER, OURAY BUILDING, WASHINGTON, D. C.)

1,544,746—J. H. Hammond, Jr. Original filed August 10, 1916, issued July 7, 1925.



NUMBER 1,544,746—Method and Apparatus for Controlling Water Craft from Aircraft

METHOD AND APPARATUS FOR CONTROLLING WATER CRAFT FROM AIRCFAFT, where the water craft is provided with steering means and a radio receiving apparatus which is arranged to control the steering means. A directional loop is arranged aboard the water craft so that signals may be received from a radio transmitter aboard an aircraft directly over the loop for controlling the steering mechanism aboard the water craft.

1,545,040—W. Dornig, filed May 10, 1923, issued July 7, 1925.

MULTIPLYING TRANSFORMER for radio transmission systems, in which a secondary oscillation circuit is connected between the transformer and the antenna system, and the circuit tuned to the frequency of the antenna system. An auxiliary circuit is connected to the transformer and tuned to the upper harmonics of the primary frequency by which the desired frequency is impressed upon the antenna system.

1,545,041—W. Dornig, filed May 10, 1923, issued July 7, 1925.

CIRCUIT ARRANGEMENT FOR FREQUENCY-MULTIPLYING

*Received by the Editor, September 15, 1925.

TRANSFORMERS, wherein high frequency oscillations are produced in a single transforming step by wave distortion in the transformer core. A circuit is provided including with oscillation producer which is arranged to impress upon a radiating system the desired high frequency signaling energy due to the exclusion of undesired frequencies.

1,545,207—C. G. Smith, filed August 30, 1920, issued July 7, 1925. Assigned to S-Tube Corporation, Dover, Delaware.

ELECTRICAL APPARATUS comprising a tube construction having an electrode of extended surface area with a second minimum area across an intervening space. The space between juxtaposed surfaces of the electrodes is sufficiently short and the gas pressure sufficiently low as to prevent initiation of substantial conduction directly across the space by potentials high enough to initiate conduction across longer gaps. The electrodes are insulated to prevent substantial conduction between all other portions of the area thereof. The plates form a condenser disposed in vacuum with extremely high break-down potential.

1,545,247—J. O. Gargan, filed October 17, 1919, issued July 7, 1925. Assigned to Western Electric Company, Incorporated.

SUPPORT FOR VACUUM TUBES, by which vibrations are prevented from reaching the tubes by means of a resilient mounting. The vacuum tube support comprises a layer of yielding material, such as sponge rubber, with a rigid member attached to be spaced from the material with the vacuum tube secured to this member. The tube projects from the member and toward the material. A plurality of tubes are suspended from the flexible mounting by members which hang downward from the resilient material.

Re. 16,113—R. J. Fitzgerald. Original filed November 4, 1919, issued July 14, 1925. Assigned one-half to J. Arthur Fischer, New York.

CONDENSER having a plurality of stationary conducting plates and a plurality of interposed movable plates connected together and movable in their own planes into and out of position between the stationary plates. Each plate has a non-conducting coating on opposite sides thereof to enclose the plate. The coating of each movable plate is separate from the coating of each adjacent stationary plate.

1,545,502—Marius Latour, filed August 29, 1921, issued July 14, 1925. Assigned to Latour Corporation.

Radio Telephony, in which telegraphic signals are received from a radio frequency transmitting station by super-imposing locally generated radio frequency oscillations on the receiving oscillation and adjusting the difference of the locally generated frequency and the signal frequency within the limits of audibility so that the beat note does not interfere with the speech. The invention is an extension of the heterodyne principle used in telegraphic systems to reception in radio telephony.

1,545,523—H. Riegger, filed November 18, 1924, issued July 14, 1925. Assigned to Siemens and Halske, Berlin.

Means for Transmitting Time Signals, by the discharge of a condenser across an inductance and an ohmic resistance both of which are so dimensioned that the discharge requires a certain duration only which is determined by the prescribed accuracy. The condenser circuit is accurately adjusted so that the discharge occurs over predetermined time intervals.

1,545,591—J. J. Madine, filed March 6, 1923, issued July 14, 1925. Assigned to Western Electric Company, Incorporated.

Manufacture of Electron Discharge Devices, in which a tight seal between the leading-in wires and the glass envelope is insured. The envelope of the tube and the glass stem which supports the electrode are made of different types of glass. Apertures are formed at the junction of the different types of glass and the leading-in wires passed therethru by applying a bead of glass to the leading-in wires. The bead is fused to close the aperture between the glass portions.

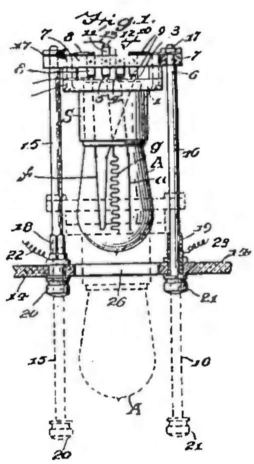
1,545,599—P. O. Pedersen, filed March 22, 1921, issued July 14, 1925. Assigned to Poulsen Wireless Corporation.

Method of and Means for Producing Oscillating Currents of Radio Frequency, in which the efficiency of an arc generator is increased. The arc generator is provided with two electrodes between which the arc is formed with magnetic pole pieces arranged on opposite sides of the arc with adjustable shoes on the pole faces for shaping the magnetic field about the arc. The arc voltage is maintained at a low value during the longer part of the cycle.

1,545,607—J. C. Schelleng, filed December 22, 1920, issued July 14, 1925. Assigned to Western Electric Company, Incorporated.

System of Wave Distribution, in which circuits are provided for maintaining the frequency of an oscillator constant under varying conditions of load. A wave distorting circuit is coupled to a frequency determining circuit and connected to a source for producing harmonics of the wave from the source. A work circuit is provided which constitutes parallel resonant paths for the harmonic frequency which is maintained constant and which may be impressed upon an antenna circuit for transmission.

1,545,639—S. Cohen, filed July 11, 1922, issued July 14, 1925. Assigned to Grace A. Barron, New York.



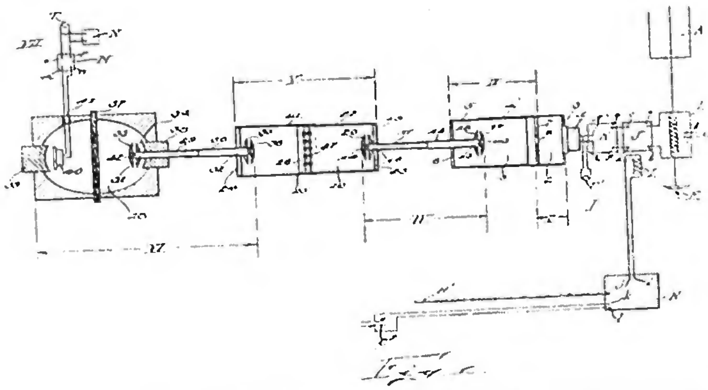
Number 1,545,639 —Vacuum Tube Mounting

Vacuum Tube Mounting, in which the electron tube is carried upon a movable structure by which the tube may be normally disposed within a cabinet and withdrawn to permit removal or re-insertion of a tube in the socket member. The socket member is guided by rods on opposite sides thereof enabling it to be readily moved to a point adjacent the front of the panel or returned to a position behind the panel when the tube is to be inserted or removed from the socket.

1,545,654—A. H. Hoppock, filed November 20, 1920, issued July 14, 1925. Assigned to Western Electric Company, Incorporated.

Water-Cooled Anode for Vacuum Tubes, comprising a closed vessel having thin parallel side walls closely adjacent each other. One of the side walls is provided with depressions forming a tortuous path thru the vessel in which a cooling fluid may be passed.

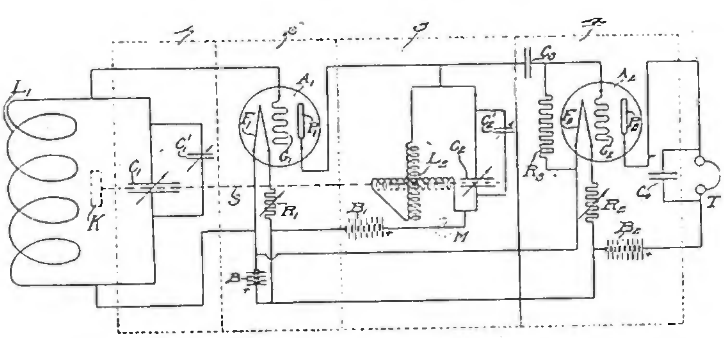
1,545,697—O. C. Roos, filed November 4, 1921, issued July 14, 1925.



NUMBER 1,545,697—Electromagnetic Wave Receiving System

ELECTROMAGNETIC WAVE RECEIVING SYSTEM, in which the effect on the signal-indicating device of electrical vibrations created in the system by static disturbances may be acoustically eliminated while the desired signals may be amplified and received. A percussion chamber is provided into which the sound vibrations from the telephone receiver of the receiving system are delivered. A reverberation chamber is acoustically associated with the percussion chamber with which there is associated a stationary wave separating chamber from which desired signaling energy is delivered to a signaling indicating device while the passage of static disturbances is acoustically prevented.

1,545,940—C. Cabot, filed May 25, 1922, issued July 14, 1925.

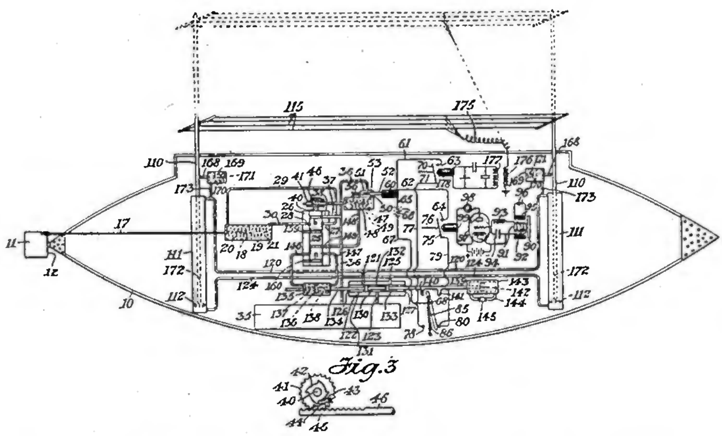


NUMBER 1,545,940—Electromagnetic Wave Receiving System

ELECTROMAGNETIC WAVE RECEIVING SYSTEM of the radio frequency amplifier type which is non-regenerative. The radio frequency amplifier comprises several stages having parallel branch circuits with inductance in one branch and a capacity in another branch, both of which may be simultaneously adjusted to resonance. A vernier tuning adjustment is provided for insuring the exact resonance of the system and preventing oscillations in the radio frequency amplifier.

1,546,579—J. H. Hammond, Jr., filed October 14, 1925, issued July 21, 1925.

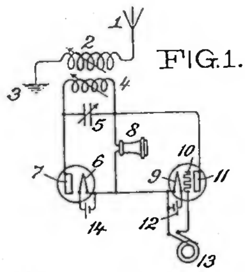
Fig. 1



NUMBER 1,546,579—Dual System of Control for Dirigible Devices

DUAL SYSTEM OF CONTROL FOR DIRIGIBLE DEVICES, such as marine vessel, a torpedo, an airplane, or any other dirigible device, which may be steered or stabilized with respect to a given axis. A control mechanism is provided on the dirigible device whereby the receiving antenna may be automatically elevated on receipt of a particular signal.

1,546,639—C. L. Farrand, filed May 14, 1919, issued July 21, 1925. Assigned one-third to Cornelius D. Ehret, Philadelphia.



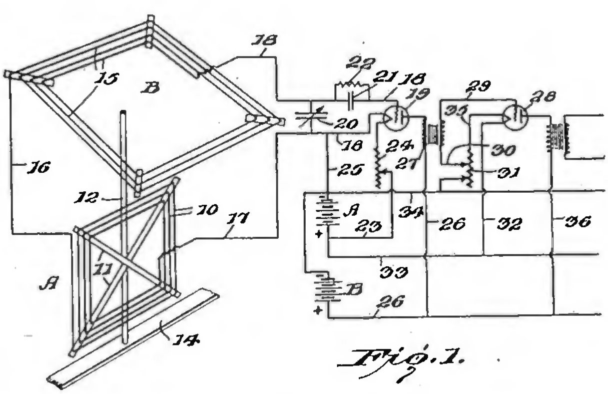
NUMBER 1,546,639—Method of and Apparatus for the Reception of Radio Signals

Method of and Apparatus for the Reception of Radio Signals, by impressing the received signaling energy upon the anode-cathode circuit of a thermionic impedance. The impedance is independently varied by varying an electrostatic field at predetermined frequency different from the incoming signaling frequency whereby the signaling current may be translated into intelligible sounds.

1,546,696—J. F. Yates, filed August 7, 1923, issued July 21, 1925.

Vacuum Tube, in which a mid-tap is taken from the cathode to a contact exterior of the tube which connects to the grid circuit and alternating current supplied across the cathode. The variations in the input circuit therefore occur between a substantially equipotential point on the cathode and the grid, avoiding interference from the alternating current hum.

1,546,731—J. H. Herzog, filed January 23, 1923, issued July 21, 1925. Assigned to Herzog Radio Corporation.



Number 1,546,731—Radio Apparatus

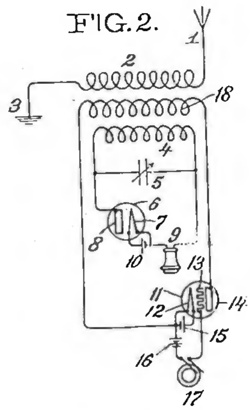
Radio Apparatus, in which signals are received from a single direction only and undesired signals from the opposite direction blocked out. A pair of coil antennas is arranged in such physical relationship and electrically connected in series in such manner that uni-directional reception is secured.

1,546,776—W. R. Bullimore, filed November 24, 1924, issued July 21, 1925.

Manufacture of Filaments for Electric Lamps, Thermionic Tubes, and the Like, which consists in passing a base or metallic core thru a liquid containing in suspension an agglutinant and an alkaline earth metal compound for the purpose of simultaneously effecting a coating of agglutinant and metal compound. The agglutinant is subsequently burnt away, leaving the filamentary cathode.

1,546,781—C. L. Farrand, filed October 13, 1919, issued July 21, 1925. Assigned one-third to Cornelius D. Ehret, Philadelphia, Pennsylvania.

FIG. 2.



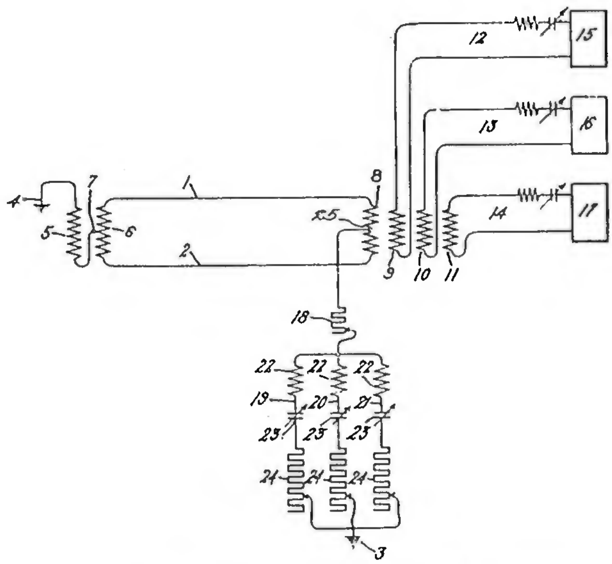
NUMBER 1,546,781 —Methods of and Apparatus for the Reception of Radio Signals

METHOD OF AND APPARATUS FOR THE RECEPTION OF RADIO SIGNALS transmitted by continuous waves where the received signaling energy is impressed upon a thermionic detector, the operation of which is periodically varied by means of a thermionic impedance which varies in magnitude periodically at a frequency above audibility. The received signaling current as modified by the impedance variation is translated into intelligible signals.

1,546,801—C. P. Sorensen and R. W. Satterholm, filed January 22, 1915, issued July 21, 1925.

HOLDER FOR CONDENSERS, which does not require the use of soldered connections between the condenser terminals and the metallic clamps on the condenser stack. A pair of resilient arms extend on opposite sides of the clips which clamp the condenser stack and support the condenser mechanically at the same time that good electrical connection is established.

1,546,878—E. F. W. Alexanderson, filed June 7, 1921, issued July 21, 1925. Assigned to General Electric Company.



NUMBER 1,546,878—Radio Receiving System

RADIO RECEIVING SYSTEM for the operation of a multiple number of receivers simultaneously on the same antenna system. A long horizontal receiving antenna is used with a plurality of receiving sets connected therewith and a plurality of tuned circuits connected in the ground circuit for reflecting over the antenna from another point therein currents of equal magnitude and opposite phase to the undesired currents for suppressing undesired oscillations in the system.

1,547,412—Roy Crocker, filed May 8, 1922, issued July 28, 1925

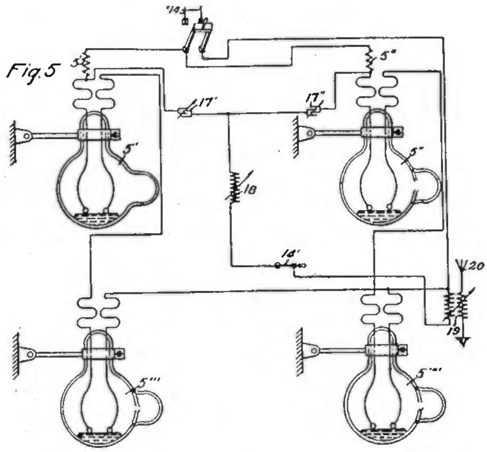
VARIABLE CONDENSER, in which flexible metallic sheets spaced by flexible dielectric material are rolled from one roller to another for effectively varying the capacity of the condenser.

1,547,670—J. W. Radu, filed November 8, 1910, issued July 28, 1925. Assigned to Western Electric Company, Incorporated.

VACUUM TUBE, in which the base of the tube is formed from a molded piece of insulated material with dome shaped projections on the base thereof over which metallic contacts are inserted and connected to the electrodes of the tube thru the molded base. This is the construction for the terminal contacts on the Western Electric Company's "peanut tube."

1,547,684—H. C. Rentschler, filed August 17, 1923, issued July 28, 1925. Assigned to Westinghouse Lamp Company.

OSCILLATION GENERATOR AND JOINT OPERATION THEREOF, where oscillation generators of the arc type are employed in association with a transmitting antenna system. The arcs are enclosed in vessels which contain a pool of mercury. The vessels are tilted in order to start the arcs, thereby bridging the distance between the arc electrodes with the mercury, and while in this position the power is impressed across the electrodes and then the vessels tilted in upright position for setting up a sustained arc.



NUMBER 1,547,684—Oscillation Generator and Joint Operation Thereof

1,547,753—W. G. Housekeeper, filed August 30, 1920, issued July 28, 1925. Assigned to Western Electric Company.

PROCESS OF TREATING METAL to a high heat in a vacuum by which the metal is prepared for use in thermionic tubes by clearing the metal of occluded gases. The electrodes for the tubes are stamped from untreated metal and the formed electrodes then subjected to a high heat in vacuum. The electrodes are assembled within the enclosing vessel and then the vessel evacuated simultaneously with the heating of the electrodes.

1,547,760—R. W. King, filed July 22, 1919, issued July 28, 1925. Assighed to Western Electric Company, Incorporated.

ELECTRON DISCHARGE DEVICE, in which provision is made for preventing leakage between the leading-in wires at high voltages and ionization of the gas in the tube at high voltages due to the emission of occluded gases from the electrodes is avoided. The electrodes are supported within the tube on arms of refractory material. Wires are sealed into the tube and a metallic clamp provided between the ends of the arms and the wires.

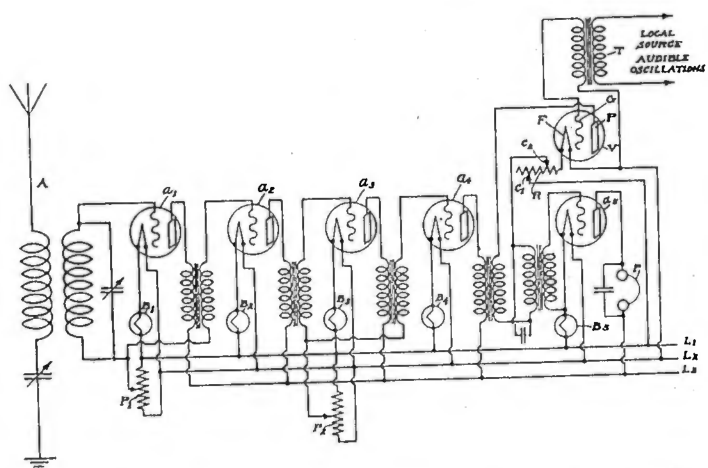
1,547,812—W. F. Hendry, filed September 4, 1919, issued July 28, 1925. Assigned to Western Electric Company, Incorporated.

Vacuum Tube and Method of Manufacturing the Same, in which the electrodes within the tube are positively spaced apart by an insulating block of fusible material which is poured into a mold into which supporting wires from the electrodes extend. When the material hardens, the electrodes are positively secured against displacement.

1,547,885—J. F. Lindberg, filed December 19, 1923, issued July 28, 1925. Assigned to Reliance Die and Stamping Company.

Electric Condenser of variable construction in which the rotatable plates are interleaved with the stator plates in varying degrees with a coarse adjustment control shaft and a fine adjustment cam and lever mechanism actuated by a second concentric shaft by which the rotor plates may be moved thru small angular increments for finely adjusting the capacity of the condenser.

1,547,995—W. L. Carlson, filed February 14, 1922, issued July 28, 1925.



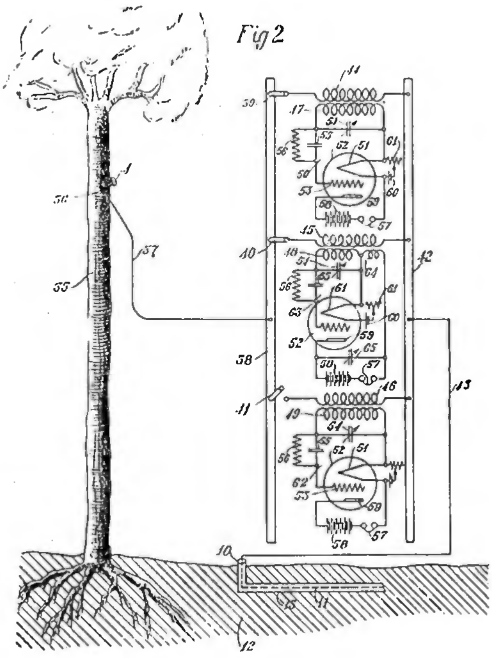
Number 1,547,995—Method of and Apparatus for Receiving Radio Signals

Method of and Apparatus for Receiving Radio Signals, which consists in rectifying the radio frequency signaling currents in a circuit in which no current can normally flow and producing variations of impedance in the circuit only when the signal frequecy is present and then translating the rectified current as modified by the impedance variations into intelligible signals. One of the tubes in the system has its plate filament circuit interposed in the coupling circuit with the preceding tube while a local source of audio freqency oscillations is interposed in the grid filament circuit and a negative bias provided on the plate electrode of the tube. The tone of the received telegraphic signals may be readily adjusted at the rceiver.

1,548,015—A. B. Bergen, filed October 4, 1924, issued July 28, 1925. Assigned to United States Tool Company, Incorporated.

Condenser Plate System, wherein the stator plates of a variable condenser are made up of a continuous strip of sheet metal folded back and forth from one end to the other. Narrow strip-like tongues of sheet metal integrally connect adjacent edges of the stator plates, providing positive spacing means for the plates and electrical connectors between which securing posts may be inserted. This method of manufacturing a variable condenser facilitates the quantity production of condensers.

1,548,032—G. O. Squier, filed August 8, 1919, issued August 11, 1925.



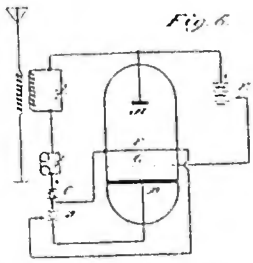
Number 1,548,032—Tree Telephony and Telegraphy

Tree Telephony and Telegraphy, where living vegetable organisms are employed as a radiating system for a radio transmitter. The output of a radio transmitting set is connected to a point in a tree or other vegetable organism which serves as an antenna.

1,548,408—N. B. Davis, filed October 18, 1924, issued August 4, 1925.

CRYSTAL DETECTOR, in which a body of mercury is provided with a crystal floating thereon and a vertically adjustable contact member arranged to contact with the top surface of the crystal. The detector is arranged for vertical mounting on the front of a panel of a radio receiver.

1,548,757—J. Scott Taggart, filed November 30, 1920, issued August 4, 1925. Assigned to Commercial Cable Company.



NUMBER 1,548,757—Electron Discharge Device

ELECTRON DISCHARGE DEVICE, which includes a cathode and two anodes. A cathode is provided and the circuits arranged so that electrons flow to both of the anodes. The circuit is such that the potential of one of the anodes may be varied with respect to the cathode and the flow of electrons to the anode may be increasingly diverted to the other anodes as the potential of the first named anode is increased. The tube may be used as an amplifier and is termed in the specification "a negatron."

1,548,801—O. B. Jacobs, filed March 24, 1922, issued August 4, 1925.

VARIABLE CONDENSER construction comprising inter-leaved flexible condenser plates with interposed flexible dieletric interfolded along parallel lines and longitudinally adjustable with respect to each other. The plates may be tubular in form and may slide with respect to each other or a flat or rectangular shape of plate may be used, the plates being telescopically related for varying the capacity of the condenser.

1,548,811—J. H. Hammond, Jr., filed January 6, 1920, issued August 4, 1925.

SYSTEM OF CONTROL BY LIGHT WAVES, wherein a circuit arrangement is provided for preventing the continued conductivity of a solenium cell circuit after the cessation of the light signal which normally results in a considerable lag in the circuit. The received light energy is concentrated upon a solenium cell and then the circuit to the cell momentarily opened as a result of the received signal for reducing the inertia of the operation of the cell as a control element in the receiving system.

1,549,183—G. H. Clark, filed February 23, 1921, issued August 11, 1925. Assigned to Radio Corporation of America.

RADIO SIGNALING APPARATUS, consisting of an arc generator which does not radiate between the signaling periods. An electromagnetic mechanism is provided on the arc so that the arc electrodes, which are normally short-circuited, are separated for the production of an arc during the signaling period by which oscillations are set up and impressed upon the antenna system. The arc is intermittently suppressed and re-ignited for the production of signals.

1, 549, 253—W. G. Housekeeper, filed October 5, 1920, issued August 11, 1925. Assigned to Western Electric Company.

ELECTRODE FOR ELECTRON DISCHARGE DEVICES, which consists of a boxlike grid structure which entirely surrounds the cathode adjacent the plate electrode. The grid structure is stamped from sheet metal with upwardly extending side members and lateral members integral with the side members. The lateral members are bent in opposite directions to form a rectangular boxlike structure around the cathode.

1,549,310—Leroy E. Humphries, filed October 22, 1923, issued August 11, 1925. Assigned one-fourth to Asa W. Candler, Atlanta, Georgia.

RADIO FREQUENCY SIGNAL RECEIVING SYSTEM for reduction of strays and interference from undesired signals. A pair of electron tube systems is provided which connects to separate collecting circuits tuned to different radio frequencies. The output circuits of the electron tube systems are tuned to substantially the same frequency. A link circuit is provided for coupling the two electron tube systems upon which link circuit local oscillations are impressed and delivered to each of the electron tube systems. The frequency from the local oscillator, which is impressed upon one electron tube system, is equal to the frequency of the opposite radio frequency energy collecting circuit, and vice versa. The output circuits are differentially coupled and arranged to deliver a resultant field to an independent radio receiving circuit.

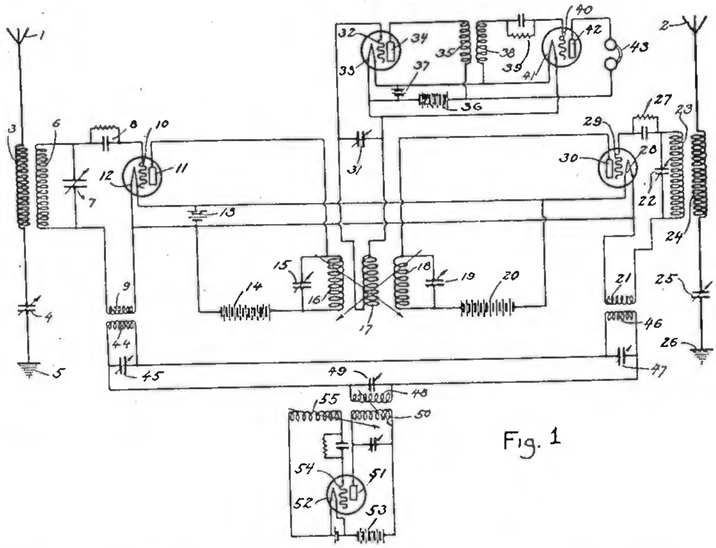


Fig. 1

NUMBER 1,549,310—Radio Frequency Signal Receiving System

1,549,196—R. E. Hall, filed November 14, 1918, issued August 11, 1925. Assigned to Hall Radio Corporation.

Fig 1

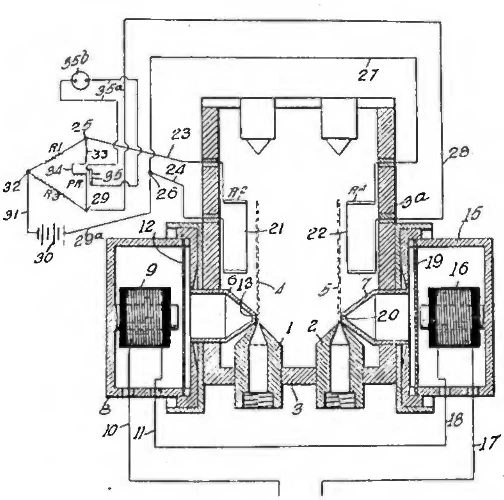


Fig 2.

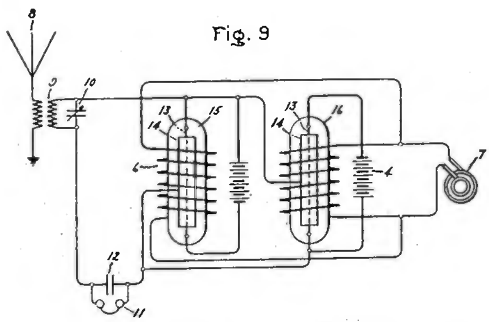
NUMBER 1,549,196—Method of and Means for Translating Sounds

METHOD OF AND MEANS FOR TRANSLATING SOUNDS, comprising jet relays arranged in the output circuit of a radio receiving circuit and selectively responsive to a particular tone. The jets operate alternately to heat and cool a resistance unit which is connected to control a suitable recording circuit. The jets are arranged to be extremely sensitive to a particular tone quality of the desired signal.

1,549,355—J. J. Ghegan, filed February 12, 1924, issued August 11, 1925.

VACUUM TUBE CONTACT, which consists of a coil spring secured to an inwardly extending strip-like member and to which the pins on the base of an electron tube may be inserted. The coil springs insure good contact with the pins of the electron tube over a large area of the pin.

1,549,737—E. F. W. Alexanderson, filed September 15, 1919, issued August 18, 1925. Assigned to General Electric Company.



NUMBER 1,549,737—Signaling System

SIGNALING SYSTEM for radio reception where a detector is provided which consists of a resistance device which may be included in the receiving circuit. The current thru this device substantially follows Ohm's law and is, therefore, directly proportional to the impressed voltage. The necessary asymmetry of the device for securing the required rectifying effect is secured by periodically varying the value of this resistance by means of a suitable modifying force which is controllable at the will of the operator at the receiving station. The value of the resistance is controlled or varied in such a way that it is made comparatively small during desired periods and is made exceedingly large during other periods. This permits the flow of an appreciable current in the receiving circuit during desired portions of the impressed signaling wave and causes the practical suppression of the current in receiving circuit during other portions of the signaling wave.

1,549,882—L. L. Jones, filed June 7, 1924, issued August 18, 1925. Assigned to Amsco Products, Incorporated.

Condenser of the variable type in which end supporting plates are provided for enclosing a set of stator plates. A pair of transversely arranged insulating beams are carried by each of the end plates in a plane normal to the plane of the end plates and which serve to support the stator plates. The rotor plates are journaled in the end plates in such manner that the rotor plates may be interleaved between the stator plates.

1,549,926—F. Schneider, filed November 16, 1921, issued August 18, 1925.

Receiving Device for Electric Waves, consisting of a crystal detector where the crystal member is secured between two plate electrodes which may be adjusted with respect to the crystal for securing a junction of maximum sensitivity.

1,550,016—W. W. Dodge, Jr., filed October 19, 1922, issued August 18, 1925.

Electrical Condenser, in which coarse and fine adjustment of variable condenser plates is secured by a mechanism under control of a single knob or actuator. The actuator is positively connected to a movable condenser plate or plates of small capacity with a lost motion connection between the small unit and the large unit so that the actuator may be turned in one direction to engage the large unit, and by continued movement in this direction will then adjust both units in unison. Reverse movement of the actuator within the limits of the lost motion will then produce a relatively negative adjustment of the small unit only.

1,550,421—L. A. Bonish, filed April 27, 1922, issued August 18, 1925.

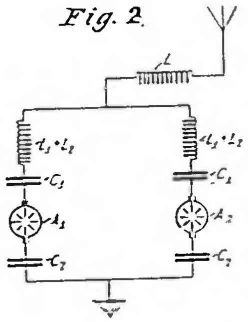
Detector of the crystal variety in which a crystal is supported on the end of a resilient spring arm which is arranged to yield vertically at its free end. A cat whisker engages the crystal and means are provided for adjusting the position of the crystal and the position of the cat whisker with respect thereto.

1,550,571—H. J. Round, filed March 31, 1920, issued August 18, 1925. Assigned to Radio Corporation of America.

Receiving System for Radio Telegraphy and Telephony, in which the effect of certain signals upon a receiver may be eliminated by hetrodyning the signals in each of two receiving systems which are spaced a fraction of the wave length of the signals apart. The same phase difference between the signal and the heterodyne may be established and therefore the beat currents in the two antenna systems are made to balance one another with the result that the signals are ineffective. The heterodyne energy may be supplied from a separate antenna system set up with relation to the receiving antenna so that the desired phase relation is brought about for the reception of one of the signals to the exclusion of another.

1,550,682—H. M. Dowsett, filed September 23, 1922, issued August 25, 1925. Assigned to Radio Corporation of America.

Fig. 2.



NUMBER 1,550,682—Arc Generator of Electric Oscillations

ARC GENERATOR OF ELECTRIC OSCILLATIONS where two arcs are operated in parallel with minimum inter-arc current circulating between the arcs for affording the maximum output current in the antenna system. The inter-arc circuit is provided with condensers of large capacity as compared with the output circuit. The output of each arc is fed into the antenna system with substantially no circulating current in the inter-arc circuit.

1,550,768—H. W. Weinhart, filed July 14, 1919, issued August 25, 1925. Assigned to Western Electric Company.

ELECTRIC DISCHARGE DEVICE, in which the electrodes are supported on wire members which extend from the glass press within the tube. A cylindrical anode is provided with spacer members thereon which engage with the inner walls of the tube for preventing movement of the electrodes. The grid electrode has each turn thereof fastened to the supporting rod which extends from a glass press.

1,550,877—E. L. Chaffee, filed March 10, 1916, renewed September 11, 1923, issued August 25, 1925. Assigned to John Hays Hammond, Jr.

Electric Relay operated from a detector with a circuit arrangement for increasing the sensitiveness of the detector so that it is normally adjusted in such manner that no current flows in the relay circuit. The signaling energy is employed for controlling the current in the output circuit of the tube, the curcuit being so proportioned that the persistence of the operation of the detector, after the impulse which initiated such operation has ceased, is reduced to a minimum.

1,551,087—F. Christiani, filed May 17, 1924, issued August 25, 1925.

Radio Receiving Set, having a crystal detector therein mounted upon a panel on one side of which a variable inductance is variously mounted, and on the other side of which a cover portion is provided for entirely enclosing the set within a small volume.

1,551,391—E. F. Hennelly, filed August 29, 1921, issued August 25, 1925. Assigned to General Electric Company.

Electron Device of high power construction where the plate electrode is positively spaced within the evacuated container by compressible holder elements which are secured to the surface of the cylindrical plate electrode and frictionally engage the inner walls of the tube for resisting displacement of the anode under conditions of use for handling.