VOLUME 17 MAY, 1929 NUMBER 5

PROCEEDINGS

of

The Institute of Radio Engineers

General Information and Subscription Rates on Page 766

Institute of Radio Engineers

Forthcoming Meetings

CLEVELAND SECTION
Cleveland, Ohio, May 3, 1929

DETROIT SECTION
Detroit, Michigan, May 17, 1929

LOS ANGELES SECTION
Los Angeles, Calif., May 20, 1929

PHILADELPHIA SECTION
Philadelphia, Pa., May 24, 1929

PITTSBURGH SECTION
Pittsburgh, Pa., May 21, 1929

ROCHESTER SECTION
Rochester, N. Y., May 10, 1929

SAN FRANCISCO SECTION
San Francisco, Calif., May 17, 1929

TORONTO SECTION
Toronto, Ont., Canada, May 3, 1929

PROCEEDINGS OF

The Institute of Radio Engineers

Volume 17 May, 1929 Number 5

Board of Editors, 1929
WALTER G. CADY, *Chairman*
STUART BALLANTINE G. W. PICKARD
RALPH BATCHER L. E. WHITTEMORE
CARL DREHER W. WILSON

CONTENTS

PART I

PART II

Technical Papers

Copyright, 1929, by The Institute of Radio Engineers

The Institute of Radio Engineers

GENERAL INFORMATION

The PROCEEDINGS of the Institute is published monthly and contains papers and discussions thereon submitted for publication or for presentation before meetings of the Institute or its Sections. 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.

Subscription rates to the PROCEEDINGS for the current year are received from non-members at the rate of $1.00 per copy or $10.00 per year. To foreign countries the rates are $1.10 per copy or $11.00 per year.

Back issues are available in unbound form for the years 1918, 1920, 1921, 1922, 1923, and 1926 at $9.00 per volume (six issues) or $1.50 per single issue. Single copies for the year 1928 are available at $1.00 per issue. For the years 1913, 1914, 1915, 1916, 1917, 1918, 1924, and 1925 miscellaneous copies (incomplete unbound volumes) can be purchased for $1.50 each; for 1927 at $1.00 each. The Secretary of the Institute should be addressed for a list of these.

Discount of twenty-five per cent on all unbound volumes or copies is allowed to members of the Institute, libraries, booksellers, and subscription agencies.

Bound volumes are available as follows: for the years 1918, 1920, 1921, 1922, 1923, 1925, and 1926 to members of the Institute, libraries, booksellers, and subscription agencies at $8.75 per volume in blue buckram binding and $10.25 in morocco leather binding; to all others the prices are $11.00 and $12.50, respectively. For the year 1928 the bound volume prices are: to members of the Institute, libraries, booksellers, and subscription agencies, $9.50 in blue buckram binding and $11.00 in morocco leather binding; to all others, $12.00 and $13.50, respectively. Foreign postage on all bound volumes is one dollar, and on single copies is ten cents.

Year Books for 1926, 1927, and 1928, containing general information, the Constitution and By-Laws, catalog of membership etc., are priced at seventy-five cents per copy per year.

Contributors to the PROCEEDINGS are referred to the following page for suggestions as to approved methods of preparing manuscripts for publication in the PROCEEDINGS.

Advertising rates to the PROCEEDINGS will be supplied by the Institute's Advertising Department, Room 802, 33 West 39th Street, New York, N. Y.

Changes of address to affect a particular issue must be received at the Institute office not later than the 15th of the month preceding date of issue. That is, a change in mailing address to be effective with the October issue of the PROCEEDINGS must be received by not later than September 15th. Members of the Institute are requested to advise the Secretary of any change in their business connection or title irrespective of change in their mailing address, for the purpose of keeping the Year Book membership catalog up to date.

The right to reprint limited portions or abstracts of the papers, discussions, or editorial notes in the PROCEEDINGS is granted on the express condition that specific reference shall be made to the source of such material. Diagrams and photographs published in the PROCEEDINGS may not be reproduced without making special arrangements with the Institute through the Secretary

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

All correspondence should be addressed to the Institute of Radio Engineers, 33 West 39th Street, New York, N. Y., U. S. A.

Entered as second class matter at the Post Office at Menasha, Wisconsin.

Acceptance for mailing at special rate of postage provided for in the Act of February 28, 1925, embodied in paragraph 4, Section 412, P. L. and R. Authorized October 26, 1927.

Published monthly by

THE INSTITUTE OF RADIO ENGINEERS, INC.

Publication office, 450–454 Ahnaip Street, Menasha, Wis.

BUSINESS, EDITORIAL, AND ADVERTISING OFFICES,

33 West 39th St., New York, N. Y.

Copyright, 1929, by I. R. E.

SUGGESTIONS FOR CONTRIBUTORS TO THE PROCEEDINGS

Preparation of Paper

Form—Manuscripts may be submitted by member and non-member contributors from any country. To be acceptable for publication manuscripts should be in English, in final form for publication, and accompanied by a summary of from 100 to 300 words. Papers should be typed double space with consecutive numbering of pages. Footnote references should be consecutively numbered and should appear at the foot of their respective pages. Each reference should contain author's name, title of article, name of journal, volume, page, month, and year. Generally, the sequence of presentation should be as follows: statement of problem; review of the subject in which the scope, object, and conclusions of previous investigations in the same field are covered; main body describing the apparatus, experiments, theoretical work, and results used in reaching the conclusions and their relation to present theory and practice; bibliography. The above pertains to the usual type of paper. To whatever type a contribution may belong, a close conformity to the spirit of these suggestions is recommended.

Illustrations—Use only jet black ink on white paper or tracing cloth. Cross-section paper used for graphs should not have more than four lines per inch. If finer ruled paper is used, the major division lines should be drawn in with black ink, omitting the finer divisions. In the latter case, only blue-lined paper can be accepted. Photographs must be very distinct, and must be printed on glossy white paper. Blueprinted illustrations of any kind cannot be used. All lettering should be $^3/_{16}$ in. high for an 8 x 10 in. figure. Legends for figures should be tabulated on a separate sheet, not lettered on the illustrations.

Mathematics—Fractions should be indicated by a slanting line. Use standard symbols. Decimals not preceded by whole numbers should be preceded by zero, as 0.016. Equations may be written in ink with subscript numbers, radicals, etc., in the desired proportion.

Abbreviations—Write a.c. and d.c., kc, μf, $\mu\mu$f, emf, mh, μh, henries, abscissas, antennas. Refer to figures as Fig. 1, Figs. 3 and 4, and to equations as (5). Number equations on the right in parentheses.

Summary—The summary should contain a statement of major conclusions reached, since summaries in many cases constitute the only source of information used in compiling scientific reference indexes. Abstracts printed in other journals, especially foreign, in most cases consist of summaries from published papers. The summary should explain as adequately as possible the major conclusions to a non-specialist in the subject. The summary should contain from 100 to 300 words, depending on the length of the paper

Publication of Paper

Disposition—All manuscripts should be addressed to the Institute of Radio Engineers, 33 West 39th Street, New York City. They will be examined by the Committee on Meetings and Papers and by the Editor. Authors are advised as promptly as possible of the action taken, usually within one month.

Proofs—Galley proof is sent to the author. Only necessary corrections in typography should be made. *No new material is to be added.* Corrected proofs should be returned *promptly* to the Institute of Radio Engineers, 33 West 39th Street, New York City.

Reprints—With the galley proof a reprint order form is sent to the author. Orders for reprints must be forwarded promptly as type is not held after publication.

INSTITUTE SECTIONS

Section	*Chairmen*	*Secretaries*
ATLANTA	Walter Van Nostrand	George Llewellyn, P. O. Box 1593, Atlanta, Ga.
BOSTON	George W. Pierce	Melville Eastham, 30 State St., Cambridge, Mass.
BUFFALO-NIAGARA	L. C. F. Horle	P. S. March, 428 Richmond Ave., Buffalo, N. Y.
CHICAGO	H. E. Kranz	J. H. Miller, Jewell Electrical Inst. Co., 1650 Walnut St., Chicago, Ill.
CLEVELAND	Bruce W. David	D. Schregardus, Ohio Bell Tel. Co., 750 Huron Road, Cleveland, Ohio
CONNECTICUT VALLEY	Q. A. Brackett	F. C. Beekley, 96 S. Main St., W. Hartford, Conn.
DETROIT	A. B. Buchanan	W. R. Hoffman, 615 West Lafayette Blvd., Detroit, Mich.
LOS ANGELES	Thomas F. McDonough	W. W. Lindsay, Jr., 1348 Club View Drive, Los Angeles, Calif.
NEW ORLEANS	Pendleton E. Lehde	Anton A. Schiele, 1812 Masonic Temple, New Orleans, La.
PHILADELPHIA	J. C. Van Horn	John C. Mevius, 5135 N. Fairhill St., Philadelphia, Pa.
PITTSBURGH	L. A. Terven	T. D. Cunningham, 513 Holmes St. Wilkinsburg, Pa.
ROCHESTER	A. B. Chamberlain	A. L. Schoen, 3 Kodak Park, Rochester, N. Y.
SAN FRANCISCO	Donald K. Lippincott	Paul Fenner Custom House, San Francisco, Calif.
SEATTLE	Austin V. Eastman	Abner R. Willson, 8055–14th Ave., N. E., Seattle, Wash.
TORONTO	A. M. Patience	C. C. Meredith, 110 Church St., Toronto, Ontario
WASHINGTON	F. P. Guthrie	Thomas McL. Davis, 4302 Brandywine St., N. W., Washington, D. C.

MELVILLE EASTHAM
Treasurer of the Institute, 1927–1929

Melville Eastham was born in Oregon City, Oregon, on June 26, 1885.

For two years he was employed by a local electric light and street railway company. In 1905 he came to New York City and was chief engineer of Willyoung and Gibson, instrument manufacturers.

In 1906, with J. Emery Clapp, Mr. Eastham founded the Clapp-Eastham Company, one of the pioneer manufacturers of radio equipment and accessories. In 1915 with several other persons Mr. Eastham organized the General Radio Company. Since that time he has been President of the company. He is the designer of many instruments used in radio-frequency measurements and holds a number of patents on them.

Mr. Eastham has served on a number of the Committees of the Institute throughout his long active association with the Institute. He has been on the Board of Direction continuously since 1922. In 1927 he was elected Treasurer of the Institute, in which capacity he has continued to serve.

Mr. Eastham was elected to Associate membership in the Institute in 1913, was transferred to the Member grade in 1913, and to the Fellow grade in 1925. He is a member of the American Institute of Electrical Engineers, the American Physical Society, and the Optical Society of America.

INSTITUTE NEWS AND RADIO NOTES

April Meeting of the Board of Directors

A meeting of the Board of Direction of the Institute was held on April 3rd in the office of the Institute in New York City. The following Board members were present: Ralph Bown, (acting chairman), Melville Eastham, treasurer; John M. Clayton, secretary; Arthur Batcheller, Walter G. Cady, R. A. Heising, Lewis M. Hull, C. M. Jansky, Jr., R. H. Manson, and R. H. Marriott.

One hundred and forty-four Associate members and fourteen Junior members were elected.

By unanimous vote of the Board, it was decided that the Institute annual awards for 1929 are to be as follows:

Institute Medal of Honor to Professor G. W. Pierce, of Harvard University.

Morris Liebmann Memorial Prize to Professor E. V. Appleton, of King's College, London.

Both of these awards were presented at the Banquet of the Fourth Annual Convention in Washington.

The Board authorized the appointment of a preliminary committee to investigate the possibility of the Institute's sponsoring the publication of a complete bibliography on radio.

Standard Frequency Transmissions by the Bureau of Standards

The schedule of standard frequency transmissions by the Bureau of Standards for the months of April and July (inclusive) appear below. This schedule includes many of the border frequencies between services as set forth in the allocation of the International Radio Convention of Washington which went into effect January 1, 1929. The signals are transmitted from the Bureau's station WWV, Washington, D. C. They can be heard and utilized by stations equipped for continuous-wave reception at distances up to 1,000 miles from the transmitting station.

The transmissions are by continuous-wave radiotelegraphy. The modulation which was previously on these signals has been eliminated. A complete frequency transmission includes a "general call" and "standard frequency" signal, and "announcements." The "general call" is given at the beginning of the 8-minute period and continues for about 2 minutes. This includes a statement of the frequency. The "standard frequency signal" is a series of very long dashes with the call letter (WWV) intervening. This signal continues for about 4 minutes. The "announcements" are on the same frequency as the "standard frequency signal" just transmitted and contain a statement of the frequency. An announcement of the next frequency to be transmitted is then given. There is then a 4-minute interval while the transmitting set is adjusted for the next frequency.

Information on how to receive and utilize the signals is given in Bureau of Standards Letter Circular No. 171, which may be obtained by applying to the Bureau of Standards, Washington, D. C. Even though only a few frequency points are received, persons can obtain as complete a frequency meter calibration as desired by the method of generator harmonics, information on which is given in the letter circular. The schedule of standard frequency signals is as follows:

Radio Transmissions of Standard Frequency; Schedule of Frequencies in Kilocycles

Eastern Standard Time	April 22	May 20	June 20	July 22
10:00–10:08 P.M.	4000	125	550	1500
10:12–10:20	4500	150	600	1700
10:24–10:32	5000	200	700	2000
10:36–10:44	5500	250	800	2300
10:48–10:56	6000	300	1000	2700
11:00–11:08	6500	375	1200	3100
11:12–11:20	7000	450	1400	3500
11:24–11:32	7300	550	1500	4000

Proposed Lehigh Valley Section

The second organization meeting of the proposed Lehigh Valley section was held March 8th in the Science Building of Muhlenberg College, Allentown, Pa. Carlton F. Maylott, temporary chairman, presided. Twenty-three members and guests attended the meeting.

The paper, "Recent Developments in Superheterodyne Receivers," by G. L. Beers and W. L. Carlson, was presented by Carlton F. Maylott.

Temporary officers were elected as follows: Carlton F. Maylott, chairman; Francis J. Hardner, vice-chairman; Fred. W Clauss, secretary-treasurer; Byron H. Eckert, chairman Meetings and Papers Committee; Byron H. Eckert, chairman Membership Committee; A. J. D. Haines, chairman, Publicity Committee.

Proposed Kansas City Section

Members of the Institute residing in the vicinity of Kansas City, Missouri, have expressed a desire to organize a Kansas City section of the Institute. E. A. McDowell, E. W. Hodge, and W. G.Wheat have been instrumental in the preliminary organization plans. An organization meeting was held in the Alladin Hotel, Kansas City, Missouri, on April 4th. E. A. McDowell presided.

W. J. MacDonald, Assistant U. S. Radio Inspector of that district, spoke on the work of the Radio Division of the Department of Commerce.

Institute Meetings

Boston Section

The Boston section held a meeting in the Cruft Laboratory, Harvard University, Cambridge, Mass., on March 14th. G. W. Pierce, chairman of the section, presided and ninety-eight members and guests attended.

Two papers were presented; one by C. F. Cairns entitled "Voltage Regulators," and another by G.W. Pierce entitled "High-Frequency Sounds." Messrs. Lamson, Putnam, Murray, McElroy, and Tyzzer participated in the discussion which followed.

Buffalo-Niagara Section

On March 29th the Buffalo-Niagara section held a meeting at the University of Buffalo, Buffalo, N. Y. L. C. F. Horle, chairman, presided. Sixty members and guests attended the meeting.

Lewis M. Hull, of the Radio Frequency Laboratories, presented a paper on "Recent Developments in Aircraft Radio."

Messrs. Eichman, Horle, Hector, and Lidbury participated in the discussion which followed.

Chicago Section

On March 8th a meeting of the Chicago section was held in the Engineering Hall of the Engineering Building, Chicago, Ill., and was presided over by the chairman, H. E. Kranz. The meeting was attended by seven hundred members and guests.

The paper, "The Kyle Condenser Reproducer," was presented by V. Ford Greaves. The speaker presented a mathematical study of the condenser reproducer, and showed the effect which is obtained in the Kyle speaker; where the heavy back plate is corrugated, an insulator between the dielectrics is used with an extremely thin conductor on the front, and a rolling action then takes place at the edges of the supporting ridges. Methods of connection of the condenser speaker to various types of circuits were also discussed, including data on the proper matching of impedances as well as the optimum resistance capacity ratio to secure a balanced reproduction. Numerous models of the speaker units, which are flat plates 8 x 12 inches, were shown in various stages of manufacture, as well as complete devices in various types of cabinets, screens, and other types of support. A large speaker having an equivalent area of 64 square feet was used for the major part of the demonstration, and feeding it from an amplifier using four type 250 tubes in the output circuit, the quality was everything that could be desired. Tuning forks of 56, 112, 1024, 4096 and 8192 cycles all came through clearly when struck and held before the microphone.

Messrs. Sabine, Kranz, Kyle, and others participated in the discussion which followed.

On April 5th, at the Electric Club, Chicago, Ill., the Chicago section held their regular meeting, presided over by H. E. Kranz, chairman of the section. Fifty-eight members and guests attended the meeting.

A. E. Shaw, of the Ryerson Laboratory of the University of Chicago, presented a paper, "Cold Cathode Rectification." This paper is published in this issue of the PROCEEDINGS.

Messrs. Morrison, Kranz, Eppstein, and Miller participated in the discussion which followed.

CLEVELAND SECTION

In the Case School of Applied Science, Cleveland, Ohio, the Cleveland section held a meeting on March 29th. Bruce W. David, chairman of the section, presided. There were fifty-three members and guests in attendance.

R. G. Ransom, of the American Telephone and Telegraph Company, presented a paper, "Chain Broadcasting—A New Art." A brief history of chain broadcasting was given beginning with the "wire transmission" of a ceremony at the Arlington Cemetery in 1922. Problems in the transmission of high quality programs such as distortion due to unequal attenuation were discussed and characteristic curves shown. The paper was illustrated by lantern slides.

LOS ANGELES SECTION

The Los Angeles section held a meeting March 18th in the Elite Cafe, Los Angeles, California. T. F. McDonough, chairman of the section, presided. Sixty-five members and guests attended.

Mr. Carter and Mr. Mitchell, of the Radio Corporation of America, presented a moving picture film, "Manmade Miracles," showing the production of R. C. A. Radiotrons.

Bert Fox presented a paper, "Recent Developments in Superheterodyne Receivers," by G. L. Beers and W. L. Carlson.

K. Dalton demonstrated a power amplifier audio receiver using a fifty-watt output tube and feeding nine dynamic speakers. The rectifier supplying power to the entire system is an arrangement of four 281-type radiotrons in a bridge-type circuit.

New Orleans Section

The New Orleans section held a meeting March 27th in the Louisiana Engineering Building, New Orleans, La. J. N. Du Treil, vice-chairman of the section, presided. There were fifty-one members and guests in attendance.

J. N. Du Treil, Radio Inspector of the United States Department of Commerce, presented a paper, "Crystal Oscillators." The paper covered various crystals that exhibited piezo-electric effects, methods of grinding and cutting crystals, precaution being observed in cutting them. The various circuits in which they might be used and the advantages of each were also explained. Mr. Du Treil exhibited samples of crystal blanks, finished crystals, and complete General Radio crystal oscillator for broadcast station use.

Messrs. Val Jensen, Jones, Gardberg, and Mackie participated in the discussion which followed.

New York Meeting

The monthly New York meeting of the Institute was held on April 3rd in the Engineering Societies Building, 33 West 39th Street, New York City. In the absence of President Taylor, R. H. Marriott presided.

The papers presented at the meeting comprised a series on the general subject of frequency measurement. These papers were as follows:

"The Routine Measurement of the Operating Frequencies of Broadcast Stations," by Henry L. Bogardus and Charles T. Manning, presented by Mr. Bogardus.

"The Testing of Piezo Oscillators for Broadcasting Stations," by E. L. Hall.

"The Precision Measurement of Time," by Alfred L. Loomis.

"A High Precision Standard of Frequency," by W. A. Marrison.

"Observations on Modes of Vibration and Temperature Coefficients of Quartz Crystal Plates," by F. R. Lack.

"A Convenient Method for Referring Secondary Frequency Standards to a Standard Time Interval," by L. M. Hull and James K. Clapp, presented by Mr. Clapp.

"Frequency Measurement," by S. Jimbo, presented by Walter G. Cady.

It is expected that these papers will be published in the PROCEEDINGS.

Four hundred and fifty members of the Institute and guests attended this meeting.

PHILADELPHIA SECTION

On March 22nd, at the Franklin Institute, Philadelphia, Pa., the Philadelphia section held their regular meeting. The meeting was presided over by J. C. Van Horn, chairman, and was attended by twenty-five members and guests.

This was a business meeting and the following officers were elected, to serve until June 1930: J. C. Van Horn, chairman; C. Brown Hyatt, vice-chairman; John C. Mevius, secretary-treasurer.

An open discussion followed on "The Trend of Radio Receivers."

ROCHESTER SECTION

The Rochester section held a meeting February 1st in the Sagamore Hotel, Rochester, New York. A. B. Chamberlain presided. There were seventy-eight members and guests in attendance. This was a joint meeting with the Rochester Section of the American Institute of Electrical Engineers.

Sedwick M. Wright, of the General Railway Signal Company of Rochester, was the speaker, having as his subject "Centralized Traffic Control."

On March 15th the Rochester section held a meeting in the Sagamore Hotel, Rochester, New York, presided over by A. B. Chamberlain, chairman of the section. This was a joint meeting with the Rochester Engineering Society and the local section of the American Institute of Electrical Engineers. Eighty-six members and guests attended.

Edward C. Jerman, of the Victor X-Ray Corporation of Chicago, Ill., was the speaker. His subject was, "Progress in X-Ray in Medicine, Research, and Industry."

SAN FRANCISCO SECTION

On March 20th the San Francisco section held a meeting in the Hotel Bellevue, San Francisco, California. The meeting was presided over by Donald K. Lippincott, chairman of the section. Forty members and guests attended.

Dr. F. E. Terman presented a paper, "The Possibilities and Limitations of Intelligence Transmission with a Limited Band of Frequencies." The paper told of the great increase in number of radio stations and how this increase makes necessary steps towards improving of conditions in order to accommodate them on the available frequency channels. Dr. Terman explained that broadcasting telephones require about 5,000 cycles of channel space, speech telephones require about 2,500 cycles, 60-line picture transmission about 15,000 cycles, and telegraph stations about 35 to 130 cycles, depending on speed of transmission.

The paper brought out the fact that more stations could be accommodated than possible at present by utilizing means now at our disposal, and stated that new developments were not necessary.

As remedies for congested conditions the speaker gave; first, better frequency control; secondly, multiple modulation; thirdly, frequency multiple systems; fourthly, assignment of frequency bands to radio companies, allowing them to crowd as many stations as possible into them.

In order to standardize frequencies a system was suggested to have a primary frequency standard station and several secondary stations to transmit control frequencies and to use these frequencies as master controls, multiplying to secure the desired frequency output.

A brief discussion by the members present followed the presentation of the paper.

Seattle Section

On February 26th, the Seattle section held their regular meeting in the Telephone Building, Seattle, Washington. W. A. Kleist, chairman of the section, presided. There were forty-eight members and guests in attendance.

W. A. Kleist presented an informal paper on "Sound Reproduction, Apparatus for Motion Picture Theatres." Some of the apparatus for this purpose was demonstrated.

Messrs. Libby, Tolmie, and Eastman participated in the discussion which followed.

The annual election of officers was held with the following results Austin V. Eastman, chairman; Abner R. Willson, secretary-treasurer.

The Seattle section held their regular meeting March 29th in the Philosophy Hall of the University of Washington. Austin V. Eastman, chairman, presided. Fifty-four members and guests attended the meeting.

F. M. Reynolds, of the General Electric Company, presented a paper "Keyport 30-kw Tube Transmitter." The paper described the construction and operation of the 30-kw tube transmitter just installed for the Navy Department at Keyport, Washington. One of the new features of this transmitter is the use of mercury-vapor filled hot cathode rectifier tubes for plate current supply. The keying circuit cuts in and out grid bias voltage on the master oscillator circuit to start and stop these tubes oscillating. The amplifier uses two 20-kw tubes in parallel. The antenna current is about 100 amperes at 50 kc. The radiation resistance is about two ohms at this frequency. The transmitter may also be operated at 102 kc.

Messrs. Libby, Deardorf, Threlkeld, Kleist, and Willson participated in the discussion which followed.

Toronto Section

The Toronto section held a meeting March 13th in the Electrical Bldg., University of Toronto, Toronto, Canada. The meeting was presided over by A. M. Patience, chairman of the section, and one hundred members and guests attended. This was a joint meeting with the Rochester and Buffalo-Niagara sections of the Institute.

Irving Wolff, of the Radio Corporation of America, presented a paper, "Problems of Small Moving Iron Type Speakers."

Messrs. Bayly, Karker, Hector, and Pollock participated in the discussion which followed.

On April 3rd, the Toronto section held a meeting in the Electrical Bldg., University of Toronto. A. M. Patience, chairman, presided. Two hundred members and guests attended the meeting.

J. H. Vennes, of the Northern Electric Company, presented a paper on "Audible Motion Pictures."

Messrs. Patience, Pipe, Elliott, Bayly, and Burns participated in the discussion which followed.

Washington Section

In the Continental Hotel, Washington, D. C., on March 14th, the Washington section held a meeting. The meeting was presided over by F. P. Guthrie, chairman of the section. Seventy-two members and guests attended the meeting.

Captain Guy Hill, of the Engineering Division of the Federal Radio Commission, presented a paper on "The Re-allocation of Broadcast Frequencies."

Following the presentation of this paper, Commissioner La Font and Mr. Dellinger gave interesting talks on the activities of the Federal Radio Commission.

Messrs. Guthrie, Gunn, Hyland, Robinson, Brown, Pettsing, and Smith participated in the discussion which followed.

Committee Work

Committee on Admissions

A meeting of the Committee on Admissions was held in the office of the Institute at 9:30 A.M. on April 3rd. The following members were present: R. A. Heising, chairman; F. H. Kroger, C. M. Jansky, Jr., E. R. Shute, J. S. Smith, and A. F. Van Dyck.

The Committee considered twenty-two applications for transfer or election to the higher grades of membership in the Institute.

Committee on Sections

A meeting of the Committee on Sections was held on April 2nd. Those present were E. R. Shute, chairman; Austin Bailey, B. E. Shackelford, John M. Clayton, and C. J. Porter.

The Committee considered the revision of the Sections Manual of Organization and Operation.

The Committee outlined in detail the program for the Annual Meeting of Section Delegates at the Annual Convention in Washington, D. C.

Personal Mention

Lloyd J. Andres, formerly chief engineer, Musical Device Corporation of Chicago, has recently taken charge of the talking picture and sound projection equipment design and development for the Dramaphone Corporation of Chicago.

Lester D. Culley, recently of the Department of Physics, University of California, is now a receiving engineer of the Radio Corporation of America at Marshalls, Cal.

Edwin Mraz is now engineer with the Electrical Research Laboratories, Inc., of Chicago. Mr. Mraz was formerly chief engineer of the Greene, Brown Mfg. Co.

G. Edwin Stewart has recently become associated with the Paramount Famous Lasky Corporation of New York City as chief recording engineer, having resigned his position as maintenance engineer with the National Broadcasting Company of New York.

C. L. Walker is now inspection engineer in the Radio Engineering Department of the American Bosch Magneto Corporation at Springfield, Mass.

H. F. Wareing, late instructor in radio with the University of Wisconsin, has recently become associated with the Universal Wireless Communication Company, Inc. in the position of engineer in charge of the Transmission Laboratory at Chicago.

J. H. Pressley, formerly a radio engineer with the Hazeltine Corporation of Hoboken, is now chief engineer of the U. S. Radio and Television Corporation at Marion, Ind.

Hollis S. Baird, until recently consulting engineer for the Automatic Radio Company of Boston, Mass., is now associated with the Short-Wave and Television Laboratory of Boston as chief engineer.

J. S. Douglas has recently become proprietor of the Peerless Radio Shop of Chicago.

Russell A. Cline has recently assumed connection with the Bell Telephone Company of Canada as assistant transmission engineer, Central Plant Department. Mr. Cline formerly was engaged as consulting engineer for Radio Station CKCL of Toronto.

Pierre Boucheron, until recently advertising and publicity manager of the Radio Corporation of America of New York City, is now sales manager of the Southern District of that organization at Atlanta, Ga.

Lyman T. Newell is now associated with the Airways Division of the Bureau of Lighthouses at Station WWX. Mr. Newell was formerly employed by the Radio Corporation of America as operator.

Paul R. Nachemson has recently become laboratory supervisor for the Brooklyn Radio Service Corporation, having left the Eagle Radio Company of Brooklyn where he formerly was employed as engineer.

Elmer B. Lyford was for some time an engineer with the Electrical Testing Laboratories of New York City and is now recording engineer with the RCA Photophone, Inc., of New York.

A. R. Hopkins, until recently associated with the Radio Laboratory of the Day Fan Electric Co. of Dayton, Ohio, is now in the employ of the Radio Corporation of America as radio engineer in the Technical and Test Department.

Oliver Wright, until recently a student at the University of Arizona, is now a technical employee of the American Telephone and Telegraph Company at its Lawrenceville, N. J. radio station.

GEOGRAPHICAL LOCATION OF MEMBERS ELECTED APRIL 3, 1929

Elected to the Associate grade

California	Los Angeles, 5308 Third Ave.	Howe, Franklin Joachino
	Los Angeles, 521 Amethyst St.	Oodrys, Arthur
	Palo Alto, Federal Telegraph Co.	Shermund, Ralph C.
	San Jose, 1148 Lincoln Ave.	Saine, Harry
	Stanford University, Box 1331	Skinner, Clifton Ross
Connecticut	Bridgeport, 68 Mead St.	Tillman, John Elmer
	Kensington, P.O. Box 276	Edgerly, A. H., Jr.
Dist of Columbia	Washington, Radio Section, Bureau of Standards	Arnold, Prescott N.
	Washington, 1705 Bay St., S.E.	Bower, Ward E.
	Bellevue, Naval Research Laboratory	Hyland, Lawrence A.
	Washington, 2301 Cathedral Ave., N.W.	Jackson, William E.
	Washington, 900 F St., N.W.	Kaplan, Jacob
	Washington, 2618-13th St. N.W.	Moulton, Theodore S.
	Washington, The Chastleton, 1701 16th St. N.W.	Newton, Jane Elizabeth
Illinois	Chicago, 5054 Agatite Ave.	Buesman, Robert Marshall
	Chicago, 6716 Parnell Ave.	Cubert, Joseph R.
	Chicago, 411 S. Ashland Blvd.	Kempf, Frank J.
	Chicago, 3250 North Crawford Ave.	Kincaid, Owen D.
	Chicago, 501 North Central Ave.	Knutson, Ben M.
	Chicago, 1706 N. Mayfield Ave.	Lamb, Harold A.
	Chicago, 3823 S. Kedzie Ave.	Patterson, Joseph A.
	Chicago, 3621 E. 107th St.	Siovic, John E.
	Chicago, 7728 Calumet Ave.	Van Sickel, R. E.
	Litchfield, Box 214	Hopper, C. L.
Indiana	Evansville, 112 Jackson Ave.	Norwood, Vandle Clarence
Iowa	Des Moines, 1538-31st St.	Hutchison, Sam T.
Kansas	Pittsburg, Pittsburg Radio Service	Forman, H. W., Jr.
Louisiana	New Orleans, 2625 Jefferson Ave.	Goldstein, Henry R.
Maine	Yarmouth, Greeley Road	Tamminen, Nestor
Massachusetts	Belmont, 98 Payson Road	Anthony, A. W., Jr.
	Boston, 472 Massachusetts Ave.	Nunez, F. J.
	Boston, Custom House, c/o Supervisor of Radio	Weston, Irving L.
	Cambridge, 22 Bigelow St.	Battison, Wallace A.
	Cambridge, General Radio Co., 30 State St.	Thiessen, Arthur E.
	Chatham, c/o Radio Corporation of America	Thing, K.
	North Attleboro, 9 Elm St.	Hale, Willis L.
	Revere, 62 Malden St.	Fletcher, Frederick R.
	Salem, 28½ Grove St.	Heffernan, S. K.
	Springfield, 62 Kimberly Ave.	Ferguson, George Well
	Stockbridge, Box 982	Harrington, George N.
Michigan	Alpena, 111 Tawas St.	Snyder, Leslie T.
	Ann Arbor, 1030 Church St.	Mathison, Gerald
	Detroit, 3028 Lothrop Ave.	Woehr, William
Minnesota	Minneapolis, 1521 University Ave., S.E.	Reed, Harry F.
Missouri	Bucklin	Holmlund, A. Earle
	Mendota, R.F.D.	Davis, Glen A.
	St. Louis, 4047 W. Pine St.	Humphreys, Irl W.
Nebraska	Falls City, 1801 Morton St.	Chesley, Arthur D.
New Hampshire	Claremont, 227 Main St.	Hodge, V. W.
New Jersey	Bloomfield, 25 Grace St.	Henry, T. J.
	Camden, 303 North 6th St.	Galvin, Robert
	Clayton, 326 Broad St.	Purvis, Charles G.
	Deal, Box 122	Shaw, Robert C.
	Glen Ridge, 129 Midland Ave.	Grabo, Irving C.
	Linden, 104 Luttgen Place	Angle, Gafford Brock
	New Brunswick, R.C.A. Radio Station	Bohman, Victor A.
	New Brunswick, 149 Hale St.	Lucas, Earle F.
	Stanhope, Box 261	Peterson, Arthur C.
New York	Astoria, L.I., 14-34 Grand Ave.	Ractliffe, Charles Lione
	Brooklyn, 392 Sackman St.	Berner, Aaron
	Brooklyn, 1121 Bedford Ave.	Dean, Leon W.
	Brooklyn, 506 Amboy St.	Epstein Reuben
	Brooklyn, 421 Chester St.	Haynes, Nat
	Brooklyn, 1300 New York Ave.	Herdman, Raymond C.
	Brooklyn, 1257 New York Ave.	Hesse, Henry Richard
	Brooklyn, 1859-62nd St.	Sass, Isidore
	Brooklyn, 55 Johnson St.	Skinker, Murray F.
	Buffalo, 191 Franklin St.	Bandetson, Harry
	Greenport, 829 Main St.	Larsen, Carl L.
	Jamestown, 72 Campbell Ave.	Beaumont, William Frederick
	New York City, 1050 Park Ave.	Cohn, Ralph I.
	New York City, 617 West 141st St.	Kahn, Morton B.
	New York City, 760 West End Ave.	Littman, Leon
	New York City, 160 West 100th St.	Lopez, Melchor, Jr.

New York (con't)	New York City, 2740 Marion Ave., Bronx	Myers, Theobald
	New York City, 500 Riverside Drive	Sicari, Domenic
	New York City, 404 Riverside Drive	Turner, Eugene T., Jr.
	New York City, 781 East 182nd St., Bronx	Wheeler, George D.
	Richmond Hill, 8512 110th St.	Hudtwalker, William Theodore
	Riverhead, P.O. Box 982	Trevor, Bertram
	Rochester, 55 Hortense St.	Dwyer, Vincent J.
	Rochester, 207 Ave. C.	Wiebach, William T.
	Rocky Point, c/o R.C.A.	Goldstine, Hallan E.
	Schenectady, 105 Seward Place	Clarke, Varro J.
	Schenectady, 422 Y.M.C.A. Bldg.	Lynn, L. H.
	Schenectady, 842 Union St.	Orr, Robert W.
	Whitestone, L. I.	Summers, Llewelyn L. B.
Ohio	Akron, 160 Fir St.	Ehrisman, Henry O.
	Ashtabula, R.D. No. 2	Andrus, Roy E.
	Cincinnati, 1212 Sassafras St.	Verkeley, B. M.
	Cincinnati, 3484 Vine St.	Wells, Martin M.
	Columbus, 34–18th Ave.	Auckerman, U. H.
	Columbus, Ohio State University, E.E. Dept.	Roetken, A. Allen
	Dayton, 43 Victor Ave.	Franzwa, Frederick J.
	Gambier, Kenyon College	Cottrell, Casper L.
	Lakewood, 2028 Waterbury Road	Hood, William A.
	Marion, 360 Silver St.	Ackerman, Francis R.
	Niles, 424 Allison St.	De Cola, Rinaldo
	Youngstown, 3630 Market St.	Pennock, P. L.
Oklahoma	Norman, 132 Page St.	Moffett, Le Roy, Jr.
	Oklahoma City, 1624 East Park Place	Pata, Yaromir J.
	Tulsa, Radio Station KVOO	Golder, Frank E.
Oregon	Portland, 605 Marguerite Ave. N.	Trumbull, A. F.
Pennsylvania	Allentown, 531 N. 7th St.	McGee, Michael J.
	Easton, 528 Centre St.	Messinger, Reuben R.
	Lancaster, 36 S. Lime St.	Russell, Walter L.
	Narberth, 403 N. Narberth Ave.	Bates, Clifford W.
	Philadelphia, 2030 E. Hazard St.	Martino, Alphonso E.
	South Tamaqua	Delp, Paul L.
	Upper Darby, 297 Springton Road	Lewis, Oliver I.
	Wilkinsburg, 901 South Ave.	Armstrong, Ralph W.
Rhode Island	Providence, 160 Cypress St.	Adams, Raymond R.
Tennessee	Memphis, 1961 Harbert St.	Brooks, Maurice W.
Texas	Dallas, 2603 Madera St.	Bennett, Porter T.
	Dallas, 1205½ Elm St.	Godard, L. G.
	Dallas, 5004 Goodwin Ave.	Melroy, Harry C.
	Fort Worth, 907 W. T. Waggoner Bldg.	Zeidlik, William J.
	Moody	McCauley, E. Ray, Jr.
Virginia	Alexandria, Box 107 R4	Meyers, Paul F.
	Marion	Cummings, G. N.
Washington	Seattle, 1833-13th Ave.	McAvoy, Edward J.
Wisconsin	Menasha, 526 Keyes St.	Peerenboom, Cyril A.
	Sheboygan, 922 Clara Ave.	Flentje, Le Roy G.
	Stoughton, 313 S. Academy St.	Turner, Russel S.
	Wausau, 108 Grand Ave.	Krueger, Otto J.
Canada	Montreal, Que., Northern Electric Co., Ltd., Keefer Bldg.	Cash, J. Allen
	Montreal, Que., 89 Laurier Ave. E.	Minorc, J. L.
	Montreal, Que., 4581 Sherbrook St. W.	Wilcox, B. B.
	St. Hyacinthe, Que., 7 Bourassa St.	Chagnon, Adolphe
Denmark	Copenhagen, Kastelsvej No. 3	Bertzow, Johannes Andreas
England	Chelmsford, Essex, 26 Queen's Road	O'Neill, R. F.
	Leigh-on-Sea, Essex, 106 Western Road	Richardson, F. C.
	London, N.W.6, 42 Fairhazel Gardens, Hampstead	Erdman, H.
	London, SW5. 12 Trebovir Road	Megaw, E.
	Parkstone, Dorset, St. Nicholas Castledene Road	White, John Walter
Holland	2 Dedelstraat den Haag	Bartelink, E. H. B.
Japan	Kumamoto, Kumamoto Broadcasting Station JOGK	Hirose, M.
	Kumamoto, Kumamoto Broadcasting Station	Morita, Kazuyoshi
	Tokyo, Teinshin-kanri-renshusho siba Park	Tei, Sasaki
	Kumamoto, c/o Shimizu-Hosojo	Kanayama, Toyosaku

Elected to the Junior Grade

California	Oakland, 627 Poirier St.	Ford, Charles Y.
Dist. of Columbia	Washington, Loomis Radio College	Carlson, O. D.
Illinois	Lake Forest, 1199 Edgewood Road	Baker, James Maurice
Indiana	Valparaiso, 405 E. Monroe St.	Ratts, Bruce H.
Iowa	Iowa City, c/o Kappa Eta Kappa, 728 Bowery St.	Stauffer, Ray Everett
Kansas	Manhattan, 413 N. 17th St.	Kipp, Aaron
Michigan	Battle Creek, 245 Lake Ave.	Fay, Lewis C.
Montana	Bozeman, 201 South Third	Pelton, George A.
New York	Brooklyn, 886 Putnam Ave.	Osterland, Edmund
	Brooklyn, 24 Bay 31 St.	Weinberg, Sidney
Ohio	Columbus, 75 West 10th Ave.	Conrad, Willard Oliver
Oklahoma	Stilwell	Neeley, Carl E.
Pennsylvania	Philadelphia, 653 North 10th St.	Huttenloch, Robert M.
Canada	Toronto, Ont., 10 Kew Beach Ave.	Hamox, Harold
England	Gloucester, 48 Weston Road	Carlyon, C.

Proceedings of the Institute of Radio Engineers
Volume 17, Number 5 *May, 1929*

APPLICATIONS FOR MEMBERSHIP

Applications for election to the various grades of membership have been received from the persons listed below, and have been approved by the Committee on Admissions. Members objecting to election of any of these applicants should communicate with the Secretary on or before June 1, 1929. These applicants will be considered by the Board of Direction at its June 5th meeting.

For Transfer to the Member grade

Dist. of Columbia	Washington, Federal Radio Comm.	Butman, Carl H.
	Washington, 1018 Douglas St., N. E.	Young, Leo C.
New Jersey	Newark, Brandes Products Corp., 200 Mt. Pleasant Ave.	Gerns, Wm. H.

For Election to the Member grade

Dist. of Columbia	Washington, 1821 Rigga Place, N. W.	Schrenk, M. H.
New York	New York City, c/o Imperial Japanese Navy, Inspectors Office, 1 Madison Ave.	Nakamura, T.
Czechoslovakia	Prague 11, u Karlovu 5,	Zacek, August
England	Cambridge, Sidney Sussex College	Ratcliffe, J. A.
Germany	Berlin-Wilmersdorf. Guntzelstr. Berlin	Watanabe, Yasusi

For Electoin to the Associate grade

Alabama	Mobile, c/o Adams Glass Co., Inc. 17–19–21 So. Royal	Heyen, Rudolph J.
California	Hollywood, 1123 Poinsettia Drive	Signer, John J.
	Inglewood, 826 65th St.	Green, Charles M.
	Los Angeles, 4846 Rosewood Avenue	Cooper, George R.
	Los Angeles, 1601 So. Hope St.	Holcomb, E. Russell
	Los Angeles, Western Air Express Inc., 117 W. 9th St.	Hoover, Herbert, Jr.
	Los Angeles, 316 N. Reno St.	Ludlum, William T.
	Los Angeles, 921 W. 6th St.	McGonagil, H. A.
	Los Angeles, 2812 So. Main	Meyer, R. H.
	Los Angeles, 1609 Hipoint St.	Walter, Edward F.
	San Francisco, 1266 McAllister St. Apt. 8	Slavin, Samuel B.
	San Francisco, 715 Bush Street	Stanton, James M.
Connecticut	Hartford, 235 Collins St.	Heris, George
	Hazardville, South St.	Thompson, Stanley W.
Dist. of Columbia	Bellevue, U. S. N. Lab.	Wortman, E. C.
	Washington, 5013 8th St., N. W.	Seiler, Donald W.
	Washington, 1860 Clydesdale Place, N. W.	Struthers, Francis William
	Washington, c/o Federal Radio Comm.	Webster, Betheul M., Jr.
Illinois	Chicago, 4736 N. Racine Ave.	Alexander, Wayne
	Chicago, 1820 North Wells St.	Arnold, Lowell George
	Chicago, 2837 South St. Louis Ave.	Koutnik, J. A.
	Chicago, 5115 S. Winchester Ave.	Pletka, James
	Chicago, 5409 Agatite Ave.	Ramm, Carl H.
	Chicago, 312 N. Central Ave.	Walter, Wilbur Tayman
	Evergreen, 9343 Richmond Ave.	Randall, Lemuel E.
Indiana	Fort Wayne, 2925 Bowser Avenue	Ramm, Harold William
	Valparaiso, Stiles Hotel	Hayes, Arthur J.
	Valparaiso, 405 South Monroe St.	Munroe, A. D.
	Valparaiso, 505 E. Jefferson St.	Olinger, Robert
Iowa	Wapello, 312 Franklin Ave.	Fry, Lloyd L.
Massachusetts	Attleboro, Park Hotel	Bargamian, John
	Boston, Tropical Radio Tel. Co., 1 Federal St.	Kelly, Michael F.
	Cambridge, Stoughton Hall 14	Hazard, Willis Gilpin
	Jamaica Plain, Wireless Specialty Apparatus Co.	Blodgett, Edward D.
	Lynn, 87 Myrtle St.	Mayo, Royal E.
	Roxbury, 130 Marcella St.	Stone, Elmer F.
	Springfield, Am. Bosch Mag. Corp.	Benner, Howard J.
	Springfield, Am. Bosch Mag. Corp.	Bond, M. E.
	Springfield, Am. Bosch Mag. Corp.	Raskhodoff, Nicholas
	Winthrop, 23 Sagamore Ave.	Dalton, Robert E.
Michigan	Jackson, 306 Steward Ave.	Stoll, Paul A.
Mississippi	Jackson, 944 West Capitol St.	Meyers, James A., Jr.
Missouri	Independence, 819 W. Van Horn Road	Dennis, Ralph M.
	Independence, 813 No. River Road	Edwards, Harold C.
	Independence, 630 Crysler St.	Johnston, Ivan F.
	Kansas City, 702 Shukert Bldg.	Blum, Sidney J.
	Kansas City, 1004 Davidson Bldg. 17th & Main	Clements, Thos. C.
	Kansas City, 1827 Norton	Haase, Edwin John
	Kansas City, 2112 Aberdeen Court	Hodge, Albert William
	Kansas City, 2722 Brighton Ave.	Kiefer, Harry Dukes
	Kansas City, 2503 Harrison St.	McCormick, Benjamin S.
	Kansas City, 4511 E. 23 St.	Payne, Harry Kenneth
	Kansas City, 2004 Prospect	Watter, George V.
	Kansas City, 3614 Brooklyn Ave.	Upham, Stuart W.
	Kansas City, 4012 Michigan St.	Vogel, Henry W.
	Kansas City, 1110 West 41st St.	Walters ,Wm. J

Montana	Froid	Jacobs, Marcellus L.
New Jersey	Camden, 315 N. 27 St.	Sumner, Raymond Stokes
	East Orange, 137 Halsted St.	Feindel, Abbott
New York	Brooklyn, 253 Cumberland St.	Bower, James
	Brooklyn, 616 Bainbridge St.	Rehbein, Arthur Frederick
	Brooklyn, 1715 West 13 St.	Romeo, Anthony
	Flushing, 19 Smart Ave.	Sage, Frederic H.
	Jackson Heights, L. I. 125 22nd St.	Hickman, C. Nicholas
	New York City, 89 Cortlandt St.	Blan, Michael
	New York City, 2040 7th Ave.	Cass, Lewis S.
	New York City, 1010 First Ave.	Haug, Joseph
	New York City, c/o R.C.A. Van Cortlandt Park So.	Krueger, Barton
	New York City, 117 E. 24th St.	Kunc, Frank
	New York City, R.C.A. 70 Van Cortlandt Park So.	Malter, Louis
	New York City, Bell Tel. Labs., 463 West. St.	Morrison, Howard
	New York City, 894 Riverside Drive	Rathner, Jack
	New York City, 64 East 103 St.	Rifkin, J. L.
	New York City, c/o General Delivery	Svendsen, A. V.
	New York City, 1820 Bryant Ave. Bronx	Trapkin, Jack H.
	Ozone Park, L. I.	Misenheimer, Rob't G.
	Rochester, 145 So. Fitzhugh St.	Foster, Charles W.
	Rockville Centre, 259 Raymond Ave.	Lester, Paul Sabine
	Southampton, Box 269	Buckingham, Wm. D.
	Woodhaven, 7424 87th Ave.	Cooper, Gustavus
North Carolina	Ashville, Battery Co.	Sorelle, J. L.
Ohio	Cincinnati, 2042 Baltimore Ave.	Fisher, Ellwood T.
	Columbus, 28 W. Longview Ave.	Graham, J. P.
Oklahoma	Tulsa, 114 West Third St.	Pitcher, J. W.
	Tulsa, 627 Main St. S.	Wise, James Orr
	Tulsa, Willard Hotel	Robinson, L. L.
Pennsylvania	Allentown, 1801 Liberty St.	Kurtz, Clyde R.
	Bethlehem, B-Taylor Hall	Farnsworth, Daniel W.
	Chambersburg, Box 139	Ramsey, R. W.
	Clearfield, 326 Locust St.	Moyer, Elmo Emerson
	Easton, 1852 Freemansburg Ave.	Fox, Paul S.
	Philadelphia, 843 E. Price St	Benge, J. R.
	Philadelphia, 457 No. 12th St.	Mousley, Franklin
	Philadelphia, 5205 Akron St.	Travis, Charles
	Pittsburgh, 5866 Burchfield Ave.	Schlesinger, Louis B.
	Pottstown, 53 N. Charlotte St.	Roeller, Henry S.
Rhode Island	Providence, 663 Academy Ave.	Thomas, Harold
Utah	Spanish Fork	Fullmer, Don A.
Virginia	Roda, Box 42	Brien, William J.
Washington	Seattle, 113 E. 55th St.	Fitzpatrick, George Wm.
	Seattle, 503 Melrose Ave. No.	Hemrich, Walter A.
Japan	Kawasaki, c/o The Tokyo Elec. Co.,	Kuno, T.
	Kawasaki, c/o The Tokyo Elec. Co.	Kuwajima, T.
	Kawasaki, c/o The Tokyo Elec. Co.	Matsui, K.
	Kawasaki, c/o The Tokyo Elec. Co.	Miyauchi, T.
	Kawasaki, c/o The Tokyo Elec. Co.	Ohtani, S.
	Kawasaki, c/o The Tokyo Elec. Co.	Otsuka, Y.
	Kawasaki, c/o The Tokyo Elec. Co.	So, Manabu
	Kawasaki, c/o The Tokyo Elec. Co.	Suga, Y.
	Kawasaki, c/o The Tokyo Elec. Co.	Suzuki, Hisao
	Sendai City, Harano-machi, Sending Station of JOHK, Sendai Broadcasting Station	Kanno, Gengo
	Tokyo, c/o Tokyo Central Broadcasting Station Atagoyamam	Fukushima, T.
	Near Tokyo, 1244 Hirahari, Magomemachi	Hamada, Shigenori
	Tokyo, c/o Tokyo Central Broadcasting Station, Atagoyamam	Koshikawa, Y.
	Tokyo, 59, Hitotsugicho, Akasakaku	Mita, S.
	Tokyo, c/o M. Kaneko, 2, 5-Chome, Kirakawa-Cho, Kojimachiku	Nagao, R.
	Tokyo, c/o Kaigun Kantokukan-Jimusho, 3, 1 Chome Uchisaiwai-cho, Kojimachiku	Nakajima, S.
South Africa	Tongaat, Natal.	Howard, W. B.
South Australia	Eleanor Terrace, Murray Bridge	Miller, Francis G.
New Zealand	G. P. O. Box 188, Wellington	Russell-Boyle, H.

For Election to the Junior grade

Arkansas	Little Rock, 723 Wright Ave.	Stover, Arthur R., Jr.
Florida	Avon Park	Collins, Florine
Georgia	Atlanta, 933 Oak St.	Harrison, Richard H.
	Commerce	Hood, Sam
Illinois	Carpenter, Box 272	Bennett, Leslie W.
	Waukegan, 653 Mill Court	Herrmann, Albert Jr.
Indiana	Connersville, 1948 Indiana Ave.	Hamilton, Charles Ed.
	Valparaiso, 557 So. Locust St.	Cox, Hestor S.
	Valparaiso, 155 College Ave.	Johnson, Julien S.
	Valparaiso, 502 East Jefferson	Mealy, Max B.
	Valparaiso, 155 College Ave.	Reid, Herbert G.
Maryland	Baltimore, 2449 Lauretta Ave.	Ridenour, Wm. S.

Massachusetts	Boston, 570 Columbus Ave.	Hatten, Arthur Thomas
	Dorchester, 894 Blue Hill Ave.	Berkowitz, Louis
Michigan	Harbor Springs	Wright, Wilford C.
	Jackson, 302 Biddle St., E.	Atkins, Carl Edward
New Jersey	Elizabeth, 419 Livingston St.	Engel, Albert L.
	Paterson, 489 Main St.	Trifari, Edmund
	Pleasantville, 1507 S. Main St.	English, James G.
New York	Brooklyn, 1121 Bedford Ave.	Gray, De Wayne R.
	Brooklyn, 1272 E. 10th St.	Charlat, Arnold
Ohio	Cleveland, 2915 E. 130th St. No. 10	Goetz, V. Wm.
	Cleveland, 2088 Cornell Road	Hybarger, H. Kenneth
	Payne	Huhuenin, Glenda
Oklahoma	Tulsa, KVOO	White, Karl K.
Pennsylvania	Allentown, 618 N. 12th St.	Richardson, George A.
	Cynwyd, 407 State Road	March, Hallman W.
	Easton, 17 So. 6th St.	Deutschman, Berah
Washington	Seattle, 7811 Stroud Ave.	Thomson, Howard M.
Federated Malay States	271 Kota Road Taiping	Sinh, Harbaksh
Hawaii	Honolulu, E. 1518 Liliha St.	Hisamoto, Masayuki

OFFICERS AND BOARD OF DIRECTION, 1929

(Terms expire January 1, 1930, except as otherwise noted)

President

A. Hoyt Taylor

Vice-President

Alexander Meissner

Treasurer

Melville Eastham

Secretary

John M. Clayton

Editor

Walter G. Cady

Managers

R. A. Heising
J. V. L. Hogan
L. M. Hull
R. H. Marriott
L. E. Whittemore
J. H. Dellinger
(Serving until Jan. 1, 1931)
R. H. Manson
(Serving until Jan. 1, 1931)
Arthur Batcheller
(Serving until Jan. 1, 1932)
C. M. Jansky, Jr.
(Serving until Jan. 1, 1932)

Junior Past Presidents

Ralph Bown
Alfred N. Goldsmith

Board of Editors. 1929

Walter G. Cady, *Chairman*

Stuart Ballantine
Ralph Batcher
Carl Dreher
G. W. Pickard
L. E. Whittemore
W. Wilson

Committees of the Institute of Radio Engineers, 1929

Committee on Meetings and Papers

K. S. Van Dyke, *Chairman*
Wilson Aull
W. R. G. Baker
Stuart Ballantine
R. R. Batcher
M. C. Batsel
Zeh Bouck
Ralph Bown
H. H. Buttner
W. G. Cady
L. M. Clement
E. T. Dickey
Carl Dreher
Edgar Felix
V. M. Graham
O. B. Hanson
L. C. F. Horle
J. W. Horton
L. M. Hull
S. M. Kintner
S. S. Kirby
F. H. Kroger
D. G. Little
Wm. H. Murphy
E. L. Nelson
H. F. Olson
G. W. Pickard
R. H. Ranger
B. E. Shackelford
N. H. Slaughter
H. M. Turner
Paul T. Weeks
Julius Weinberger
Harold A. Wheeler
L. P. Wheeler
W. C. White
L. E. Whittemore
W. Wilson
R. M. Wise
Irving Wolff

All chairmen of Meetings and Papers Committees of Institute sections, *ex officio.*

Committee on Admissions

R. A. Heising, *Chairman*
Arthur Batcheller
H. F. Dart
C. P. Edwards
C. M. Jansky, Jr.
F. H. Kroger
A. G. Lee
George Lewis
Alexander Meissner
E. R. Shute
J. S. Smith
A. F. Van Dyck
All chairmen of Institute sections, *ex officio.*

Committee on Awards

Melville Eastham, *Chairman*
L. W. Austin
Ralph Bown
W. G. Cady
A. Hoyt Taylor

Committee on Broadcasting

L. M. Hull, *Chairman*
Arthur Batcheller
Carl Dreher
Paul A. Greene
J. V. L. Hogan
C. W. Horn
R. H. Marriott
E. L. Nelson

Committee on Constitution and Laws

R. H. Marriott, *Chairman*
Ralph Bown
E. N. Curtis
W. G. H. Finch
H. E. Hallborg
J. V. L. Hogan
G. W. Pickard
Harold Zeamans

Committee on Membership

I. S. Coggeshall, *Chairman*
F. R. Brick
W. W. Brown
H. B. Coxhead
H. C. Gawler
R. S. Kruse
Pendleton E. Lehde
H. P. Maxim
S. R. Montcalm
A. F. Murray
M. E. Packman
J. E. Smith
John C. Stroebel, Jr.
All secretaries of Institute sections, *ex officio.*

Committee on Nominations

Melville Eastham, *Chairman*
Alfred N. Goldsmith
Donald McNicol
R. H. Manson
G. W. Pickard

Committee on Publicity

W. G. H. Finch, *Chairman*
H. W. Baukat
Zeh Bouck
C. E. Butterfield
Orrin E. Dunlap
Fred Ehlert
A. H. Halloran
R. D. Heinl
Lloyd Jacquet
Arthur H. Lynch
J. F. J. Maher
A. H. Morse
U. B. Ross
J. G. Uzmann
Willis K. Wing

Committee on Institute Sections

E. R. Shute, *Chairman*
Austin Bailey
M. Berger
L. A. Briggs
F. E. Eldredge
D. H. Gage
A. F. Murray
B. E. Shackelford
All chairmen of Institute sections, *ex officio.*

Committee on Standardization

J. H. Dellinger, *Chairman*
M. C. Batsel
W. R. Blair
C. E. Brigham
E. L. Chaffee
T. A. M. Craven
T. McL. Davis
E. T. Dickey
H. W. Dreyer
C. P. Edwards
S. W. Edwards
General Ferrie
Alfred N. Goldsmith
O. B. Hanson
J. V. L. Hogan
W. E. Holland
C. B. Jolliffe
R. S. Kruse
George Lewis
R. H. Manson
Alexander Meissner
C. B. Mirick
Gino Montefinale
E. L. Nelson
L. G. Pacent
Haraden Pratt
H. B. Richmond
C. E. Rickard
A. F. Rose
H M. Turner
K. B. Warner
C. E. Williams
Hidetsugu Yagi

Part II

TECHNICAL PAPERS

Proceedings of the Institute of Radio Engineers
Volume 17, Number 5 *May, 1929*

DOUBLE AND MULTIPLE SIGNALS WITH SHORT WAVES*

By

E. Quäck and H. Mögel

(Transradio, Berlin, Germany)

Summary—*Multiple signals have been observed in a frequency range of 20,000 to 16,667 kc, or 15 to 18 m, only when the great circle between transmitter and receiver passes through the twilight zone, in which conditions are especially favorable for these frequencies.*

The conditions for various positions of great circles are discussed in detail, and the expected times of occurrence of double signals are given and compared with those measured. As the greatest angle which the plane of the circle must form with the twilight plane at the most favorable time of day and year, in order to receive multiple signals, the value $\phi \leq 10$ deg. is assigned.

The propagation conditions in the twilight zone appear, at least for Berlin as receiving point, to be more favorable in the winter in the indirect sense, and in the summer in the direct. For reception from the west, this has been clearly confirmed for North and South America, while the direction of summer double signals from the east is not yet entirely determined. Next year, after the increase and improvement of transmitters, the observation of the lines favorable for double signals from Osaka, Mukden, and Manila will be possible.

Indirect double signals also appear in the range of 25,000 to 13,636 kc (12 to 22 m), outside of the twilight zone, when the indirect night path is in summer. Under these circumstances the same condition of the atmosphere prevails at night as in the daytime, perhaps even the same as at twilight.

Lower frequencies, between 12,000 and 6,667 kc (25 and 45 m) can also pass along the indirect path at night, when the solar radiation on the illuminated portion is not so intense. The amplitude received on the direct path is at this time just on the border of audibility.

An example cited from Baires shows that the indirect double signals can be supported or even amplified by reverse radiation from the transmitter.

The frequency ranges are given, in which the various double signals occur. Double signals have been found thus far between 25,000 and 6,667 kc (12 and 45 m).

The time intervals between main and double signals and between multiple signals themselves were obtained experimentally and by calculation, on the assumption that the velocity was the same as that of light in free space. It was found in all cases that the path was about 3.5 per cent longer than the actual distance over the surface of the earth. Observations extending over two years show within the limits of error no such variations in time intervals as those indicated in the results of Taylor and Young. Variations in time intervals between main and double signals could always be traced to an irregular beginning and cessation of the signal due to faulty keying.

Methods are indicated for screening off the indirect double signals by suitable antenna apparatus at the receiving end.

With the appearance of magnetic disturbances the double signals disappear more

* Dewey decimal classification: R113. Original manuscript received by the Institute, November 14, 1928. Translation received, January 11, 1929.

completely the more the earth's field is disturbed and the more the angle between the direction of the earth's field and the transmission direction approaches a right angle.

A graphic representation is shown of amplitudes received from New York as a function of time of day and year, giving the amplitudes of double signals in per cent of the main signals; these results are published in somewhat different form, for the main lines of Transradio.[1]

The various great circles are shown graphically with data concerning the distribution of day, twilight, and night as a function of the time of year. The great circles Berlin-Rio-Mukden and Berlin-New York are indicated for January 1 and July 1. One can see at a glance the illumination of the direct and indirect paths, and can gain an idea of the possibility of communication, and particularly can determine in advance the times for double signals.

Regarding the work of A. H. Taylor and L. C. Young we should like to point out that we recently succeeded in ascertaining incontestably the existence of so-called short range echoes, which are discussed in the following supplement.

1. Introduction

SUPPLEMENTING previous publications concerning the occurrence of double and multiple signals on short waves,[2] there are presented here additional observations and a summary of the results to the present time.

All observations were made at the Geltow receiving station of the Transradio A.G. für drahtlosen Uebersee Verkehr. It must be mentioned that the routine receiving work prevented systematic experiments, so that the results to be reported were largely derived in the course of regular commercial operation. These are to serve as stimulation for further observations. In the meantime the interesting investigations of Taylor and Young[3] and of Eckersley[4] have been reported, the results of which will be discussed below.

The observation of double signals has, of course, a special value, since it undoubtedly extends our still meager positive knowledge concerning the transmission of short waves and the structure of the Heaviside layer. The observations made in Geltow and the results achieved can be considered as rather definite, since they extend over more than two years. Certain principles were set up at the very beginning, which have been further followed out, and have been so far very well confirmed. Nevertheless new phenomena are observed almost daily, the explanation of which will take time. Also as already

[1] *Elec. Nach. Tech.*

[2] E. Quäck, *Jahr.* 28, p. 177, 1926, and *Elek. Nach. Tech.*, 4, p. 74, 1927. See also *Jahr. der draht. Tel.*, 30, No. 2, p. 147, 1927. For an account of these papers in English see Stuart Ballantine: "Review of Current Literature," Proc. I. R. E., 15, 341; April, 1927, and 15, 1065; December, 1927.

[3] A. H. Taylor and L. C. Young: Proc. I. R. E., 16, 561; May, 1928.

[4] Eckersley: *Jour.* I. E. E., 1927, pp. 600–614.

mentioned, the commercial receiving and the experimentation cannot be easily combined.

A description of the experimental methods used will first be given.

2. Apparatus and Precision

For the analysis of low-frequency currents coming from the receiver the Siemens loop oscillograph with three loops is used, which conveniently permits the photographic recording of continuous phenomena. The holder takes a strip of sensitive paper five meters (15 ft.) long, and the speed of the paper can be regulated from about 2 cm per second to 2 m per second. Only loops having a natural frequency of 10,000 cycles are used, in order to exclude loop effects, etc., and in

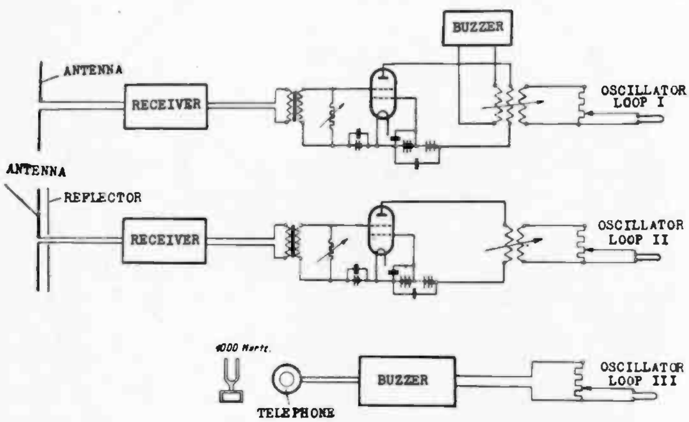


Fig. 1—Apparatus for recording of double signals (antenna, reflector, receiving set, audio generator, oscillograph loops).

order to record as exactly as possible the beginning of the signals or of oscillation groups of the order of 0.001 second. The requisite current of about 100 milliamperes for the loops is obtained by connection of one stage of low-frequency amplification with a Siemens OR tube. The amplitude of the loops can be varied by resistance and coupling.

For the determination of time a comparison frequency of 1000 cycles is also recorded, which is produced by a loosely coupled audio-frequency tube generator, which is occasionally tuned to a sonic fork. The precision of this arrangement (Fig. 1) is not required to be exceedingly high since other errors, amounting to 1 to 2 per cent, are present; for example, the beginning and cessation of signals often requires 1/1000 to 1/5000 sec., due to faulty keying. Since the quantities measured range from 1/10 to 1/30 sec. the precision is seldom greater than 1 per cent. Therefore, it is not possible with these means to detect and explain phenomena, the measured values of which lie within the order of magnitude of these errors.

3. Discussion of Oscillograms

First of all, a number of oscillograms of double and multiple signals will be shown, with the necessary explanations. Further discussion will follow in the succeeding sections.

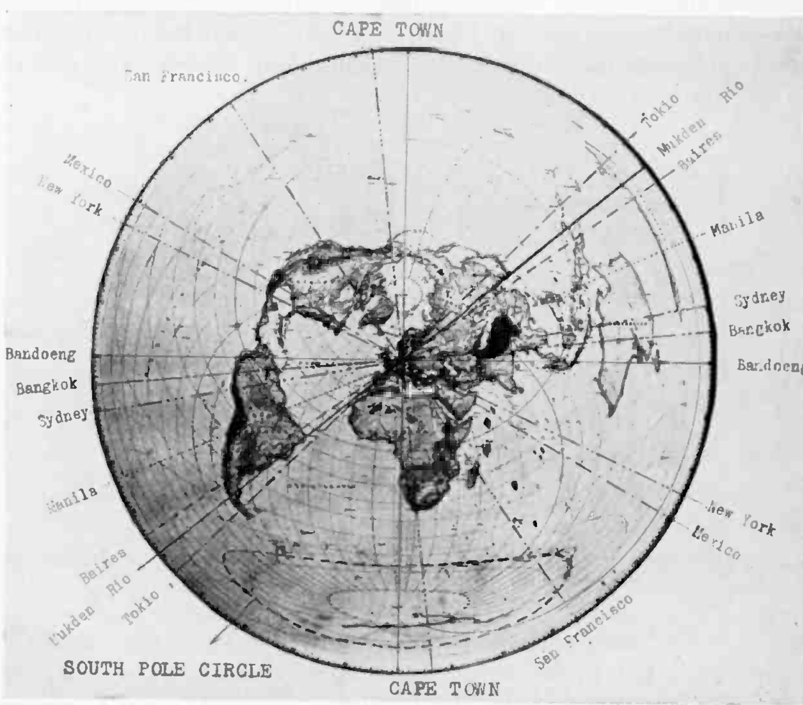


Fig. 2—Azimuthal projection of the earth, showing Geltow in the center as pole, the antipodal point being represented by the outer circle. The principal great circles appear as straight lines.

For the sake of clearer distinction we shall call those double and multiple signals which travel in the direction of the direct signal (that is, forward around the earth), "direct" double signals and "direct" multiple signals, respectively; those, however, which take the other course around the earth (that is, circulate in the reverse direction), "indirect" double signals and "indirect" multiple signals, respectively.

The photographs are arranged according to the various directions (Fig. 2), and are further subdivided with regard to direct and indirect double signals. The double signals belonging to one main signal are designated by the same letter; the direct multiple signals, which pass around the earth several times in the same direction, are designated by superscripts, e.g., a^1, a^2, a^3, while for the indirect signals subscripts are used, as a_1, a_2, etc. Any signal indicated by a letter without index or subscript passes by the shortest route between transmitter and receiver.

I. South America

As examples of direct double signals the following are presented. Direct double signals from the short-wave transmitters in Rio* and Baires* appear in spring between 9 and 10 P.M., Central European Time, C.E.T. Gradually they grow stronger, reaching their maximum on the longest day. The directions toward Rio and Baires deviate only a few degrees (about 5 deg.) from each other, as shown by the map (Fig. 2), so that both can be considered as practically similar.

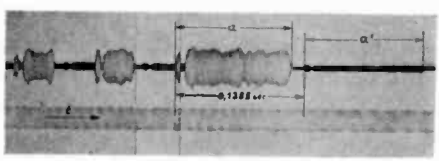


Fig. 3—Direct double signals from Rio, SPU (19,231 kc, or 15.6 m). April 11, 1928, 10:45 P.M., C.E.T. $\Delta t = 0.1385$ sec.

The record (Fig. 3) of April 11, 1928, shows weak double signals from station SPU ($f = 19{,}231$ kc, or $\lambda = 15.6$ m) in Rio; the difference in time, $\Delta t = 0.1385$ sec., corresponds to the earth's circumferenee. As a result of faulty keying a small insertion precedes every signal, which reappears exactly in the double signal and permits the difference in time to be determined more exactly than would otherwise be possible. The amplitude is very weak at this season, yet attains values of 30 per cent of the main signal. The following records, Figs. 4 and 5, of the same station SPU were made at about the time of the longest day, on June 26, 1927, about 9 P.M., C.E.T. At least five repetitions of the two short signals sent from Rio at an interval of about 1/25 second could be clearly traced here. In the upper record of Fig. 4, the signals a and b pass around the earth again in the same sense (a^1, b^1). In the lower exposure, Fig. 4, which was taken about $\frac{1}{3}$

* Editorial note: These terms, "Rio" and "Baires," presumably refer to Rio de Janeiro, Brazil, and Buenos Aires, Argentina, respectively.

second later, the signals pass completely around the earth a second time in the direct sense (e.g., b^1, b^2), in addition to which also weak, indirect, double signals (a_1, b_1) can be traced. The differences in time amount in the first case (direct) to 0.1385 second, in the second case (indirect) to 0.069 second. Fig. 5, which was photographed a few minutes later, contains, after a further time difference of 0.138 sec.,

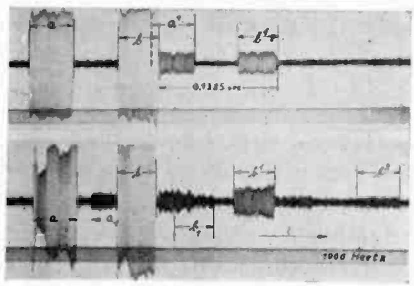


Fig. 4—Rio, SPU (19,231 kc, or 15.6 m), June 26, 1927, between 9 and 9:05 P.M., C.E.T. Triple signals b, b^1, b^2 in direct direction ($\Delta t = 0.1385$ sec.), and simple indirect signal b_1 ($\Delta t = 0.069$ sec.)

even a third weak direct signal, a^3, which accordingly has travelled over 130,000 km. The next oscillogram, Fig. 6, from station LP2 in Baires, shows direct double signals again with the normal difference in time $\Delta t = 0.138$ second. Fig. 7 shows a variation of the amplitude of station SPU taking place within $\frac{1}{4}$ second; this is of interest as showing that the fadings of the main and double signals bear no relation to each other.

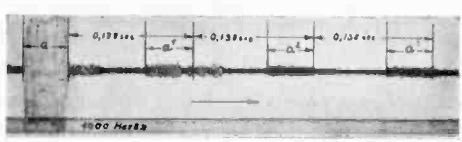


Fig. 5—Rio, SPU (19,231 kc, or 15.6 m), June 26, 1927, between 9 and 9:05 P.M., C.E.T. Four-fold direct signals (3 echoes). $\Delta t = 0.138$ sec.

There follow some pictures of indirect double signals. In the record, Fig. 8, from the Telefunken station LP3 in Baires, the main signals and indirect double signals overlap each other, so that the groups (Morse signals) appear longer than normal. The individual signals, which form the letter l (· — · ·), can, however, be easily read, while in the following picture, Fig. 9, from Rio SPU, this is no longer the case. The speed of sending is here so unfavorable that main and double signals merge completely. At any time, when both signals overlap, the amplitudes are added and can give the most varying pictures according to the amplitude and phase relations of main and double signals. The modulation of the transmitter must also be taken into consideration here.

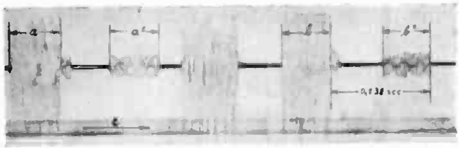


Fig. 6—Baires, LP2 (20,690 kc, or 14.5 m), May 20, 1928, 9:30 P.M., C.E.T. Direct double signal, $\Delta t = 0.138$ sec.

In Fig. 10, from the Baires station LP3, there appear besides the main signal a also two indirect double signals a_1 and a_2, a_1 with a time difference $\Delta t_1 = 0.056$ second after a and a_2 with $\Delta t_2 = 0.138$ second after a_1. In Figs. 11 and 12, a and b are simultaneous records from the

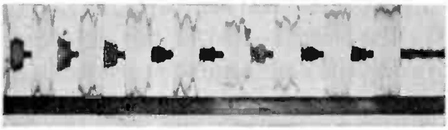


Fig. 7—Rio, SPU (19,231 kc, or 15.6 m), May 31, 1927, 9:33 P.M., C.E.T. Fading of direct double signals (F) within 1/4 sec.

Baires station LP3 ($f = 19{,}608$ kc, or $\lambda = 15.3$ m) and LP2 ($f = 20{,}690$ kc, or $\lambda = 14.5$ m) showing multiple indirect signals. In Fig. 11 (from LP3) the first indirect signal a_1 is stronger than the main signal a. Amplitude and phase happen to be such that the total amplitude

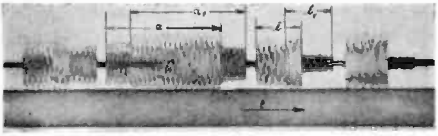


Fig. 8—Baires, LP3 (19,608 kc, or 15.3 m), Feb. 18, 1928, 12:20 P.M., C.E.T. Indirect double signal, $\Delta t = 0.056$ sec.

becomes greater during the overlapping of a and a_1. There appears also another signal a_2 which has passed around the earth again in the indirect sense with a time difference $\Delta t_2 = 0.138$ second with respect to a_1. On the same record (Fig. 11) in the case of LP2 the variation in the amplitudes of main and indirect signals within one second can be easily recognized. The same is the case in Fig. 11b, with LP3, where on the left side the main signal b has a much greater amplitude than the indirect double signal b_1, while on the right side the double signal c_1 is stronger than the main signal c. In Fig. 12b the main signal a and the indirect double signal a_1 from LP3 happen to have about the same amplitude, while the phase is shifted about 180 deg., so that the result-

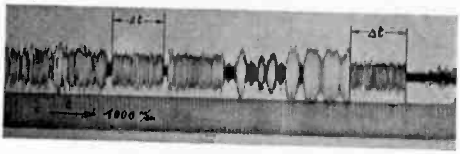


Fig. 9—Rio, SPU (19,231 kc, or 15.6 m), May 19, 1927, 3:45 P.M., C.E.T. Disturbance caused by indirect double signal. (Doppler effect.)

ing amplitude through overlapping becomes almost 0. There would accordingly seem to exist two separate groups of oscillations. The real length of the emitted signal is derived from the indirect round-the-world signal a_2, which with respect to a_1 has a time difference of $\Delta t_2 = 0.138$ sec. On the same record at the right below with LP2 the amplitude drops during the overlapping twice to 0, so that one receives the impression of beats or of a transmitter that is strongly modulated at about 20 cycles. (Perhaps Doppler effect). Furthermore, with LP2 there are no round-the-world signals to be found on this record.

II. North America

As a result of the rather unfavorable location of the great circle through New York (Rocky Point) and Berlin (Geltow) (see Sec. 4

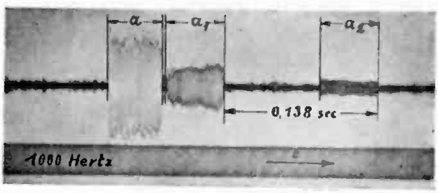


Fig. 10—Baires, LP3 (19,608 kc, or 15.3 m), Dec. 2, 1927, about 9.55 A.M., C.E.T. Indirect multiple signal. $\Delta t_1 = 0.056$ sec., $\Delta t_2 = 0.138$ sec.

and the map, Fig. 2) there appear here in general only double signals. Moreover, the times of occurrence of direct double signals are rather narrowly limited. Fig. 13 of July 13, 1928, 2 A.M., (C.E.T.), shows direct double signals of the North American station WTT ($f = 18{,}750$ kc, or $\lambda = 16$ m). In the upper record the double signals fall within the main signals; in the lower one they are separated from them. The double signals b_1 and c_1 have with respect to the main signals b and c a time-difference of 0.138 second. The disturbances happened to be very great here, so that the double signals stand out very indistinctly in the disturbed pattern.

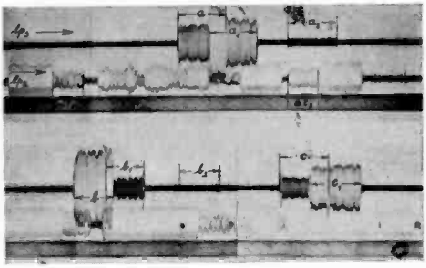


Fig. 11—Simultaneous records of Baires, LP3 (19,608 kc, or 15.3 m) and LP2 (14.5m) Oct. 27, 1927, 9.05 A.M., C.E.T. Indirect double signals. $\Delta t_1 = 0.056$ sec. $\Delta t_2 = 0.138$ sec.

There are next a few oscillograms of indirect double signals. Fig. 14, showing records of indirect double signals from station WTT ($f = 18{,}750$ kc, or $\lambda = 16$ m), was made on December 16, 1927, at 2:30 P.M. (C.E.T.), and gives a time difference of the double signal a_1 with respect to the main signal a of $\Delta t = 0.095$ second.

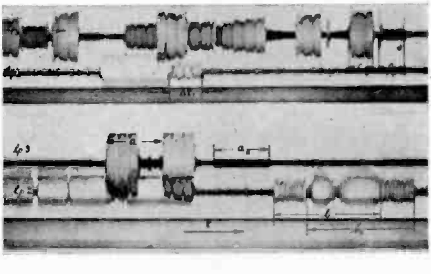


Fig. 12—Simultaneous records of Baires, LP3 (19,608 kc, or 15.3 m) and LP2 (20,690 kc, or 14.5 m) Oct. 27, 1927, 9.05 A.M., C.E.T. Indirect multiple signals. $\Delta t_1 = 0.056$ sec., $\Delta t_2 = 0.138$ sec. (On the right side perhaps Doppler effect.)

Fig. 15 contains indirect double signals of the station WTT, where in the lower picture b the double signals are somewhat weakened through the addition of a single reflecting system of wires. The time difference amounts in all cases to $\Delta t = 0.095$ sec. Similar oscillograms taken, however, simultaneously with and without screen arrangement, are shown in Fig. 16, station WLL, and Fig. 17, station 2XT, where the indirect double signals are eliminated sufficiently for practical purposes. Here two receivers were used with separate antennas, employing the same heterodyne circuit, in order to eliminate the disturbing influence of whistling. Fig. 18 gives another record from station 2XBC ($f=20{,}630$ kc, or $\lambda=14.54$ m) with indirect double signals which

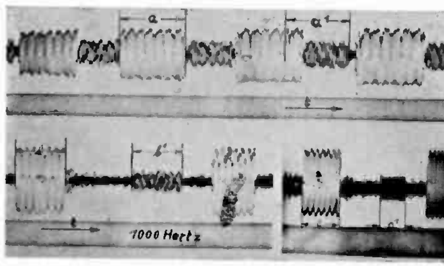


Fig. 13— Rocky point, WTT (18,750 kc, or 16 m), July 13, 1928, 2 A.M., C.E.T. Direct double signal, $\Delta t=0.138$ sec.

have the normal time difference of $\Delta t=0.095$ sec. with respect to the main signal.

III. China (Mukden)

So far only indirect multiple signals have been found from Mukden.

Fig. 19 contains two oscillograms from station XOM ($f=17{,}341$ kc, or $\lambda=17.3$ m) in Mukden, of November 3, 1927, 8:30 A.M. (C.E.T.). In the upper picture main and double signals, a and a_1, are equally large and result during overlapping in an approximately doubled

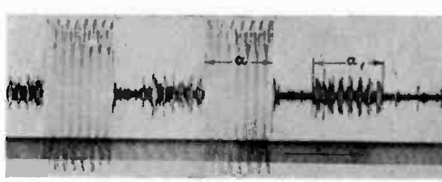


Fig. 14—Rocky Point, WTT (18,541 kc, or 16.18 m), Dec. 16, 1927, 2.30 P.M., C.E.T. Indirect double signal, $\Delta t=0.095$ sec.

amplitude. In the case of the lower signal b there is also to be distinguished a second indirect double signal b_2 with a time difference of $\Delta t_2=0.138$ sec. with respect to b_1. The indirect double signal b_1 has, with respect to the main signal b, a time difference of $\Delta t_1=0.086$ sec. The indirect double signals of Fig. 20 of the station XGA in Mukden ($f=15{,}000$ kc, or $\lambda=20$ m) are, in contrast to the previous picture, separated from the main signals, and show again a time difference of 0.086 sec.

Fig. 21, with a weak indirect double signal from station XGA, Mukden ($f=21,410$ kc, or $\lambda=15.01$ m), was taken at a time when we expected direct double signals. Further details are discussed in Sec. 4.

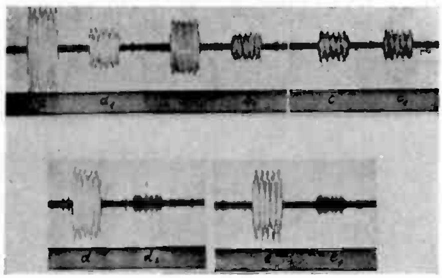


Fig. 15—Rocky Point, WTT (18,541 kc, or 16.18 m), Oct. 25, 1927, 2.35 P.M., C.E.T. Indirect double signals, $\Delta t=0.095$ sec. Records marked *a* are without reflector, *b* with reflector.

IV. Manila

Also on the line Manila-Berlin only indirect double signals could be traced in the records, and here again the amplitude of the double signal was usually greater than that of the main signals which had covered the shorter path. The time difference always amounted to 0.070 sec.

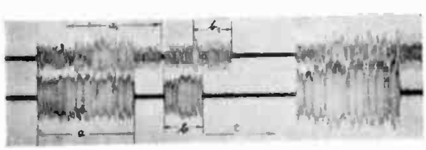


Fig. 16—Rocky Point, WLL, middle of January 1927. Indirect double signals with reflector, *b*; and without, *a*.

Fig. 22 is a record of indirect double signals from KZEN ($f=20,000$ kc, or $\lambda=15$ m) at Manila, in which the signals run completely together. A similar record of the 10,000-kc wave from KZET is shown in Fig. 23 for January 30, 1928, in which the much weaker main signal is considerably distorted, apparently because of rapid fading. The time difference is measured with considerable certainty as $\Delta t=0.070$ sec. Further records from Manila need not be given, since they offer nothing new.

V. Java (Bandoeng)

The great circle Bandoeng-Berlin might be considered unfavorable for double signals, since Berlin in the northern hemisphere and its antipodal point in the southern hemisphere have about the shortest distance from the polar circles on the great circle. Hence only indirect double signals were noted, the photographic reproduction and analysis of which is very difficult in general, since the Java stations are excep-

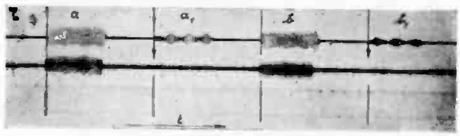


Fig. 17—Rocky Point, New York, 2XT (18,750 kc, or 16 m), Dec. 30, 1926, 3.20 P.M., C.E.T. Indirect double signal ($\Delta t = 0.095$ sec.), with and without reflector.

tionally strongly modulated, so that the beginning and cessation of the signals cannot usually be exactly determined. Hence only a few records are of practical value.

Fig. 24 shows weak indirect double signals of the Java station in Bandoeng ANK ($f = 18{,}072$ kc, or $\lambda = 16.6$ m) with a time difference of $\Delta t = 0.062$ sec. Fig. 25 gives the same time difference, where the double signals stand out somewhat more clearly and appear in the further course of the record at times stronger than the main signals.

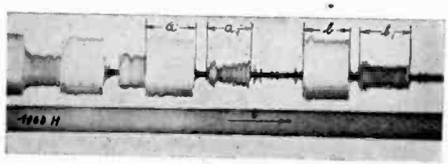


Fig. 18—Rocky Point, New York, 2XBC (20,630 kc, or 14.54 m), Jan. 31, 1928, 3.30 P.M., C.E.T. Indirect double signals, $\Delta t = 0.095$ sec.

VI. Siam (Bangkok)

After the establishment of a Telefunken short-wave transmitter in Bangkok early in 1928, rather strong double signals were sometimes observed, the amplitude of which in most cases was much larger than that of the main signals, which had covered a much shorter distance. Figs. 26 and 27 give examples of indirect double signals from the Siamese station HHP ($f = 17{,}751$ kc, or $\lambda = 16.9$ m) in which the time difference in both cases amounts to $\Delta t = 0.077$ sec. The station was working as a broadcasting station and had no directional antenna.

VII. Japan

Also in the case of Japanese transmitters there were at first difficulties, as a result of poor modulation and lack of power, in observing the appearance of double signals. One record is given here, Fig. 28, from the Japanese station JAA, Iwaki ($f = 12{,}050$ kc, or $\lambda = 24.9$ m)

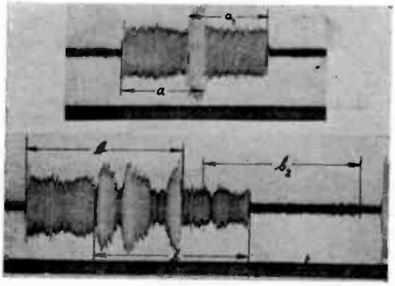


Fig. 19—Mukden, XOM, (17.3 m), Nov. 3, 1927, 8.30 A.M., C.E.T. Indirect double and multiple signals. $\Delta t_1 = 0.086$ sec., $\Delta t_2 = 0.138$ sec. (During the overlapping Doppler effect.)

which contains an indirect double signal with greater amplitude than the main signal and a time difference $\Delta t = 0.076$ sec.

VIII. Nauen

Round-the-world double signals from our own Nauen transmitters were often observed and photographed. Here it was shown that the time difference, which corresponds to a circumference of the earth, remained constant within 1/10,000 sec. throughout the year. Variations at first (early in 1927) were due to incomplete facilities for

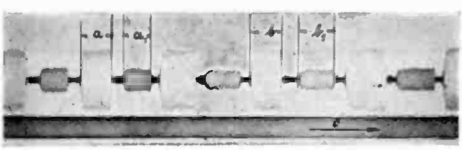


Fig. 20—Mukden, XGA (15,000 kc, or 20 m), Mar. 9, 1928, 8.00 A.M., C.E.T. Simple indirect double signals, $\Delta t = 0.086$ sec.

measurement. The time difference varied between 0.138 and 0.1385 sec. A few oscillograms are presented.

Fig. 29 shows a complete round-the-world signal from the Nauen station AGA ($f = 20{,}070$ kc, or $\lambda = 14.95$ m) where in the case of the double signal, the irregular beginning of the main signal is very clearly shown.

Fig. 30 shows a corresponding record from station AGC ($f=16{,}465$kc, or $\lambda=18.22$ m) with the same time difference. Fig. 31 may be of greater interest, as it shows a round-the-world signal from the experimental station AGK ($f=24{,}920$ kc, or $\lambda=12.04$ m), which station has also served for some time in commercial transoceanic communication. The time difference here also amounts to $\Delta t=0.138$ sec.

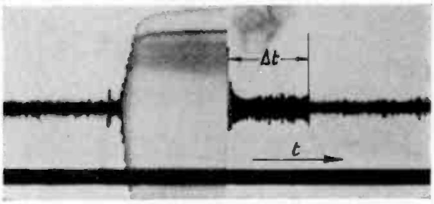


Fig. 21—Mukden, XGA (19,980 kc, or 15.01 m), July 16, 1928, 10.15 P.M., C.E.T. Indirect double signals, $\Delta t=0.0855$ sec.

In Fig. 32 another complete round-the-world signal from AGA is given, where the letter *v* at a sending speed of 150 w.p.m. appears as a double signal separated from the main signal.

IX. South Africa

There follows one more record, Fig. 33, of an indirect double signal from the Marconi station VNB ($f=18{,}750$ kc, or $\lambda=16$ m) in Cape Town, which we shall refer to in Sec. 4 in commenting upon the paper by Taylor and Young; the time difference is $\Delta t=0.072$ sec.

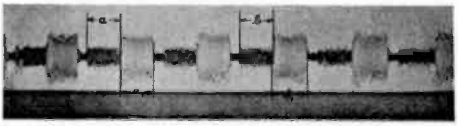


Fig. 22—Manila, KZEN (20,000 kc, or 15 m), Apr. 26, 1928, 8.40 A.M., C.E.T. Indirect double signals, $\Delta t=0.070$ sec.

4. Occurrence of Double Signals for the Various Directions, as Dependent upon the Time of Year and Day

Soon after the first observation of multiple signals from a North American station in the fall of 1926, the question arose concerning a certain regularity in their occurrence, especially because the double signals at certain times cause great disturbance in practical operation, when their amplitude exceeds about 30 per cent of the main signals. No conclusion could be drawn at that time, since there were but few short-wave transmitters available which operated regularly. Moreover, at that time commercial transoceanic communication with short waves was carried on only experimentally and to a very small extent. Hence, it was all the more important to determine in advance, with the appearance of new stations and new short-wave routes, the times for double signals.

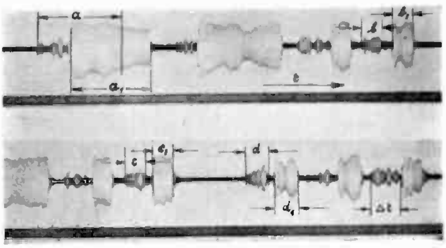


Fig. 23—Manila, KZET (10,000 kc, or 30 m), Jan. 30, 1928, 10.40 A.M., C.E.T. Indirect double signals which are stronger than the direct. $\Delta t = 0.070$ sec.

(*a*) *Twilight: Multiple signals*

A glance at the globe showed first of all, purely empirically, that some double signals were always present whenever the great circle connecting transmitter and receiver lay as close as possible to the twilight belt.

During the past year it has been discovered that the signals can pass around the earth several times only when the great circle lies in the twilight zone. The probability that encircling takes place more

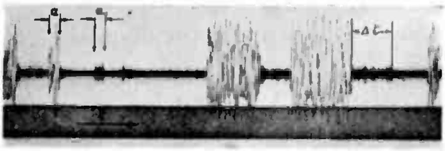


Fig. 24—Java, (Bandoeng) ANK (18,072 kc, or 16.6 m), Feb. 14, 1928, 10.30 A.M., C.E.T. Indirect double signals, $\Delta t = 0.062$ sec.

than twice is greater the more closely the plane of the great circle approaches the twilight plane.

In order to determine whether the times of appearance of multiple signals coincide with the times of the passage of the great circles through the twilight zone, we must consider first somewhat more closely the relations between the various directions.

We consider first the three possible extremes:

(1) The great circle, on which transmitter and receiver are situated, touches the polar circles:

In this case it is evident that the great circle on the longest, as well as on the shortest day, i.e. in summer and winter, at a definite time of

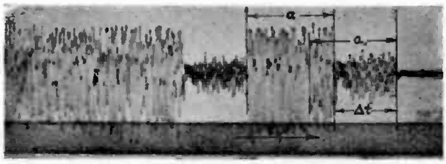


Fig. 25—Java (Bandoeng), ANK (18,072 kc, or 16.6 m), Aug. 31, 1928, 11.15 A.M., C.E.T. Indirect double signals, $\Delta t = 0.062$ sec.

day, depending on the location of the circle, coincides exactly with the twilight circle. Here it should be noted that the two times of day differ in summer and winter by twelve hours.

(2) The great circle passes through the poles:

Here the two circles coincide twice per day at the spring and fall equinoxes, at 6 A.M. and 6 P.M. sun time.

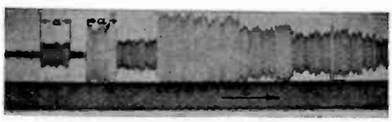


Fig. 26—Siam (Bangkok), HHP (17,741 kc, or 16.91 m), May 9, 1928, 11.10 A.M., C.E.T. Indirect double signals, $\Delta t = 0.077$ sec.

(3) The great circle passes along the equator:

In this case the circles can never coincide; the angle ϕ, which the twilight plane forms with the plane of the great circle, can only reach a minimum, once each on the longest and shortest day.

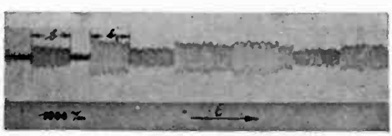


Fig. 27—Same as Fig. 26, only on Apr. 9, 1928, 9.05 A.M., C.E.T.

Hence, one can say that all of the great circles, which lie outside of the polar circles, are located nearest to the twilight zone on the longest and shortest day, *i.e.*, at a definite time of day once each in summer and winter. At this time the angle ϕ becomes a minimum. If the great circles touch the polar circles, the minimum angle ϕ becomes equal to zero at the same time. For all great circles which cut the polar circles the angle ϕ becomes equal to zero four times a year at a definite time of day, and these times approach the equinoxes as the great circles approach the poles. Let us now consider those great circles which are possible through Geltow (Berlin). (See also the map, Fig. 2).

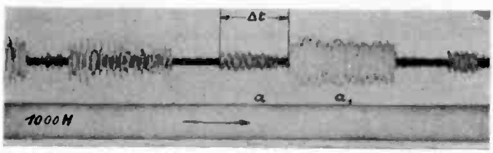


Fig. 28—Iwaki (Japan), JAA (12,050 kc, or 24.9 m), Dec. 7, 1927, 8.30 A.M., C.E.T. Indirect double signals, $\Delta t = 0.076$ sec.

ϕ_{min} can be here in the most unfavorable case = (90 deg. − 52.5 deg.) − 23.5 deg. (inclination of the earth's axis) = 14 deg. It has been found that multiple signals also occur when the twilight and great circles do not coincide exactly, owing perhaps to the finite width of the zone. As an upper limit, an angle of discrepancy of about 10 deg. has been found in practice. There is given below a tabular summary (Table I) in which for the main great circles, which correspond to the communication lines of the Transradio and a few other observed stations, the times at which angle ϕ reaches a minimum are recorded. At these times the great circles are located closest to the twilight zone. In addition the minimum value of ϕ is given.

TABLE I

Great Circle between Geltow and	Summer June 21 C.E.T	Winter Dec. 12 C.E.T.	ϕ_{min} approx.
New York	2:30 A.M.	2:30 P.M.	−9.5 deg.
Rio de Janeiro	9:00 P.M.	9:00 A.M.	−4.5
Buenos Aires	9:00 P.M.	9:00 A.M.	−6
Mukden	9:00 P.M.	9:00 A.M.	−4.5
Osaka	8:30 P.M.	8:30 A.M.	−2
Manila	9:30 P.M.	9:30 A.M.	−10.5
Java	11:00 P.M.	11:00 A.M.	−14
San Francisco	4:00 A.M.	4:00 P.M.	+3
Bangkok	10:00 P.M.	10:00 A.M.	−13.5
Capetown	Spring 6:00 A.M. 6:00 P.M.	Fall 6:00 A.M. 6:00 P.M.	(about) 4 deg. from the pole

At the end of 1926 there were, as already mentioned, only a few short-wave transmitters available, so that the above assumption could not be tested until last year. For New York the time of appearance of double signals agreed with the assumed time very well. In the fall of 1926 and in the winter 1926–27 the times for the North American stations 2XT, 2XS and WIK were grouped around 2:30 P.M., C.E.T. The double signals first appeared weakly, 1/2 to 2 hours before their maximum, increased and reached their maximum at about 2:30 P.M., C.E.T., and then decreased for about the same length of time. A few weeks before and after the time of the shortest day their amplitude amounted at times to 100 per cent of the amplitude of the main signal.

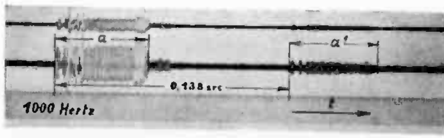


Fig. 29—Nauen, AGA (20,070 kc, or 14.95 m), Apr. 28, 1927, 10.04 P.M., C.E.T. Round-the-world signals, $\Delta t = 0.138$ sec., with a short range echo.

With the appearance of fading the main signal was at times weaker than the double signal. But it should be remarked that the fading was in general much stronger with the double signal, so that there were often difficulties in registering photographically on the oscillograph double signals on a film five meters long. Also the time 2:30 A.M., C.E.T., agrees very well for the occurrence of double signals from New York in the summer, as can be seen in the oscillogram, Fig. 13, from WTT. The direct double signal from WTT ($f = 18{,}750$ kc, or $\lambda = 16$ m) was registered at 2:00 A.M., C.E.T. While the time difference in winter corresponded to the indirect path, in summer the complete circle time of 0.138 sec. was registered throughout. The double signals

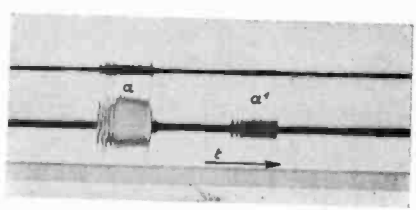


Fig. 30—Nauen, AGC (16,465 kc, or 18.22 m), Feb. 4, 1927, 10.40 A.M., C.E.T. Round-the-world signals, $\Delta t = 0.1385$ sec.

from New York appear, accordingly, to favor the indirect route in winter, the direct in summer.

After operations were begun with a new short-wave transmitter in Rio de Janeiro in the spring of 1927, it was very interesting to register the times for double signals and compare them with those calculated. Actually double signals occurred at about 8:00 P. M., C. E. T., reached a maximum at 9:30 P.M., and had disappeared about 10:30

P.M. Unfortunately, the short-wave reception was often impaired at this time for weeks, as a result of magnetic disturbances (maximum of the 11-year sunspot period), so that the double signals likewise generally appeared weaker, and often ceased for a long time. Also a few weeks before the longest day, on June 21, and a few days later, the horizontal component of the earth's magnetic field showed marked

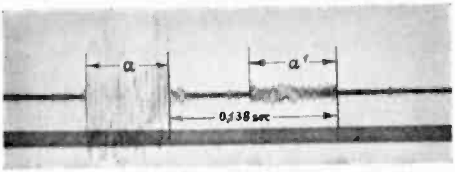


Fig. 31—Nauen, AGK (24,920 kc, or 12.04 m), Dec. 11, 1927, 11.20 A.M., C.E.T. Round-the-world signals, $\Delta t = 0.138$ sec.

disturbances, so that we waited in vain for the occurrence of multiple round-the-world signals, which we had long expected. Suddenly on June 25 multiple signals could be clearly heard, and two days later they were registered on the oscillograph.[5] We reproduce here a few extracts from the record made at that time, Figs. 4 and 5, where as many as five-fold signals from an emitted wave-train can be recognized. Rio was requested at that time to send short waves about 1/20 sec. in duration at intervals of a half second, in order to receive every

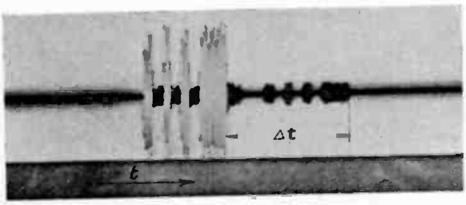


Fig. 32—Nauen, AGA, Sept. 19, 1928, 9.00 A.M., C.E.T. Direct round-the-world signal, letter *V* at sending speed of 150 w.p.m. $\Delta t = 0.1385$ sec., with short range echoes.

signal separately after encircling the earth. Unfortunately, Rio had misunderstood the communication and sent 2 dots per second with an interval of only 1/15 sec. In spite of this the signals can be analyzed clearly after passing three times around the earth. In Fig. 5 it is very interesting to note that the amplitudes of the double signals, a^1, a^2, a^3, decrease but little, quite in contrast for example, to the reception

[5] See also oscillograms in the paper by Quäck, *Elec. Nach. Tech.*, No. 4, p. 76, 1927.

in a long reflecting telephone line where the amplitudes decrease regularly according to an exponential law. Even though momentary fading is present here, yet additional records taken successively so as

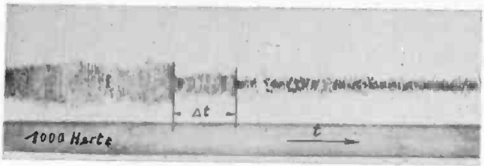


Fig. 33—Capetown, VNB (18,050 kc, or 16.62 m), May 14, 1927, 10.40 A.M., C.E.T. Indirect double signals, $\Delta t = 0.072$ sec.

to give a total length of 15 meters, are of about the same character. Some important conclusions can be drawn from this.

When in the course of 1927 and early in 1928 the short-wave stations LP2, LP3, and LP4 began operating in Baires, double and

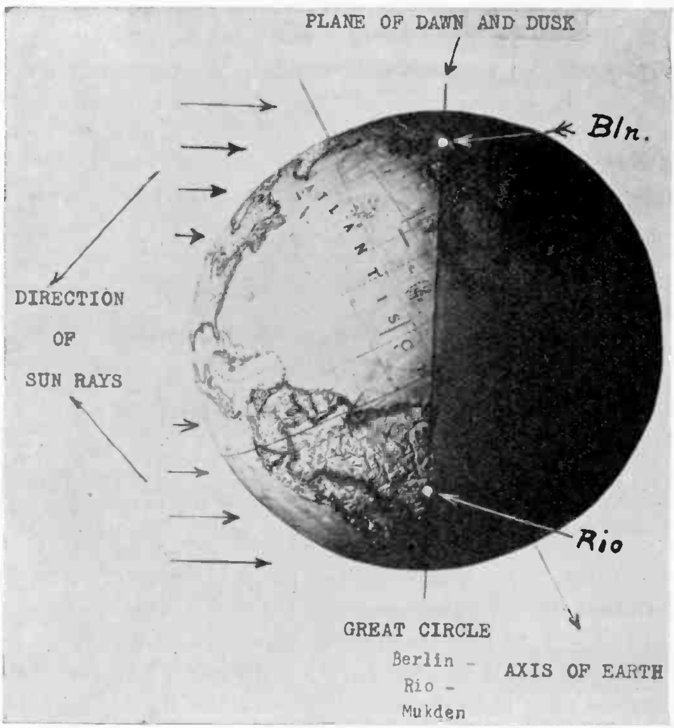


Fig. 34—The earth at the summer solstice, viewed from the side in a direction perpendicular to the sun's rays. The great circle Berlin-Rio-Mukden lies in the twilight zone at about 9.30 P.M., C.E.T.

multiple signals could be observed at the same time as for Rio in the summer and winter, as an extract from the records, Figs. 6 to 12, shows. At the time of the shortest and of the longest day multiple signals were observed, in the summer only direct and in the winter indirect. This fact has but one meaning, and is extraordinarily interesting. When, late in 1927, in Mukden, which happens to lie approximately on the great circle Berlin-Rio, a Telefunken short-wave transmitter was installed, it was of interest to examine the direction and intensity of double signals coming from the east in addition to those from the west

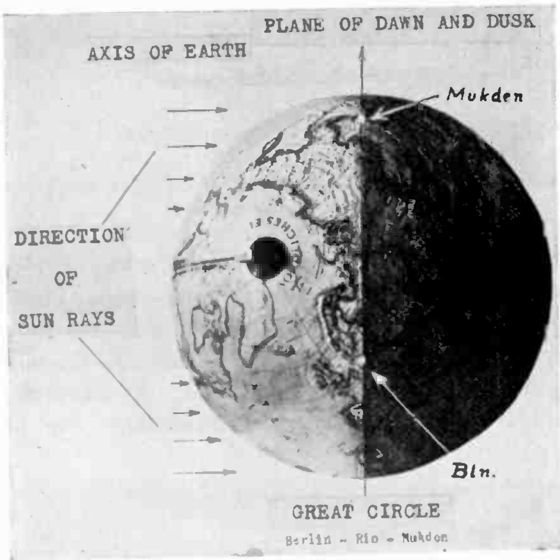


Fig. 35—The earth at the summer solstice, viewed obliquely from above. The great circle Berlin-Mukden lies in the twilight zone at about 9.30 P.M., C.E.T.

(Rio-Baires) which had been observed hitherto. The double signals expected in the winter at about 9:00 A.M., C.E.T., were registered exactly at that time; on the shortest day triple signals in the indirect direction were received. Examples are shown in Figs. 19 and 20, of November 3, 1927, and March 9, 1928. In the summer we expected, at about 9:00 P.M., C.E.T., direct double signals. Since Mukden was sending at this time with a lower frequency, and changing the frequency during operations gave rise to difficulties, the 20,000-kc frequency (15-m wave) could only be photographed once, on July 16, 1928, in which case strangely enough a weak indirect double signal (Fig. 21) appeared. This fact is extremely interesting and cannot be confirmed until next year, at which time Mukden will presumably have several transmitters. This one-day observation might be considered exceptional. No less scanty are the observations from Iwaki (Japan) in the east and San Francisco in the west. Here too the deviations of the great circles from the twilight zone are very small; ϕ_{min} amounts in the case of San

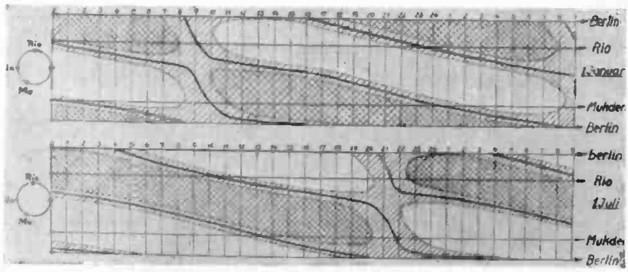


Fig. 36—Distribution of daylight, twilight, and night, on the great circle Berlin-Rio-Mukden-Berlin.

Francisco to only about +3 deg. in Iwaki (Osaka) only −2 deg., i.e., the great circle Berlin-San Francisco cuts the polar circles and coincides with the twilight zone shortly before and after the longest and shortest day, while the great circle Berlin-Osaka in the most favorable case comes very near to the twilight zone. An example of indirect double signals from Iwaki in the winter is given in Fig. 28 from JAA

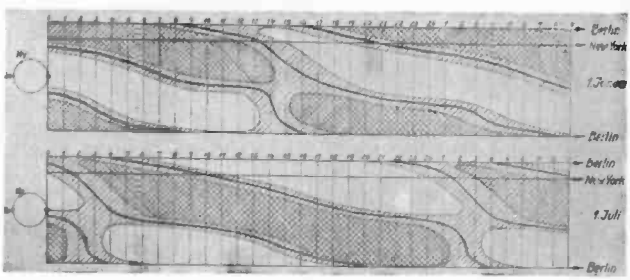


Fig. 37—Distribution of daylight, twilight, and night, on the great circle Berlin-New York-Berlin.

(December 7, 1927) about 8:30 A.M., C.E.T. The Japanese short-wave transmitters were, unfortunately, not working in the summer; however, late in September, 1928, direct double signals from the transmitter JAN in Nagoya (f = 11,720 kc, or λ = 25.6 m) were observed at about 8:30 P.M., C.E.T. The times recorded for San Francisco in Table I were also confirmed only a few times.

We will now consider a few lines whose great circle through Berlin is far removed from the twilight zone, in which case ϕ_{min} is greater than 10 deg. Extended observations have been made from Bandoeng (Java), Manila, and Bangkok (Siam). Up to the present time only indirect double signals, that is, only simple echoes in the indirect direction have been observed, except from Manila, where also simple weak direct double signals were found in the three summer months. We might expect in summer weak direct double signals from the other stations mentioned also, if the stations operated with short waves at this time. For practical purposes the longer waves are in general better

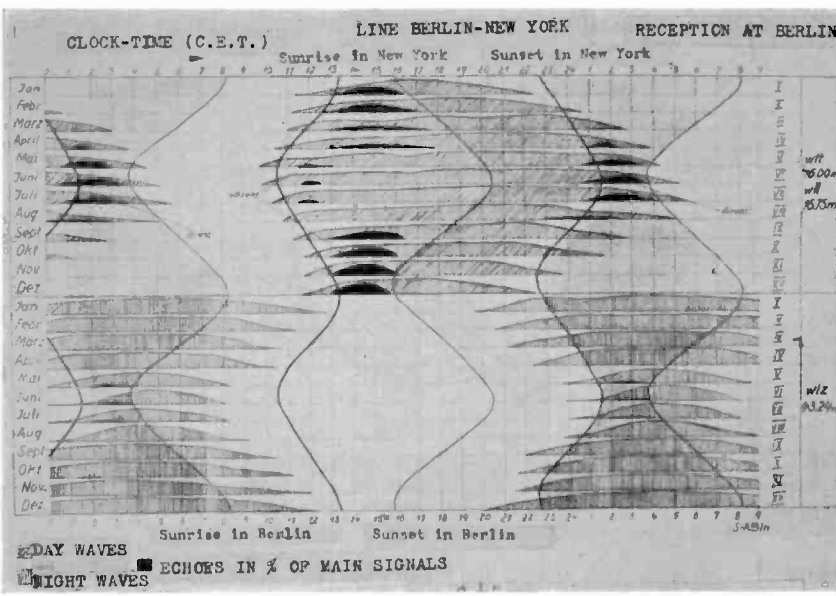


Fig. 38—Path from New York to Berlin. Diagram showing most favorable times for communication, and limits of audibility.

suited at this time. It must also be noted here that the strong indirect double signals in the winter fall more under the category treated of in Sec. 4b.

In the records of indirect double signals, Figs. 22 to 28 from Manila, Bangkok, and Iwaki, it is striking at times that the indirect double signals have a greater amplitude than the main signals. This very remarkable and regular occurrence can be reconciled, however, with the fact that the propagation conditions, at least for Berlin, are more favorable in the winter in the indirect, in the summer in the direct sense. An explanation of this cannot be given as yet.

The line Capetown-Berlin presents a special case, where the great circle cuts the polar circles and passes only about 4 deg. from the pole. Here the great circle passes through the twilight zone twice a year, in spring and fall, morning and evening. Extended observations actually showed that at about 6:00 A.M. and 6:00 P.M., C.E.T., at the equinoxes strong double signals from the transmitter VNB in Capetown were present. Their direction, as a result of high speed of transmission, has, as yet, been observed only once as indirect (see for example, Fig. 33), in which, as a result of poor conditions, it happens that the area of disturbance was very large. We can extend the observations of Taylor here to the extent that, even across the poles, double signals are possible, if at the time of equinoxes the great circles pass

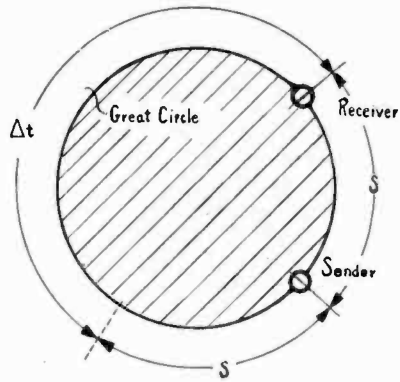


Fig. 39—Great circle of the earth, with relative locations of sending and receiving stations. Curved arrows marked s represent distances, while the long curved arrow marked Δt represents the time interval between direct and indirect signals as received.

through the twilight zone. In spite of this it is remarkable that, according to Taylor, as yet no double signals from Baires have been observed in New York, although the angle ϕ_{min} during the whole year is always smaller than 10 deg. Perhaps here the magnetic poles still have some influence. If one were to consider still other observations, which we have, though incomplete, from Baires, Rio, New York, and Mukden, one could almost come to the conclusion that the phenomena mentioned above are peculiar to certain parts of the earth. Some time will probably pass before exact continuous observations are obtained from all parts of the world.

Interesting results were obtained from the observation of complete round-the-world signals from our Nauen transmitters, which, it is true, were not always carried out quite regularly. Since the short-distance Nauen-Geltow (30 km) can be disregarded so far as direction is concerned, double signals are expected in every season at sunrise and sunset. When the stations were working with non-directive antennas, this could also be confirmed. For some time directional antennas have been used almost exclusively so that the times for double signals are somewhat more limited and hence fall in the periods where the directions used coincide with the twilight zone. Examples of double signals of the Nauen transmitters are given in Figs. 29 to 32.

To furnish a clearer picture of the passing of a great circle through the twilight zone, the globe with a corresponding position of the great circle Berlin-Rio-Mukden was photographed and is represented in Figs. 34 and 35.

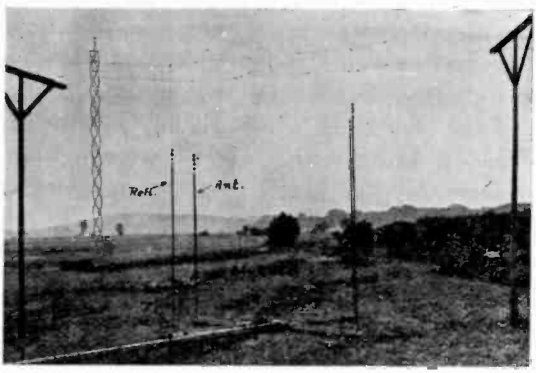


Fig. 40—Antenna systems at Geltow for directional reception from Mukden (14 and 19 meters), with electricall yexcited reflecting wires* for production of cardioid characteristic.

The pictures represent the longest day (summer), when the North Pole is farthest from the twilight zone. They consist of separate views, from the side (Fig. 34) and obliquely from above (Fig. 35), in order to permit the three places Berlin, Rio, and Mukden to be recognized. The time is about 9:30 P.M., C.E.T. In Rio and Berlin the sun is just setting, in Mukden rising. At this time the signals from Rio appear very strong. In winter on the shortest day the situation is just reversed; the sun's rays then pass parallel from right to left on the picture and light and dark are reversed. The time is then changed 12 hours to 9:30 A.M., C.E.T., when the indirect multiple signals from Rio and Mukden appear very strong.

(*b*) *Southern Hemisphere in Summer at Night: Indirect Double Signals*

It was soon found that double signals sometimes appeared outside of the twilight zone; in this case it was always a matter of indirect

* "Mit gespeisten Reflectordrähten."

double signals, which cover the usually longer reverse path, while hitherto direct, as well as indirect, multiple signals had been registered only in the twilight zone. These double signals usually take the reverse route in the summer at night; at that time the complete direct path lies entirely in the light and 20,000 km of the reverse route in the dark. Let us consider first 25,000 to 13,636-kc frequencies (12 to 22 m), which we designate as *day* and *transition* frequencies because the higher frequencies of about 25,000 to 16,667 kc (12 to 18 m) are better suited for day communication, where the complete route lies in the light while the somewhat lower frequencies, 16,667 to 13,636 kc (18 to 22 m), are suited to the transition period between day and night, where part of the path is in the light, the rest in the dark. The term "day wave" is, however, not quite appropriate, for in summer these waves pass just as well through areas that are absolutely dark. It must not be forgotten that for the propagation of short waves, and for the height of the Heaviside layer, not only sunrise and sunset and the division of the day into daytime, night, and twilight are influential, but also particularly the change of season. In the tropics the so-called day waves are just as well suited for communication at night over very great distances.

If the route in question crosses northern or southern areas, then the change between summer and winter becomes much more conspicuous. In winter, so far as short waves are concerned, transmission is possible only during the day. It is easy to see, however, that then the transmission can also take place on the reverse night path, if the summer season prevails there. That is, however, naturally always the case for a few hours; when, for example, it is winter in the northern hemisphere, the southern hemisphere is in the summer season, so that for most great circles which pass through Berlin such cases are possible in the winter, when the short waves can pass along the usually much longer reverse route because of the low Heaviside layer.

A few examples are now given for the indirect double signals discussed above. From South America (Rio and Baires) these double signals appear in the winter months between 11:00 A.M. and 7:00 P.M., C.E.T. Their amplitude is, disregarding magnetic and other influences, extraordinarily large, and often reaches values of 100 per cent of the main signals (compare Figs. 8 and 9). Fading is usually stronger and lasts longer than with the direct signal. In this kind of indirect double signal a special regularity or order is seldom recorded, in contrast to the twilight double signals discussed in the preceding section. Their amplitude, for example, can be just as large at the time of equinox, as at the time of the shortest day. In the four summer months, when the southern hemisphere has winter, these indirect double signals cease.

The indirect double signals from Bangkok, Bandoeng, Manila, and Mukden are not so clear but can, nevertheless, be distinguished; these also appear, strangely enough, on into the summer, when a considerable part of the reverse path traverses regions where night and winter prevail. Still, with Siam, Java, and Manila, the explanation may be found in that these transmitters are located near the equator, where in the summer and winter the Heaviside layer is very low. From New York only twilight double signals were observed, in general, except recently, when after an increase of power of the transmitters in New York, exceptional cases, still unexplained, also occurred.

It should be noted also that from the European short-wave transmitters in London, Paris, Kootwyk, Lisbon, and Madrid, except at twilight during the winter months, indirect double signals were found. Likewise the signals sent out from Nauen can pass around the earth in the winter months in the forenoon, when the northern hemisphere has day and the southern has summer and night.

(c) *Reverse Path Better Suited for Certain Waves: Indirect Double Signals*

It can, of course, happen that the return path is better suited for the wave than the direct path. If the distance from transmitter to receiver ranges from 5000–8000 km, a night wave can still be audible on the direct light path, while the amplitude received over the reverse route, located mostly in darkness, is just as great or greater. Such a case is presented, for example, in the reception of the 10,000-kc frequency (30-m wave) from Manila (Fig. 23). Here strong indirect double signals are observed in the winter months between 9:00 A.M. and 12:00 P.M., C.E.T., while the direct reception is very weak. This time may fall in the twilight period, in which case the situation is easily explainable for the longer waves. Characteristic for this type of indirect double signals is the fact that they almost always occur at times when the reception on the direct path is just coming through or just ceasing. Similar results were obtained in the observations of longer waves from Bangkok and Mukden. The circumstances are similar for Australia (Sydney), which is located only about 4000 km from the antipodal point of Geltow, where the reception of somewhat lower frequencies of about 12,000 kc (25 m) in the transition periods is possible from both directions, but very weak.

In general it may be noted here that the amplitudes and field strengths of direct and indirect signals are much smaller than with the short waves in the twilight period. The amplitude ratio is roughly of the order of 1:10.

(d) Strengthening of Indirect Double Signals by Reverse Radiation from the Transmitter.

In the first place, it must appear paradoxical when from those transmitters with antennas that are sharply directive toward the receiving station, there appear at the times given above *indirect* double signals. Usually the directional characteristics of these transmitters are determined either by calculation or else experimentally by means of small auxiliary transmitters on the ground. In practical communication over great distances, however, radiation appears always to be perceptible even in the reverse direction. The screening at the rear of these beam transmitters was not yet complete. In the meanwhile technical advances have been made, which allow complete elimination of reverse signals. An interesting observation was made when a new transmitter in Baires was put into operation. At a time when weak indirect double signals were to be expected *indirect* double signals, stronger than the direct ones, were observed. While two other Baires transmitters showed at the same time and at nearly the same wavelength weak indirect double signals, the amplitude of the indirect signal from the new transmitter was very materially stronger than that of the direct signal, which had only a third as much path to cover. After a few days the attention of Baires was called to this fact and inquiry was made there as to whether the direct radiation from their antenna was not accidentally screened off. The antenna of the new transmitter was then changed, whereupon normal conditions actually appeared. One sees from this that the indirect double signals can be strengthened by radiation artificially directed backwards.

(e) Location of Great Circles and Division of Day, Twilight, and Night

Since the times of sunrise and sunset, and the division of day, twilight, and night, along the great circle are of great importance in transmission, graphical charts were made for various great circles of interest, of which two are presented in Figs. 36 and 37. In Fig. 36 the great circle Berlin-Rio-Mukden is considered, in Fig. 37 the circle Berlin-New York.

The circle has been unrolled and the abscissas represent "clock-time," while the ordinates represent distances. The heavy lines represent the border between sunrise and sunset. Night areas are indicated by heavy shading, twilight areas by light shading, while day areas are left clear. The light lines mark the border between twilight and night or day. Since twilight is not sharply defined, those points were taken as the limits in which the sun, as observed at a height of 200 km, would be rising or setting. One obtains thus a clear picture at least as to points with the same illumination. The values were obtained from astronomical tables. Each diagram refers to a particular day, and approximately the most extreme cases were chosen, namely, the longest and shortest days. It is seen from Fig. 36, for example, that the entire great circle Berlin-Rio-Mukden lies in the twilight zone on January 1 about 9:00 A.M., C.E.T., on July 1 about 9:00 P.M., C.E.T.; at these times the multiple signals actually occurred. The same is true of New York in Fig. 37 on January 1 about 2:30 P.M., C.E.T., and July 1 about 2:30 A.M., C.E.T. These charts were made for every month, so that from this the amount of light along the path can be calculated at all times of day and year. The amplitudes of reception are not included in these charts to avoid confusion.

(f) Graphical Representation of Amplitudes of Reception and Their Dependence upon the Time of Day and Year.

The advantages of certain waves for the various directions is brought out clearly in graphical charts of the reception which we have prepared for most of the lines. These charts of the most favorable transmission times and limits of audibility summarize our investigations extending over three years, and contain valuable material for research in propagation phenomena.[6] As an example we present in somewhat different form in Fig. 38 the strength of received signals at day frequencies (18,750 kc or 16 m) and at night frequencies(9,090 kc or 43 m) from New York. The wavy lines running in the direction of the ordinate represent the time of sunrise and sunset at the transmitting and receiving stations as calculated from astronomical tables. The *monthly averages* of the signal strength are shown as related to the time of day. The audibilities are approximately proportional to field strengths and were measured uniformly by means of a Barkhausen audibility meter. The measurements took place at the beginning of the Geltow-Berlin land-line, where approximately constant conditions always prevail. Naturally only relative values are obtained, which suffice, nevertheless, for a judgment concerning transmission possibilities. The amplitudes are plotted approximately to scale, that is, the interval from month to month corresponds to an audibility of 5000 Wien* (units of audibility). In order to avoid the use of two small

[6] The material was published in *Elec. Nach. Tech.*

* Wien units according to Barkhausen-

Wien	Audibility
1 - 2	R 1
4 - 8	R 2
16 - 32	R 3
64 - 125	R 4
250 - 500	R 5
1000 - 2000	R 6

units, transmission values of over 4000 Wien are not indicated, since this received energy is sufficient in every case to insure good communication at high speed, so long as the transmitter is in good condition.

The double signals are indicated in black and are given in percentages of the amplitude of the main signal; the direction of the path, direct or indirect, is also indicated. Fading is not represented in this chart. Likewise the path between transmitter and receiver is not indicated here. One sees from Fig. 38 that the twilight double signals from New York are strongest when times of sunrise and sunset at the places of sending and receiving approximate each other most closely. Moreover, the possibility of good transmission is particularly pronounced in summer, while both stations are in darkness, corresponding to the low height of the ionized layer.

5. Range of Wavelengths in Which the Various Double Signals Appear.

For the sake of making the survey clearer, those frequency ranges will now be summarized in which the double and multiple signals mentioned above appear. For the twilight double signals we can select a range of 25,000 to 13,636 kc (12 to 22 m) perhaps even up to 12,000 kc (25 m). The most favorable frequencies are located apparently between 20,000 and 18,750 kc (15 and 16 m), where thus far as many as five-fold signals from a train of waves have been observed.

If one extends the meaning of "twilight double signals" somewhat farther and includes the indirect double signals noted under Sec. 4c, then the frequency range can be extended to the night frequencies also, up to about 6,667 kc (45 m). Thus in the twilight zone, direct and indirect double signals between 25,000 and 6,667 kc (12 and 45 m) were observed. The indirect double signals noted under 4b, seem, on the other hand, to be limited to a smaller range of frequency, approximately 21,430 to 13,636 (14 and 22 m). Here too a maximum between 20,000 and 17,647 kc (15 and 17 m) is found, yet a similar signal is found for certain directions at 14,286 kc. If the sending place is very near the antipodal point of the receiver, then the so-called transition waves, i.e., waves between 13,636 and 10,345 kc (22 and 29 m) are well suited for the indirect double signals which appear (e.g., Australia: 12,000 and 10,345 kc, or 25 and 29 m).

For the indirect night double signals at greater distances, where transmitter and receiver are separated about one fourth of the earth's circumference and less, a range of 10,000 to 8,820 kc (30 to 34 m) is, in general, suitable.

6. Measurement and Calculation of the Time-Differences

In contrast to the results of Taylor and Young, which show variations in the time differences, with the same transmitter, amounting sometimes to over 10 per cent, our measurements of time differences generally lie within the limits of errors of observation and the precision of the apparatus. The differences usually amount to 1 per cent or less. Occasionally there were greater variations which could, however, always be traced back to a change of frequency in the 1000-cycle generator.

One can probably assume as certain that the path of the multiple signals, even when the plane of polarization is rotated, is always along the great circle connecting transmitter and receiver.

From the time difference of multiple signals with respect to the direct main signal and to each other, it is easy to determine in which direction the waves have passed, whether directly or indirectly. Long continued observations of the double signals of our Nauen transmitter in Geltow showed a mean time difference of 0.138 sec.; when the signals were sent with great exactness even 0.1385 sec. could be measured. If one neglects the change in propagation velocity in the atmosphere, then this time difference corresponds to about 41,400 km, i.e., a route 3.5 per cent longer than the earth's circumference.

We next computed the time differences between direct and indirect signals for the various transmission paths, on the assumption that all distances were to be multiplied by 1.035.

The distances were calculated by the Geodetic Institute in Potsdam (Prof. Dr. Mahnkopf) within about 10 km, and kindly placed at our disposal. If s designates the distance along the shortest arc in km, then the time difference between direct and indirect signals is given by the following formula:

$$\Delta t_{\mathrm{calc}} = \frac{(40020 - 2s) \cdot 1.035}{300{,}000}$$

A great circle showing relative positions of transmitter and receiver is represented in Fig. 39. In Table II the calculated and measured time differences are given, as well as the actual distances within 10 km.

TABLE II

Path Geltow to	kc or	m	Distance (km)	Δt calculated (sec.)	Δt measured (sec.)
Nauen	27,270–11,538	11–26	40,020	Assumed dist. s+3.5 per cent	0.138–0.1385
New York	21,430–13,043	14–23	6,390	0.0942	0.094–0.095
Rio	20,550–19,231	14.6–15.6	9,940	0.0695	0.069–0.070
Baires	20,980– 8,570	14.3–35	11,850	0.0562	0.056
Java (Bandoeng)	18,750	16	10,930	0.0627	0.062
China (Mukden)	20,000–15,000	15–20	7,630	0.0856	0.086
Japan (Iwaki)	15,000	20	8,870	0.0769	0.076
Manila	10,000–20,000	30–15	9,900	0.0698	0.070
Siam (Bangkok)	21,430	14–17	8,650	0.0783	0.078
Capetown	18,250–17,647	16	9,590	0.0721	0.072

It is striking how well the calculated values agree with those photographed on the oscillograms.

If, as stated recently by H. T. Friis,[7] it is true that the horizontal angle of reception varies as much as 30 deg. from the geographic direction, then it may be either that the corresponding time differences are less than the errors of observation, i.e., less than 10^{-3} sec. (perhaps as a result of local conditions), or that such great variations occur but seldon, so that they were not measured by us in spite of regular photographing.

7. Effect of Magnetic Disturbances

Short-wave reception suffers in general not only from fading and from the marked influence of the illumination of the path, but particularly from magnetic disturbances. The most important causes are probably found in the appearance of sun spots, since the periodicity of short waves and of magnetic disturbances is clearly related to the rotation of the sun. The disturbances seem to be very effective for all directions approximately perpendicular to the lines of the earth's field.

With the appearance of magnetic disturbances, the multiple signals disappear in every case, while the amplitude of double signals is more or less strongly affected according to the direction. Thus, for example, even with weak magnetic disturbances, no double signals are observed from New York, whereas from South America they still occur, since the circle Berlin-Rio-Baires makes a very small angle with the magnetic lines, in contrast to New York where the great circle cuts the lines almost perpendicularly. With moderate and stronger disturbances the signals from South America also disappear.

8. Elimination of Double Signals

It is already evident that the elimination of *direct* double signals, or their exclusion from the receiving antenna, is probably not possible, in contrast to the *indirect* double signals, which strike the receiving antenna from the opposite direction. An elimination of the indirect double signals is achieved by setting up an aperiodic grounded screen, which can consist of several single wires. Here it is to be noted that in the larger receiving stations under certain circumstances several antennas are set up close together, in which case the incident waves of the double signals are scattered diffusely, so that in spite of the best side screening, effects are still noticeable. As Figs. 16 and 17 show, the screening with such simple apparatus as that mentioned above is completely successful. A further step is reached through the use of

[7] H. T. Friis, Proc. I. R. E., 16, 658; May, 1928.

tuned reflecting wires back of the receiving antenna, in which case by much simpler means the same, or better, elimination is obtained. Recently special reflector apparatus has been introduced, which results in an exact cardioid characteristic; except for the Beverage antenna, this probably offers the simplest means at present for keeping indirect double signals away from the receiver.[8]

Fig. 15 shows comparative records, obtained with and without simple reflector wires, where the amplitude of the double signals, as a result of poor tuning, was reduced only about one third.

[8] Fig. 40 shows two such directional antennas built at Geltow by Telefunken for the reception from Mukden.

Proceedings of the Institute of Radio Engineers
Volume 17, Number 5 *May, 1929*

SHORT RANGE ECHOES WITH SHORT WAVES*

By

E. Quäck and H. Mögel

(Transradio, Berlin, Germany)

Summary—*The authors have made an examination of short range echoes by means of special signals transmitted from the high-frequency stations at Nauen (21,430 to 11,538 kc, or 14 to 26 m) and recorded photographically at Geltow. The echoes are sometimes blurred and sometimes repeated at fairly regular intervals, indicating multiple reflection between the ground and a reflecting layer. In one case the height of this layer is estimated to be about 1,500 m. The character of the echoes may change radically within a few seconds. General agreement is found between the authors' observations and those of Taylor and Young and also those of Hoag and Andrew. The bearing of the echoes on radio communication is discussed and a number of oscillograms are reproduced.*

In the summary of the paper by one of the present authors on "Double and Multiple Signals on Short Waves,"[1] par. 16, reference was made to short range echoes (Nahechos). Concerning these we wish to make the following report.

On the photographic records of round-the-world signals from the Nauen transmitter made at the receiving station in Geltow it frequently happened that the signals were accompanied by small, obscure appendages, sometimes at the beginning and sometimes at the end of the signals. Since these appendages could also be recognized with certainty in the double signals as well, the phenomenon was considered an indication of faulty keying. Later it was recognized that these appearances were partly attributable to short range echoes. This term was chosen because these wave groups occur in shorter time

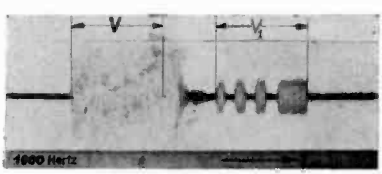


Fig. 1—Records made at Geltow of V signals from the Telefunken Transmitter AGA (20,090 kc) in Nauen, Nov. 14, 1928, 11.10 C.E.T. The direct signal V is blurred by short range echoes, while the round-the-world signal V_1 is reproduced exactly.

* Dewey decimal classification: R113. Original manuscript received by the Institute, December 27, 1928. Translation received, January 11, 1929. Supplement to "Double and Multiple Signals on Short Waves," Proc. I. R. E., **17**, 791; May, 1929.

[1] *Elek. Nach. Tech.*, **4**, p. 74, 1927.

intervals than is the case with the direct or indirect double signals, which pass completely around the earth in one direction or the other.

The first positive proof of short-range echoes from the Nauen transmitter was furnished when the signals received in Geltow from this station were completely blurred and irregular, while at the same time New York and Baires were copying the same transmitter at

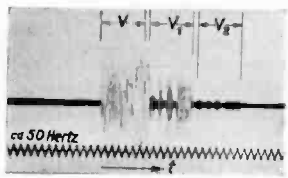


Fig. 2—V signals from AGA in Nauen (20,090 kc, or 14.93 m) received in Geltow Nov. 17, 1928, 10:40 A.M., C.E.T., showing double round-the-world signals V_1 and V_2. Owing to short range echoes, V_1 is merged into V.

Nauen at the rate of over one hundred words per minute. In order to investigate this point a series of widely spaced V signals were sent from Nauen at a rate of one hundred and twenty words per minute. At Geltow there were recorded, in addition to the greatly blurred, direct V signals, one or two round-the-world echoes which were absolutely clear and above criticism. Some examples of the oscillograms are reproduced in Figs. 1 to 3. In Figs. 1 and 2, V, the short range

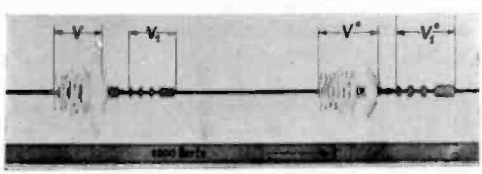


Fig. 3—Record of Nauen transmitter AGA1 made at Geltow (20,190 kc, or 14.86 m), with round-the-world signals V_1 and V°_1, in which the short range echoes appear separated.

echoes merge with the main signal, forming a complete blur. As a result of the short range echoes the total duration of the main signal V is about 0.04 sec. greater than that of the double signal V_1. In Fig. 2 the round-the-world signals can be clearly recognized. The distance from V_1 to the main signal V should be the same as that of the multiple signal V_2 from V_1; nevertheless it will be noted that the beginning of V_1 overlaps the short range echoes somewhat. It is clear from the photographs that these short range echoes, judging from the time intervals, cannot have passed around the earth. In order to investigate this matter somewhat more closely, signals were sent in intervals of ½ sec. from the Nauen transmitter AGA1 (20,440 kc, or 14.68 m), AGA (20,090 kc, or 14.93 m), and AGB (11,380 kc, or 26.36 m) in succession. For this purpose a tape was prepared containing a repetition of the letter *e* separated by ten to twenty spaces. This was sent through the machine transmitter at a rate of one hundred to one hun-

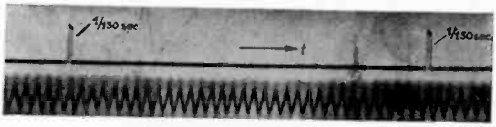


Fig. 4—Control record of AGA1 in Nauen, made in the transmitting room. Short dots of 1/150 sec. duration at intervals of about 1/2 sec. The keying is absolutely exact.

dred fifty words per minute. Special control registrations were also made in the same building in which the transmitter was located, in order to make certain that the transmitter actually was emitting short, exactly defined signals. One of these records is shown in Fig. 4.

The first of these exposures recorded at Geltow from AGA is shown in Fig. 5, in which, in addition to the direct signal a and the weak

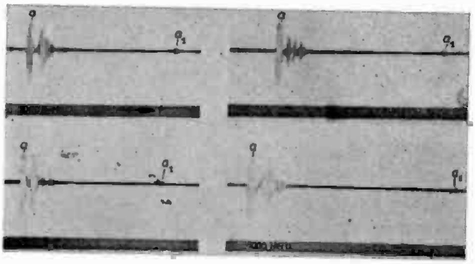


Fig. 5—Short range echo records from AGA in Nauen, Nov. 14, 1928, 12:30 P.M., C.E.T. The short range echoes, which follow the main signal a have quite varying character on the four records, all of which were made within 3 secs. a_1 is a round-the-world signal.

round-the-world signal a_1, between one and three short range echoes are present. These short range echoes present quite different appearances in the four exposures, all of which were made within three seconds. Some of them appear merged together while others are separated. By taking averages of time intervals from the entire film, which was five meters long, it was possible to distinguish three-time intervals of short range echoes with respect to the main signal:

$$\Delta t_1 = 0.0095 \text{ sec.}$$

$$\Delta t_2 = 0.020 \text{ sec.}$$
$$\Delta t_3 = 0.0295 \text{ “}$$

As a consequence of the continually varying appearance of the echoes and of the fact that the time intervals in contrast to the round-the-world signals are very variable, it is possible to give only average values, but these averages are repeated with a fair degree of regularity. Fig. 6 shows particularly well how irregularly the reflections often occur. In this figure a round-the-world signal of great amplitude is also present. It is very helpful to have a round-the-world signal on the same record, since by its use the length of the emitted signal can be determined, as cannot always be done from the direct signal itself or from the short range echoes on account of blurring. The short range echoes would probably overlap even if much shorter dot-signals were emitted, since the reflections take place not only from

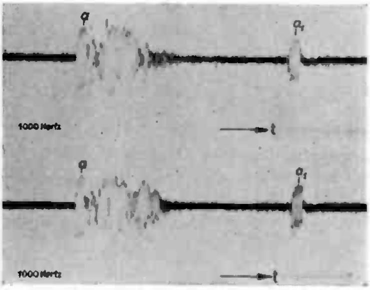


Fig. 6—Short range echoes received on non-directive antenna at Geltow, Nov. 15, 1928, 10:40 A.M., C.E.T., from AGA 1 (20,190 kc, or 14.86 m) in Nauen. Between the main signal a and the round-the-world signal a_1, which is of very great amplitude, the short range echoes merge together.

varying distances by discontinuous jumps, but also somewhat after the manner of peals of thunder. Nevertheless, there are also times when the short range echoes appear separated even when short signals of about 1/200 sec. duration are used. We have been particularly successful in making such records as these by using a directive antenna at the receiving station. An example of this is shown in Fig. 7, all three records having been taken from a single oscillograph film. The signal was received on a multiple antenna that was sharply directive toward the southwest. Nevertheless the amplitude of the direct signal from Nauen, which is located at a distance of about 30 km almost directly north from Geltow, is reduced to about a fifth part. On the other hand, the first short range echo appears particularly strong. On the whole, in addition to the round-the-world signal, seven short-wave echoes can be clearly recognized; the values of the time intervals were derived from many records, and the mean values are given in the following table, together with the corresponding distances in kilometers.

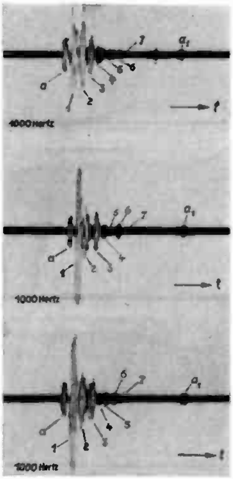


Fig. 7—Seven-fold short range echoes from AGA (20,090 kc, or 14.93 m), recorded with directive antenna in Geltow. In addition to the main signal a, the amplitude of which is reduced by the directive action of the receiving antenna, and the round-the-world signal a_1, seven short range echoes can be clearly distinguished.

As indicated in the last column of Table I, it was found almost always in the reception of AGA and AGA1 that the time intervals for a group of short range echoes were integral multiples of the time interval of the first echo. These regular time intervals, in which the short

TABLE I
TIME INTERVALS AND REFLECTION DISTANCES FOR SHORT RANGE ECHOES

Time Intervals (means)		Limits Seconds	Approximate Distance km	Approximate Multiples
Symbol	Seconds			
Δt_1	0.0105	0.085–0.012	3150	s_1
Δt_2	0.021	0.016–0.025	6300	$2s_1$
Δt_3	0.031	0.030–0.032	9300	$3s_1$
Δt_4	0.042	0.040–0.044	12600	$4s_1$
Δt_5	0.053	0.050–0.057	15900	$5s_1$
Δt_6	0.065	0.063–0.067	19500	$6s_1$
Δt_7	0.077	0.074–0.079	23100	$7s_1$

range echoes appear, lead to the conclusion that the waves are reflected several times between two layers. One of the reflecting surfaces must be the earth itself, while the other is a layer about 1,500 km in height. Short range echoes have also been observed by Taylor and Young, and they were investigated further somewhat later by Hoag and Andrew.[2] The time intervals given by them are of the same order of magnitude as our own and are in part in agreement therewith.

From the Nauen transmitter AGB (11,381 kc, or 26.36 m) short range echoes were also received at Geltow as indicated in Fig. 8. Hoag and Andrew have also found in Chicago evidence of short range

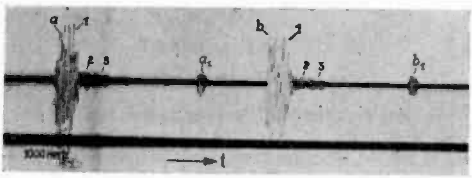


Fig. 8—Short range echoes recorded in Geltow from Transradio Transmitter AGB (11,381 kc, or 26.36 m), Nov. 16, 1928, 10:00 A.M., C.E.T. Between the main signal a and the round-the-world signal a_1 three short range echoes 1, 2, and 3 can be recognized.

echoes from this same transmitter. Their observed time intervals correspond throughout to those which we have measured, only with this limitation— that the time interval of 0.083 sec. given by Hoag and Andrew seems to correspond to a normal, indirect double signal. A comparison of the measured values is shown in the following table.

TABLE II

TIME INTERVALS IN SECONDS

AGB Received in Geltow	AGB Received in Chicago
0.006 sec.	0.005 sec.
0.015 "	0.006 "
0.028 "	0.016 "
0.055 "	0.083 "

An examination of several hundred oscillograms has shown that occasionally short range echoes occur in the reception of signals from distant stations. Fortunately, in such cases their amplitude is usually so small that distant communication, in contrast to communication over short distances, hardly suffers as a consequence. On the other hand, direct double signals can be the occasion for disturbances over great distances.

It should be remarked that it is extraordinarily difficult in the reception from distant transmitters to separate the short range echoes from irregularities in transmitting. In most cases an exact discrimination is possible only through the study of oscillograms made simultaneously at both transmitting and receiving stations. For this reason a considerable time may still elapse before the phenomena of short range echoes are completely explained.

[2] A. H. Taylor and L. C. Young, PROC. I. R. E., 16, 561; May, 1928 J. B. Hoag and V. J. Andrew, PROC. I. R. E., 16, 1368; October, 1928.

Proceedings of the Institute of Radio Engineers
Volume 17, Number 5 *May, 1929*

DETECTION CHARACTERISTICS OF SCREEN-GRID AND SPACE-CHARGE-GRID TUBES*

By
Frederick Emmons Terman
and
Birney Dysart
(Stanford University, California)

Summary—*This paper reports the results of measurements made to determine the grid-leak grid-condenser detection properties of screen-grid and space-charge-grid tubes. It is found that the rectifying properties of the grid circuit for the four-element tube used in these ways is about the same in character and magnitude as in three-element tubes with the same type of filament. The rectifying action in the grid circuit is largely independent of the voltages of the filament, plate, and second grid when compared at the same grid resistance. The space-charge-grid leak-condenser detector is superior to the screen-grid and most three-element grid leak-condenser detectors in that the space-charge-grid tube retains its full rectifying powers at adjustments which give full reproduction of the high notes. Grid detection with four-element tubes is superior or inferior to grid detection with three-element tubes primarily to the extent that audio-frequency amplification is more or less satisfactory in the two cases.*

Introduction

THE purpose of this paper is to give data on the grid-leak detection characteristics of four-element tubes, a continuation of a similar study made of three-element tubes[1]. The present results are expressed in terms of the detector voltage constant v as a function of grid resistance, for reasons that are explained in the original study,[1] and are obtained from bridge measurements[2] of dynamic grid resistance at grid voltages that differ slightly.

Performance

Screen-Grid Tube.— Fig. 1 (a) shows the connection for grid-leak grid-condenser detection with a screen-grid tube. The inner grid (G in the figure) is used here as the control grid. The rectification resulting from this connection is represented by Fig. 2, which shows the general type of v-R_g curve obtained from the screen-grid tube, while holding E_{sg} and E_p constant. The value of v rises rapidly for values of grid resistance less than 200,000 ohms. So long as the operating point is such that R_g is greater than 200,000 ohms, v has a value which may be considered to be fixed at -0.4.

* Dewey decimal classification: R 134. Original manuscript received by the Institute, December 3, 1928.

[1] F. E. Terman and Thomas M. Googin, "Detection Characteristics of Three Element Vacuum Tubes," Proc. I.R.E., 17, 149; January, 1929.

[2] F. E. Terman, "Some Principles of Grid-Leak Grid-Condenser Detection," Proc. I.R.E., 16, 1384; October, 1928.

Variation of E_p, E_{sg}, and E_f has only a small effect on the value of v even when on negative resistance parts of the characteristic. Thus the minor influence which the screen-grid potential has in de-

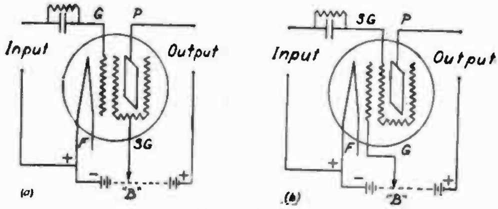


Fig. 1—Connection for Grid-Leak Grid-Condenser Detection with (a) screen-grid tube, and (b) space-charge-grid tube.

termining the detection characteristics is shown by Fig. 2. Variations in v resulting from a change in E_p are small and lie within the allowance for possible experimental error. Besides changing slightly with changes

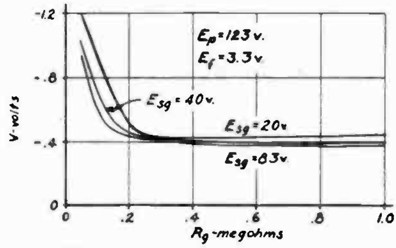


Fig. 2—Typical $v-R_g$ Characteristics of Screen-Grid Tube.

in E_p, E_{sg}, and E_f, it has been found that v may differ a little for individual tubes as is witnessed by Fig. 3.

Space-Charge-Grid Tube.— Fig. 1(b) shows the connection for grid-leak grid-condenser detection with a space-charge-grid tube.

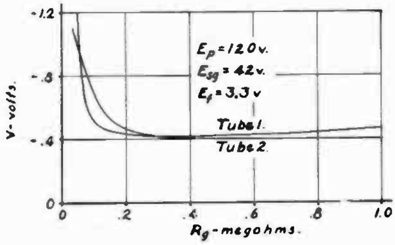


Fig. 3—Comparison of Detection Charactistics of Two Screen-Grid Tubes.

Here the outer grid (*SG* in the figure) is used as the control grid. The rectification resulting from this connection is represented by Fig. 4, which shows the general type of v-R_g curve obtained from the space-charge-grid tube, when E_g and E_p are held constant. For the whole range of R_g that was explored (50,000 to 2,000,000 ohms), v was practically constant at -0.4.

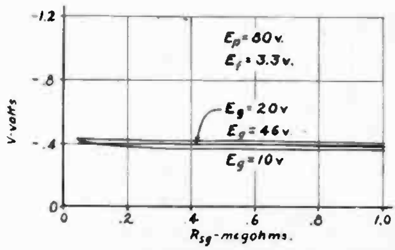


Fig. 4—Typical $v-R_g$ Characteristics of Space-Charge-Grid Tube.

The variations of v resulting from changes in E_p, E_g, and E_f are again of the same order of magnitude as for the screen-grid tube. Thus a change in E_p has no apparent effect on v, while the space-charge-grid potential is only of secondary importance as Fig. 4 shows. The value of v also may differ a little for individual tubes, as is shown by Fig. 5.

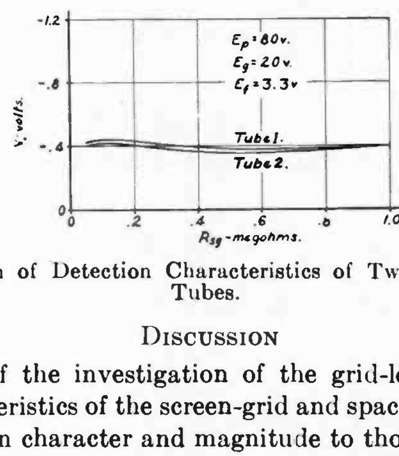


Fig. 5—Comparison of Detection Characteristics of Two Space-Charge-Grid Tubes.

Discussion

The results of the investigation of the grid-leak grid-condenser detection characteristics of the screen-grid and space-charge-grid tubes are very similar in character and magnitude to those results obtained for three-element tubes with the same type of filaments. The 201A type of tube with its thoriated tungsten filament is an example of such a three-element tube and in fact the 201A tube has a voltage constant slightly inferior to the voltage constant of the four-element tube now on the market.

In the case of screen-grid detection, the v-R_g characteristic curve rises rapidly above -0.4 for values of R_g less than 200,000 to 300,000 ohms; while the v-R_g characteristic curve for space-charge-grid detection remains constant at -0.4 to values of R_g less than 50,000 ohms.

(See Figs. 2 and 4.) This means that the space-charge-grid tube is superior to the screen-grid tube as a detector because it enables the high notes to be reproduced with much better quality without sacrificing sensitivity.

AVERAGE DETECTION CHARACTERISTICS OF A FEW TUBE TYPES

Type	v (Flat part)	R_g' at start of flat part (approximate)	μ	Highest undistorted frequency at full sensitivity*
201A	−0.47	150,000	8	3,500
227	−0.23	50,000	8	11,500
322(SG)	−0.40	250,000	300	2,200
322(SCG)	−0.40	Less than 50,000	60	Over 11,500

* For an effective grid condenser capacity of 0.0003μf.

The above table shows a comparison of the detection characteristics of several common tube types, including the screen-grid and space-charge-grid tubes, and is to be compared with Table I of the previous paper.[1]

USES OF FOUR-ELEMENT DETECTORS

Space-Charge-Grid Detector.— The space-charge-grid type of detector has the average grid rectifying action of the usual three-element tubes plus the advantage of space-charge-grid audio-frequency amplification, which is unexcelled for resistance or impedance coupling. In addition excellent quality may be secured at the highest audible frequencies without a sacrifice of rectifying properties.

Screen-Grid Detector.— The screen-grid type of detector also has about the same rectifying action on the grid side as the average tube. When systems are devised for making use of the tremendous amplification of the screen-grid tube at audio-frequencies this tube will be an excellent detector, although having the disadvantage of requiring a very small grid condenser if the high audio notes are to be reproduced with good quality and maximum sensitivity.

Proceedings of the Institute of Radio Engineers
Volume 17, Number 5 *May, 1929*

A DIRECT READING FREQUENCY BRIDGE FOR THE AUDIO RANGE, BASED ON HAY'S BRIDGE CIRCUIT*

By

Chester I. Soucy and B. DeF. Bayly

(Radio Laboratory, Dept. of Electrical Engineering, University of Toronto, Toronto, Canada)

Summary—*This paper describes the construction and operation of a direct reading bridge for measuring audio frequencies in the range from 50 to 5000 cycles per second and upwards. The circuit used is a modification of Hay's bridge for the measurement of inductance, and is obtained from it by the insertion of a variable resistance in the inductive arm. This resistance and another in the condenser arm are varied for balance. For the design as given, the frequency in cycles per second is determined by the number of ohms in the variable resistance plus that of the internal resistance of the coil in series with it.*

The bridge is portable, simple to construct, and makes use of external connection for the variable resistances to two standard decade non-inductive resistance boxes. Its operation is convenient and permits of a precision of balance of 0.1 per cent with a probable error of less than about 0.25 per cent.

THERE are several bridge circuits having reactive arms in which the balance is dependent upon frequency; but not all of these are suitable for a direct reading frequency bridge having a long range, absorbing negligible power, and offering facility of operation and construction.

In Hay's bridge[1] for measuring inductance, the equation for the inductance is nearly independent of frequency, but the equation for the resistance of the inductor is dependent upon frequency and a variable resistance.

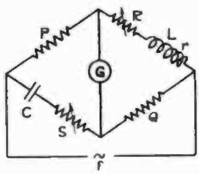


Fig. 1—P, Q—fixed non-inductive resistances; S—variable non-in-ductive resistances; R—variable non-inductive resistances (includes resistance r of coil); C—mica condenser.

This suggests a modification of the circuit by introducing a variable resistance in series with the inductance, as shown in Fig. 1.

For null balance in the detector:

$$PQ = (R + L\omega j)\left(S + \frac{1}{C\omega j}\right). \tag{1}$$

* Dewey decimal classification: R 201.6. Original manuscript received by the Institute, January 17, 1929. Presented before Toronto section, October 10, 1928.

[1] C. E. Hay, Inst. P.O. Engrs., November, 1912.

By equating real and unreal parts:

$$PQ = \frac{L}{C} + RS \tag{2}$$

and

$$\frac{R}{C\omega j} + LS\omega j = 0. \tag{3}$$

The two conditions given by (2) and (3) must be satisfied for balance of the bridge. Equation (2) signifies that, since P, Q, L, and C are constant in value, the product of R and S for any balance must be equal to a certain constant.

It may be shown mathematically and is proved experimentally that the two balances by adjustment of R and S are rapidly convergent and nearly independent of one another.

From (3).

$$\omega^2 = \frac{R}{CLS}. \tag{4}$$

Substituting from (2) to eliminate S:

$$\omega^2 = \frac{R^2}{CL\left(PQ - \frac{L}{C}\right)} \tag{5}$$

whence

$$= \frac{R}{2\pi\sqrt{L(PQC - L)}} = R \times \text{constant}. \tag{6}$$

Design

Equation (6) shows that the bridge may be so designed that the frequency is determined directly in terms of a single variable resistance, or by a convenient multiple of the number of ohms thereof.

For the use required of this bridge it was decided to make it direct reading, and to have maximum sensitivity at 1000 cycles per second. This requires that:

$$2\pi\sqrt{L(PQC - L)} = 1 \tag{7}$$

and that $L = 1/2\pi$ henry, and $C = 1/2\pi$ microfarad.

This choice of inductance and capacitance will make the phase angle of the reactive arms 45 degrees at 1000 cycles pers second. This is the condition for which a small change in either resistance or reactance will produce maximum effect upon the bridge balance.

To satisfy (7) the product of P and Q must be 2×10^6, and so that the impedance of all four arms shall be equal at 1000 cycles per second, both P and Q are chosen equal to $\sqrt{2}\times10^3$ ohms.

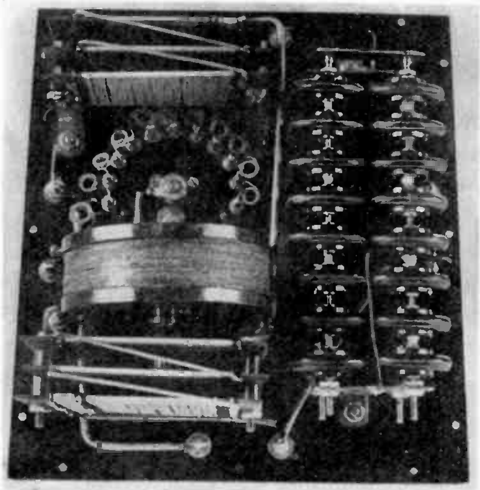


Fig. 2

Construction

Fig. 2 shows the construction employed, and Fig. 3 shows the instrument (with cover removed) connected to two external non-

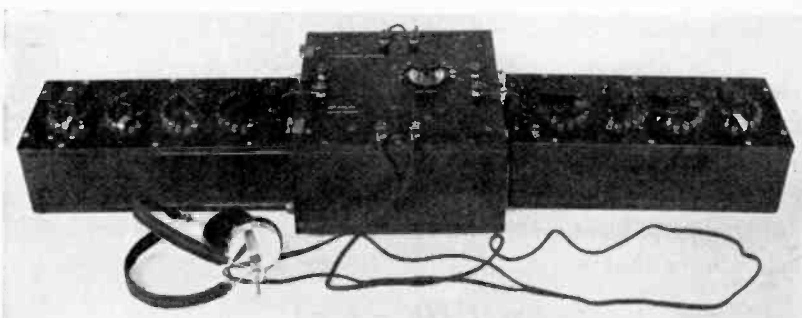


Fig. 3

inductive decade resistance boxes. The range of the instrument is from 50 cycles per second upwards, 5000 cycles per second, for practical reasons, being about the upper limit for convenient aural balance using telephones.

Below 1000 cycles per second it is convenient to use for the variable resistance R, a four-dial decade resistance box calibrated in hundreds, tens, units, and tenths, and for the variable resistance S a four-dial resistance box calibrated in thousands, hundreds, tens, and units. Below 100 cycles per second a fixed 10,000-ohm resistance can be connected in series with the S resistance box. For frequencies above 1000 cycles per second it is convenient to interchange the two resistance boxes.

Both the P and Q resistances are wound of No. 39 (B. & S.) S. C. manganin wire on three bakelite cards apiece, each 4 in.$\times$2 1/2 in.$\times$ 1/8 in. The winding is made in Ayrton-Perry fashion so as to be non-inductive.

The inductance coil L is wound of No. 26 (B. & S.) enamelled wire with 1465 turns. It is wound on a spool 2 1/8 in. in diameter and 3/4 in. wide, and the outside diameter is 3 5/8 in. Glassine paper 0.001 in. thick is used between layers. The resistance of this coil at 20 deg. C. measures approximately 45 ohms.

Since the resistance r of the inductance coil must be included in the resistance R, a bifilar series resistance of manganin wire is added to make r the convenient value of 50 ohms. This value is added to the resistance in the external resistance box at balance and the total number of ohms gives the frequency in cycles per second. Part of this additional resistance is connected between the contacts of a rotary switch to compensate in steps of 1 deg. C. for variations of the coil resistance with temperature between 15 deg. C. and 25 deg. C. This extra adjustment is a refinement which is necessary only for precise measurements and particularly for frequencies below 1000 cycles per second.

If the bridge were constructed complete with self contained variable resistances, the necessity of adding 50 ohms to the dial reading could be avoided by making the zero of the dials (of R) begin with 50 ohms, i.e., 50 cycles.

The distributed capacitance of this coil measures approximately $40\mu\mu f$. Since the variable part of the resistance R is increased with frequency, the slight increase in the coil resistance r due to capacity and eddy-current effects will be negligible.

A single high grade mica condenser of the value required could not be obtained readily, so sixteen $0.01\mu f$ units of a well known moulded type, matched to give the desired capacitance, were connected in parallel. As shown by Curtis[2] and others,[3] the variation in

[2] Curtis, Bulletin Bureau of Standards S-137.
[3] Dictionary of Applied Physics, Glazebrook, Vol. II, p. 139.

capacitance of a high grade mica condenser with temperature and frequency is small, i.e., of the order of 0.1 per cent over the audio range.

Small differences in the values of L and C from the theoretical values previously given are readily corrected for by altering either the P or Q resistance.[4]

Operation

It is undesirable that any ground should be applied to the bridge. If the a.c. source be grounded the insertion of a suitable transformer between it and the bridge is recommended. However, if the ground cannot be avoided least error will occur for the connection of the grounded line to the L and Q junction. If an amplifier be used to precede the detector a grounded filament connection should not be applied directly to the bridge.

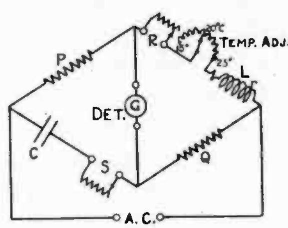


Fig. 4—Circuit of the Actual Instrument.

For very precise measurements a Wagner Earth with arms similar to the C S and Q arms and grounded at their junction may be connected across the source. This is adjusted in the usual manner after a preliminary balance of the bridge.

With careful balancing of the R and S adjustments a precision of adjustment in the R balance of 0.1 per cent can be obtained over a range of 50 to 5000 cycles per second. Due to possible variations in the capacitance of the condenser C and the limit of adjustment accuracy in the resistance boxes, and allowing for the balancing error, the probable error will be within 25 per cent. The precision and the accuracy of the balance will, of course, depend upon the detector used.

Between 200 and 2000 or 3000 cycles per second, telephones are satisfactory as a detector, and for ordinary work may be used directly with only a few volts applied to the bridge. For very accurate work or where the voltage of the unknown emf is low, or on the extreme ends

[4] After the preparation of this paper and the experimental development were complete, it was discovered that a bridge operating on the same principle but lacking some of the features of the authors' development and using different ircuit constants had been described previously in a Japanese paper: K. Kurokawa and T. Hoashi: *Jnl.* I.E.E., Japan, No. 437, pp. 1132–1138.

of the frequency range, a two-stage amplifier of good quality preceding the detector is useful.

Harmonics in the waveform being investigated are strongly in evidence when the bridge is balanced. At the very low frequencies, especially where the harmonics are much more audible than the fundamental they make it difficult to obtain a precise balance. The use of a good low-pass filter to eliminate harmonics is recommended.

To obtain the precision claimed it is necessary, below about 200 cycles per second, to make use of a vibration galvanometer as the detector, due to the insensitiveness of the ear and the telephones. Since this is a resonant device little trouble from harmonics is experienced. Given a pure waveform an amplifier and rectifying vacuum tube with microammeter, as recommended by Turner,[5] can be used to advantage as a visual form of detector.

Effect of Variation of L and C

Since the equation of the bridge used is $f=R$, it is desirable to know how R will vary with C, L, P, or Q, as errors in the original adjustment, or subsequent variation of these quantities, may affect the accuracy of balance.

From (2) and (4):

$$R=\omega\sqrt{L(PQC-L)} \tag{8}$$

$$S=\frac{1}{\omega C}\sqrt{\frac{PQC-L}{L}}. \tag{9}$$

Differentiation of (8) with respect to the several variables shows that a small change in P, Q, or C causes the same percentage change, in the same sense, in the value of R. However, for the particular choice of constants employed in this design which makes $(2L\text{-}PQC)=0$, this process shows that small changes in the value of L do not affect the R balance. This result is advantageous since errors in the measurement of the inductance L or variations in it are compensated for.

Differentiation of (9) with respect to L discloses the fact that a small change in the value of L affects the bridge by requiring the same percentage change, in the opposite sense, in the value of S.

To verify the last two statements experimentally, increments in inductance up to 3 per cent were added in series with the coil L, and to maintain balance S had to be decreased in the proportion predicted, while there occurred negligible change in the R adjustment.

[5] H. M. Turner, Bulletin of A. I. E. E. Symposium on High Frequency Measurements, May, 1927.

Differentiation of (9) with respect to C shows that the S adjustment is independent of small changes in the value of C. Since the capacitance C is likely to vary more in value with changes in temperature and frequency than the inductance, it might appear that the frequency should be determined preferably in terms of the resistance S. However, this arrangement would not be direct reading, and S must include the unknown resistance of the condenser. Fortunately the resistance of such a condenser varies approximately inversely as the frequency and likewise for the value of the S adjustment. Thus the resistance of a good mica condenser of the value employed is negligible at any frequency compared to the value of the resistance S required for balance.

In another report[6] further details of the operation of the bridge, especially for the less audible frequencies, are given. Also, its conversion by means of a double-pole double-throw switch for use as an ordinary Hay's bridge for measurement of large inductances is described.

[6] Bulletin School of Engineering Research, University of Toronto, 1929.

Proceedings of the Institute of Radio Engineers
Volume 17, Number 5 *May, 1929*

VOLTAGE SURGES IN AUDIO-FREQUENCY APPARATUS*

By
Elmer H. Fisher
(Stanford University, California)

Summary—*Transient voltages of over 2000 are shown to occur across the secondary when the normal plate current of a high inductance audio transformer is opened. The oscillograph and inverted vacuum tube are used to bring out further that these transients are oscillations of definite frequency and magnitude, depending on the primary current, inductance, and secondary distributed capacity. The manner of breaking the circuit has a minor influence, for in most cases no appreciable discharge takes place at the contacts.*

The effect of amplifier circuits on the transients is considered, and suggestions are made as to possible means of protection.

Introduction

IT is common knowledge that if the current through an inductance is broken, the collapse of the magnetic field may result in a tremendously high voltage in the windings. Audio-frequency transformers show no exception, and the magnitude and characteristic nature of their transients, as well as the effect of associated apparatus, make a subject well worthy of special study.

Consider a typical amplifier circuit such as Fig. 1. If the plate circuit of the first tube is opened at X there will be a sudden rise of

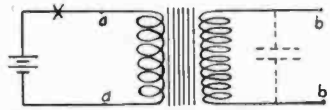


Fig. 1—Amplifier Circuit on Which Transients Were Measured.

voltage across the primary. A similar rise, greater by the turn ratio, will take place in the secondary.

If this secondary voltage is of such polarity as to make the grid of the following tube positive, a current will flow through the circuit and kill the surge. Should the grid be made negative, however, no current could flow from the transformer terminals and the voltag would be free to rise.

Under this latter condition the true nature of the transient is shown, and it is found that the distributed capacity is a determining factor. The voltage will increase to a value such that the magnetic energy formerly stored in the iron core is transformed into electro-

* Dewey decimal classification: R 390. Original manuscript received by the Institute, November 20, 1928.

static energy in the distributed capacity. This means that we have the ordinary parallel resonant circuit, as indicated in Fig. 1, with a perfectly definite maximum voltage. The surge is therefore the start of a highly damped oscillation in the secondary, but as soon as the voltage drops to zero and starts to rise in the opposite direction, the grid goes positive and kills the remainder of the oscillation.

In the second tube, when a negative surge reaches the grid, the plate current is stopped as effectively as if the circuit had been snapped open. There is no possibility of a loss of energy at the contacts, and the transient voltage is limited only by the distributed capacity. If this second transformer is of the modern, high inductance type, a transient voltage of over 2000 across the secondary is not uncommon.

Method of Measuring Transients

The measurement of these transients calls for a means which is rapid and at the same time uses practically no energy. These requirements are adequately met by the oscillograph and inverted vacuum tube[1], arranged as in Fig. 2.

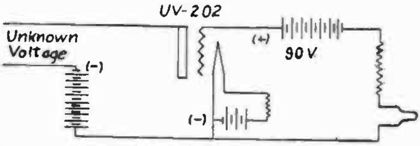


Fig. 2—Inverted Tube and Oscillograph Circuit.

In this the functions of the grid and plate are reversed and the grid is made positive, thus drawing a current sufficient to operate an oscillograph element. Any negative voltage applied to the plate then has an effect on the grid current equivalent to reducing the grid voltage by $1/\mu$ times as much as that of the plate.

A five-watt tube was used, with a grid battery of 90 volts, and sufficient resistance in the circuit to limit the grid current to 30 ma at zero plate voltage. These values gave a plate voltage-grid current curve that was quite straight over the greater part of the range. See Fig. 3.

Since the transients were oscillatory, it was necessary to provide a negative plate bias as shown in Fig. 2, to keep the plate from going positive when the oscillation reversed.

In all oscillograms the circuit was broken with an ordinary telegraph relay. When the relay was slowed down so as to barely open, any

[1] Terman, "The Inverted Vacuum Tube", Proc. I.R.E., 16, 447; April, 1928.

transient that would have gone above 200 volts or so, in the first transformer primary, was limited to that value by a discharge at the contacts. However, with normal operation of the relay, or upon the fairly rapid opening of a knife switch, the gap was apparently open before the voltage had time to build up to any appreciable amount.

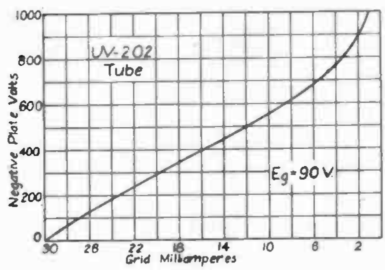


Fig. 3—Calibration Curve of the Measuring Apparatus.

Characteristics of the Transients

The nature of the transients is best shown by considering the transformers apart from the amplifier circuit. Oscillogram No. 1 (Fig.4) is typical of the results. The line just below the 60-cycle timing wave

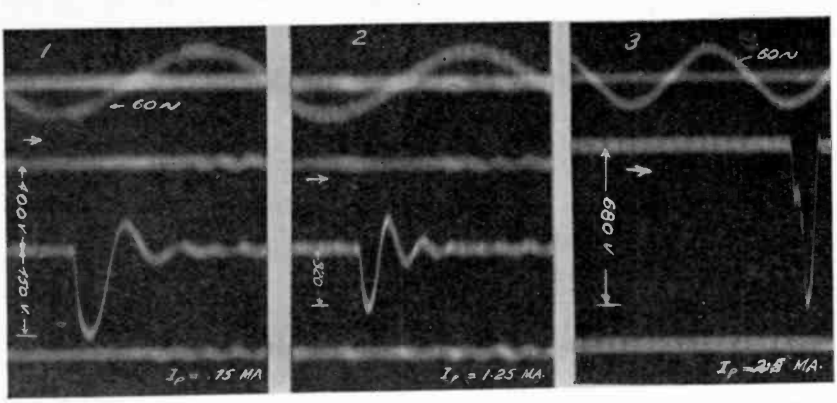


Fig. 4—Transients from a Transformer Not Connected in the Amplifier Circuit.

shows a grid current of 30 ma, i.e., zero plate voltage. In the middle line, in which the transient occurs, the grid current is reduced by a 400-volt plate bias. The bottom line shows zero grid current.

For this transient a current of 0.75 ma, as produced by one dry cell, was broken in the primary of a 3.5:1 transformer. The transformer had a primary inductance of 106 henries and was manufactured by the Ferranti Co. The secondary voltage (across *b,b*, Fig. 5) reached a value of 450 as shown. With a 6:1 transformer of 13 henries primary inductance, manufactured by the General Radio Co., the breaking of 1.25 ma gave a transient of 320 volts on the secondary (oscillogram No. 2).

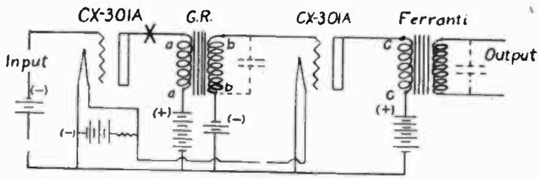


Fig. 5—Single Transformer as Used for Oscillograms 1, 2, and 3.

When the current in the primary of the Ferranti transformer was increased to the not uncommon value of 2.5 ma and the circuit opened, the surge could be measured only in the primary, and even for this the plate bias had to be removed. The voltage reached 680 (No. 3), which meant over 2000 in the secondary. The oscillation was killed as soon as the plate voltage of the inverted tube dropped to zero and started to go positive.

As already pointed out, the oscillation is apparently due to resonance between secondary inductance and distributed capacity. If this is so, it should be possible to determine the transformer constants and calculate the transient voltage.

The original inductive energy is readily obtainable from the relation

$$W = \tfrac{1}{2} L_p I_p^2. \tag{1}$$

At the peak of the voltage wave this inductive energy has been transformed into electrostatic energy so that

$$W = \tfrac{1}{2} C_s E_s^2. \tag{2}$$

Combining the two, and solving for secondary voltage

$$E_s = \sqrt{\frac{L_p}{C_s}}\, I_p. \tag{3}$$

The secondary distributed capacity may be determined from the frequency of oscillation on the oscillograms, according to the relation

$$C_s = \frac{1}{(2\pi f)^2 L_s}. \tag{4}$$

Losses are not considered, as the accuracy of the results does not warrant it. The voltages thus calculated, while of the same order of magnitude, show a variation of as much as 35 per cent on either side of the measured value. A more accurate determination of the distributed capacity would cut down the error somewhat, but it must be observed that the secondary will show a varying effective capacity, depending on the leads and tube connected to it. The above agreement is therefore sufficiently close for present purposes.

The results of tests on widely different types of apparatus are given in Table I, and show the general magnitude of transients to be expected.

TABLE I

Observed and Computed Values of Transients Caused by Opening the Primary Circuit

I_p ma	Circuit Tested	Inductance of Circuit henries	Freq. of Surge ~/sec.	Sec. Dist. Cap. (Calc.) μμf	Crest Volts (Calc.)	Crest Volts (Obs.)	Crest V. $I_p \sqrt{L}$
0.50	Sec.	1410	..	..	..	312	16.5
0.75	Ferranti	1300	..	..	..	450	16.7
1.00	3.5:1	1220	..	..	..	630	18.0
1.25		1160	300	213	550	850	20.0
0.50	Prim.	115	..	..	..	115	21
1.00		100	..	..	..	210	21
1.25	Ferranti	95	..	..	..	365	30
1.75	3.5:1	84	..	..	..	530	33
2.50		76	..	..	..	640	29
1.25	Sec.	470	500	216	215	320	11.8
2.50	G.R.6:1	465	..	..	..	650	12.0
3.0	Sec.	118	2000	54	350	265	8.1
6.8	R.C.A. 9:1	118	..	..	..	625	8.5
2.5	Phones W.E. 2200 ohm	4.5	2000	1480	100	75	14

For purposes of comparison, all voltages are divided by I_p and $\sqrt{L}$, and in that form a fair regularity is shown. The values of distributed capacity are about as could be expected, considering the concentration and physical size of the windings. It is also interesting to note that the transient voltage per ma is greater for the higher values of current; a point for which no explanation is at present apparent.

The Ferranti transformer had a small bypass condenser built in across the primary, but the fundamental wave of the transient showed no change when this was disconnected. However, oscillograms Nos. 3, 9, and 10 show small, high-frequency oscillations superimposed on the main wave which may be due to resonance between primary distributed capacity and inductance. These should be affected by the additional primary capacity, but were too irregular for a careful study.

Transients in Amplifier Circuits

The effect of the amplifier circuit on these transients is of considerable importance. Oscillogram No. 4 was taken across the points *a,a* of Fig. 1, and is the same as No. 2, except that the primary current (1.25 ma) was broken through the plate circuit and the secondary was connected so as to make the grid of the following tube negative. The additional tube capacity across the secondary makes the seecondary voltage about 10 per cent less than in No. 2, showing 290 volts across the grid-filament of the second tube. The frequency of oscillation is correspondingly a little lower, and the latter part is suppressed when the grid of the amplifier tube goes positive.

The effect on the following primary (points *c,c,* Fig. 1) is shown in oscillogram No. 5. The highly negative grid stopped the plate current as rapidly and effectively as if the circuit had been physically opened. The transient is of the same magnitude, per ma of current broken, as No. 3. With higher currents, the negative grid is even more effective for there is no possibility of a discharge at the contacts. The voltage of 530, multiplied by the turn ratio, represents the amount that is applied to the grid of the following tube.

Reversing the secondary of the first transformer kills the transient caused by opening the circuit. However, the closing then causes a disturbance in the secondary as shown in No. 6, which results in No. 7 in the following primary.

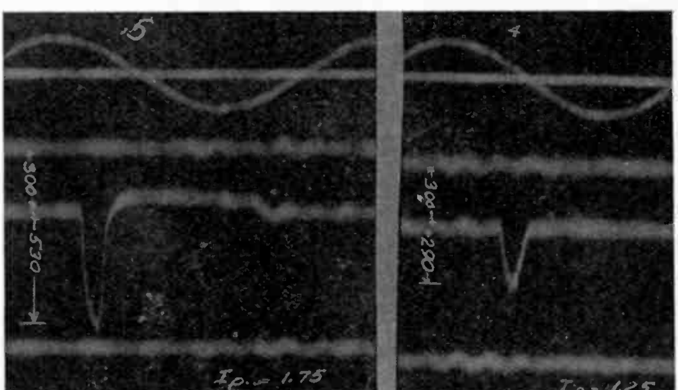


Fig. 6—Transients from Opening the Plate Circuit of an Amplifier.

These illustrations were taken with separate plate batteries in order to isolate the different effects. With a single battery, and the transformers connected according to the manufacturers' terminal markings, the transient No. 8 occurred across the primary of the second transformer, upon opening the common battery lead. It is a combination of several transients, and shows the same maximum value, per ma of current broken, as No. 3, taken across the same primary alone. When an attempt was made to reverse the connections on the secondaries, oscillation took place.

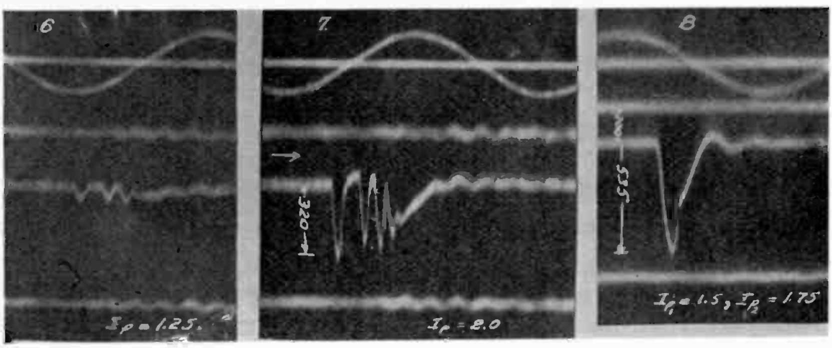


Fig. 7—Surges Caused by Closing Plate Circuit (Nos. 6 and 7) and by Opening a Common Plate Battery Lead (No. 8).

The current for tests on the amplifier circuit was obtained through a 201A-type tube without departing from recommended values of grid and plate voltage, and the secondary surges approached 2500 volts. This voltage would jump a gap of 3/16 in. The use of larger tubes, now quite common, makes possible even higher transients in coupling and output transformers.

One may say that the ordinary radio set does not have the plate circuit opened, except perhaps in testing. However, a small surge as

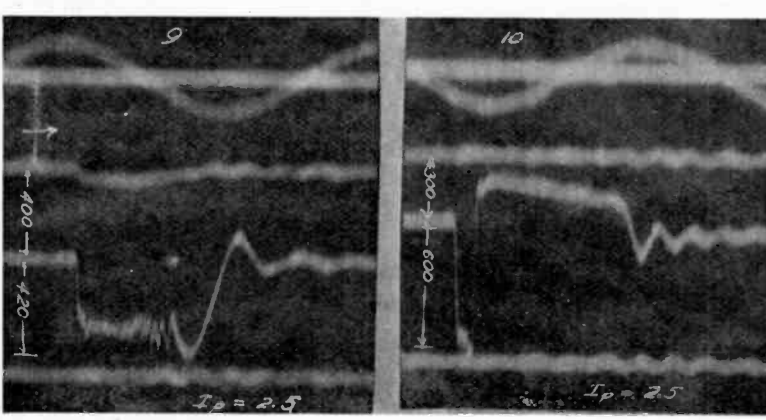


Fig. 8—Secondary Discharges across a Spark Gap.

the "B" eliminator voltage built up might be equivalent to opening the circuit in the last stage. Pulling a tube out of the socket with the filament on, or plugging speakers in, might easily cause transients of the magnitudes observed.

The transformers used for the oscillograms were well built and stood the stress, but one of a different make was found which apparently flashed across internally, thus giving an indication of why transformers sometimes "go noisy."

Protection Against Transients

A method of protecting transformers which appears both simple and effective would be to incorporate a small safety gap across the secondary. Oscillogram No. 9 shows a secondary transient that would normally have gone over 2000 volts, limited to 420 by a gap of the "horn" type, made of No. 18 wires and separated by a thickness of tissue paper. In this test the primary was connected direct to a 4 1/2-volt battery. In No. 10 the same current was broken with the gap slightly wider and the transformer connected back in the second stage of the amplifier circuit of Fig. 1.

As to the type of gap, a pair of points would have the least capacitance, but their appreciably slower action makes them undesirable. If the capacitance could be kept low enough, a small pair of plates separated by a perforated mica strip would be most effective.

Conclusion

The tests of this paper show that the transients in audio-frequency apparatus may go to seriously high values. Also they are of definite value and dependent on determinable factors. After further investigation, one should be able to take a few relatively simple measurements and predict quite accurately just what maximum voltage could be expected.

This gives a direct indication of insulation requirements. It might be further added that when the time comes that the radio industry shall be ready to adopt a set of standardization rules on the subject, there will be a definite foundation on which to work.

The writer wishes to express his sincere thanks to Dr. Frederick E. Terman, of the Stanford University faculty, for his valuable guidance and suggestions during the course of this investigation.

Proceedings of the Institute of Radio Engineers
Volume 17, Number 5 *May, 1929*

COLD CATHODE RECTIFICATION*

By
A. E. Shaw
(Ryerson Physical Laboratory, University of Chicago, Chicago, Ill.)

Summary—*Asymmetric conductivity in a gas between two electrodes can be accomplished without the use of a hot cathode, if the relative areas of the electrodes are widely different. This paper presents the results of an investigation of the discharge phenomena and asymmetric conductivity in a cold cathode rectifier tube containing two anodes and one cathode, when utilizing: (1) one anode and one cathode; (2) two anodes and one cathode; and (3) two anodes and one cathode and a low-pass filter circuit. The electrodes are situated in a gaseous atmosphere of helium and neon at 20 mm Hg. pressure.*

A theoretical explanation of the asymmetric conductivity is considered; (1) for the initial state of asymmetry; and (2) for the limiting state of asymmetry, the former referring to the phenomena of ionization by collision and the latter to the theory of normal cathode current densities.

Typical static characteristic curves are shown, from which can be anticipated the asymmetry shown by the oscillographic records.

Theoretical expressions are given for degree of asymmetry in half- and full-wave rectification, and data collected with reference to the performance of the rectifiers show that the theoretical values are closely approached by this cold cathode type of tube.

Introduction

THE subject of asymmetric conductivity in gases between physically dissimilar electrodes goes back many years. The bibliography at the end of this paper gives specific references to some of the early literature in this field. Of the more recent investigations, the work of Kneser,[1] Jolley,[2] Graetz,[3] and Günther-Schulze[4] is of particular interest. These investigators describe rectification devices which utilize one anode and one cathode, thus giving one-way asymmetry. Charlton[5] has secured design patents covering cold cathode devices possessing two anodes and one cathode, which thus give two-way asymmetry. The patents describe electric discharge devices of small and large current capacity, the capacity being determined by the surfaces available for heat radiation. One form of tube developed by Charlton is capable of handling effective potentials as

* Dewey decimal classification: R 149. Original manuscript received by the Institute, January 28, 1929.

[1] *Annalen der Physik*, 72, 519–24; 1923.
[2] "Alternating Current Rectification," 2nd Ed., p. 319; 1927.
[3] "Die Elektrizität," pp. 511–13, 1928.
[4] "Elektrische Gleichrichter und Ventile," 1st Ed., pp. 32, 130, 1924.
[5] British Patent Specifications 237, 235 and 237, 236, July 17 1924.

high as 2000 volts and currents of the order of several hundred milliamperes, with quite complete rectification.

This paper is the result of a more complete study of the influence, of variation in load, upon the voltage and current waves of a cold cathode rectifier tube with particular reference to the reverse current.

Theory

Cold cathode devices for rectification are essentially identical in that they embody a cathode, of relatively greater surface area than the anode, situated in a suitable gas of the proper density to produce the desired conductivity by ionization.

In considering the initial state of asymmetry i.e., when the first rectifying discharge occurs, we may recall a theory expressed by Townsend[6] in explaining the asymmetry he obtained in various gases, at low pressures, between two electrodes, one in the form of a tube and the other a rod coincident with the axis of the tube. Townsend attributed the unidirectional conductivity he obtained to the ionization

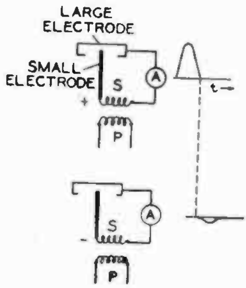


Fig. 1—Current Cycle in One-way Rectification.

by collision arising in the more intense electrostatic field near the rod or smaller electrode. This explanation, however, seems to be inadequate to account for the experimental fact to be discussed later, namely, that with a given pair of dissimilar electrodes, the initial direction of the rectifying discharge is not always dependent upon the polarity of the electrodes even though the ultimate direction is fixed. The mechanism of the initial state is not very well understood at the present time and whatever it may be, any theoretical explanation of it will have to take account not only of the nature of the gas used but also of the nature of the material[7] of the electrodes, a point not considered in Townsend's original theory. The next part of the theoretical discussion concerned with the limiting state agrees quite well with

[6] Townsend, Ionization of Gases by Collision, pp. 11–15.
[7] Holst and Osterhuis, *Phil. Mag.*, 46, 1117; 1923.

experimental fact, but it is restricted to currents that exceed the normal cathode current density, whereas a theory of the preceding state will have to explain the situation for currents less than or at most equal to the normal value.

In considering now the limiting state for unidirectional conductivity, we have recourse to the theory of normal cathode current densities and fall of potential. In regarding the operation of the rectifier having one large electrode and one small electrode, let us take the case of platinum electrodes in helium at 20 mm Hg. pressure.

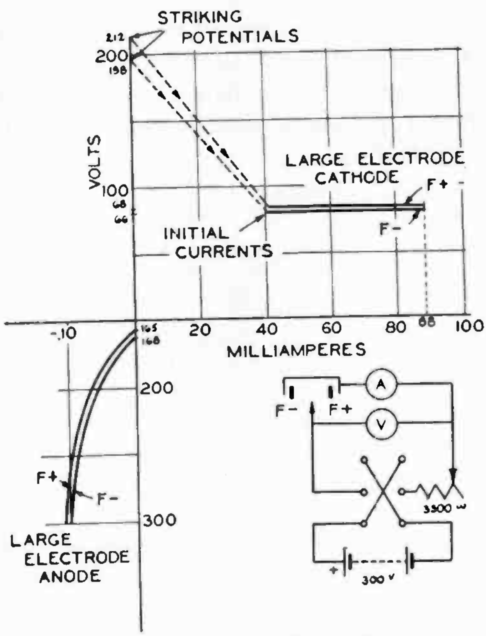


Fig. 2—D.C. Characteristic Curves.

The normal current density for a platinum cathode in helium[8] has been observed up to 4 mm Hg. pressure, and with the normal current density assumed approximately proportional to the square of the pressure, a current of 4.0 milliamperes per square centimeter is available at 20 mm Hg. pressure. For different cathode materials the normal current density is of the same order of magnitude as it is for platinum.

Let us now consider that alternation of the cycle during which the large electrode is cathode. During this interval, for increasing current values, the current per square centimeter of the cathode and

[8] Bär, *Handbuch der Physik* (Springer), Vol. 14, p. 211.

the cathode fall of potential remain practically constant, until the current becomes so large that the entire cathode surface is covered with the cathode glow. When this stage is reached the normal current density increases but is accompanied by a very great rise in the potential. With a normal current density of 4.0 milliamperes, a cathode having an area of 22.0 square centimeters will allow a current of 88.0 milliamperes to flow, with normal fall of potential. It is during this alternation in the cycle, i.e., when the large electrode is functioning as cathode, that the greatest current flow occurs and makes the large electrode positive with reference to the external circuit.

When the small electrode, with an area of 7.0 square millimeters, becomes cathode, during the next alternation in the cycle, the normal current stage ceases when 0.28 milliampere flows. A great increase of potential is required to force currents greater than this through the

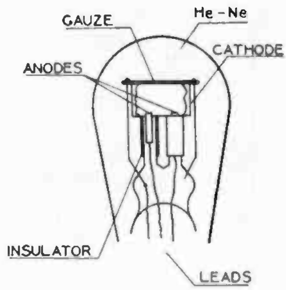


Fig. 3—Construction of Tube.

tube. In other words, the tube acquires a high resistance so that the maximum voltage applied to it causes a much smaller current to flow than when the large electrode is functioning as cathode. In the ideal case there is a complete suppression of the negative current, as we shall see later. This cycle of events is depicted in Fig. 1.

The static characteristic curves given in Fig. 2 for one tube enable us to predict this difference in current flow, depending upon whether the small or large electrode is cathode. Further interpretation of these curves will be given in connection with one way rectification.

In two-way asymmetry, using two small electrodes, the discharge is maintained alternately between the large electrode and either small electrode. This results in full-wave rectification.

Apparatus

A tube constructed as shown in Fig. 3 was used for the experiments. The electrodes are made of nickel and the tube is filled with a gaseous mixture of helium and neon[9] at 20 mm Hg. pressure. In general, for rectification purposes, the pressure of the gas in the tube may vary between 5–80 mm Hg. depending upon the characteristics of the gas which is employed, the operating potential, the current carrying capacity, and other tube conditions. Charlton[10] found that for helium a pressure[11] of 19 mm Hg. gave a minimum voltage drop between the electrodes he used. By introducing into the tube an alkali metal such

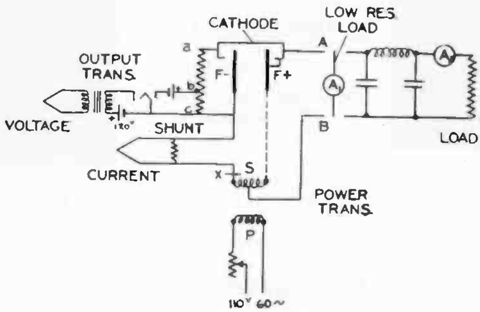


Fig. 4—Connection of Apparatus.

as caesium the voltage drop can be lowered still further. In the construction of the tube, the two small electrodes are placed sufficiently far apart or else placed on either side of the cathode which may be in the form of a disk. This prevents a discharge from taking place between the two small electrodes which would eventually change to an arc discharge.

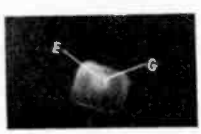


Fig. 5—Initial Glow Discharge. *E* is glow between *F*− electrode and cathode, *G* is glow through gauze.

The connection of the apparatus is given in Fig. 4, the tube being joined to a transformer, the voltage of which is varied over the range desired.

The voltage and current across the terminals of the tube were recorded photographically by means of a Duddell oscillograph. The

[9] Neon has a low cathode fall, hence a small starting potential.
[10] Loc. cit.
[11] What influence the pressure has upon the voltage and current curves has yet to be determined. This investigation was carried out at a constant pressure of 20 mm Hg.

voltage variations were taken from a part *bc* of a high resistance *ac* connected in parallel with two electrodes, i.e., a large electrode and a small electrode. The resistance[12] *ab* is 10^5 ohms and *bc* is 6×10^3 ohms. A Western Electric 201A input transformer is placed between

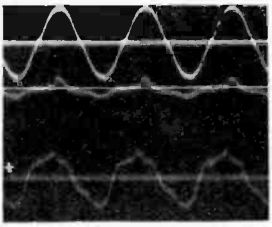


Fig. 6—Curves for 0.0004 Ampere Positive.

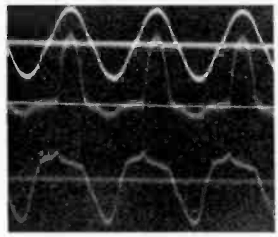


Fig. 7—Curves for 0.01 Ampere Positive.

the voltage element and the amplifier in order to eliminate from the oscillograph element the d.c. component in the plate circuit. This is necessary in order to keep the zero axis in place under normal conditions.

I. One-Way Rectification

The circuit connections for this experiment are shown in Fig. 4. The small electrode, $F+$, is shorted to the cathode, and ammeter A_1, in series with a low resistance load, is shunted across terminals $A-B$.

With 21.5 volts$_{eff}$[13] across the tube, a discharge, accompanied by a purplish glow,[14] appears in the region between the $F-$ electrode and the cathode. This discharge, the chief cause of luminosity of which is the negative glow, is the only discharge present in the tube at this

[12] It is important to note that with low resistances the magnitude of the reverse current is affected markedly by the value of this resistance. At the value of 10^5 ohms, the reverse current is not modified appreciably.

[13] Due to an apparent photo electron emission from the electrodes of this tube, this potential is less when the tube is exposed to the radiation from a 75-watt incandescent lamp. It is necessary therefore to exclude extraneous light when getting the potential values.

It may be mentioned that this apparently abnormally low voltage is probably due to the presence, on the electrodes, of alkali metals which operate to reduce the cathode fall. Charlton reports that the use of caesium oxide together with finely divided magnesium which is evaporated and deposited upon the inside of the tube will reduce the potential drop to one-half of what it is without the use of these. (For further data regarding the abnormal low voltage arc, cf. Holst and Osterhuis, loc. cit. Holst and Osterhuis, *Physica*, **4**, 42; 1924. Compton and Eckart, *Phys. Rev.*, pp. 139–146; Feb. 1925.)

[14] Although these glow discharges are alternating, they are seen as continuous due to persistence of vision.

potential. It is interesting to note that Crookes' dark space about one-half millimeter in width is perceptible near the cathode during this discharge. As the a.c. potential is raised, the glow becomes brighter but is still confined in the narrow space where the small

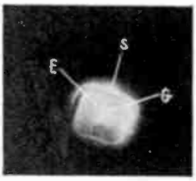


Fig. 8—Discharge at 0.01 Ampere.

electrode, $F-$, extends through the cathode. At a potential slightly in excess of the initial discharge potential, the ammeter indicates a reverse current of 0.0002 ampere. This reverse current is due to a rectifying action opposite in direction to the main rectified flow, which has not yet started.

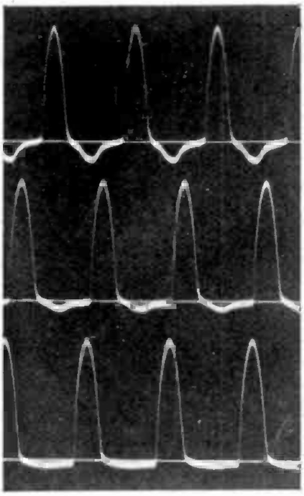


Fig. 9—Curves Showing Percentage Variation of Reverse Current with Load.

As already pointed out, this reversed rectifying action can be anticipated from the static characteristic curves given in Fig. 2. It is of interest to note further that with the tube, whose d.c. characteristics are given in Fig. 2, the negative stream or reverse current in both the positive and negative anode circuits starts at a much lower potential than the positive current. This enables us to anticipate the presence of reverse currents, preceding the positive currents which constitute the main rectified flow. Several tubes showed exceedingly small reverse currents and one tube required a lower striking potential for the positive current than for the reverse current. This indicates that the positive current preceded the reverse current and there was no initial reverse current. We can infer from this that the direction of asymmetry is apparently not fixed at the start thus throwing into question the ionization theory of Townsend, as already mentioned. The striking potential of all the tubes examined differed from one another as much as 25 per cent. The variation in the reverse currents is probably traceable to the differences in construction such as centering of the small electrodes in the hole in the cathode, inequalities in the deposits of alkali metals on the electrodes, etc.

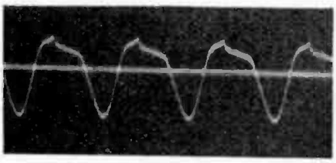


Fig. 10—Typical Voltage Curve.

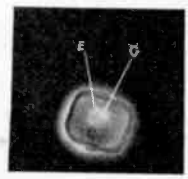
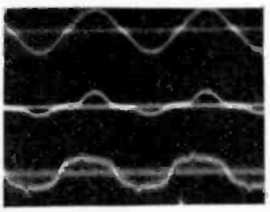


Fig. 11—Discharge at 0.05 Ampere.

If the a.c. potential is now raised to 28.5 volts$_{eff}$, the rectified stream suddenly reverses itself and the discharge from the $F-$ electrode extends over to the one side of the inner surface of the cathode. Fig. 5 shows the nature of the glow discharges. At this point, the meter indicates a positive[15] current of 0.0004 ampere. This is the initial value of the rectified current when the main discharge takes place to the cathode. When the main discharge sets in there is a sudden drop in the voltage across the discharge occurring at or near the maximum, as shown by the voltage curve[16] in Fig. 6. This continues to decrease while the positive current is building up, after which the voltage becomes negative. With a higher a.c. potential the positive current increases considerably, while the reverse current increases by only a small amount. Fig. 7 shows the curves for a rectified current of 0.01 ampere; and Fig. 8 the photograph of the corresponding glow phenomena. The reverse current does not change markedly with the

[15] In the actual experiment a middle zero instrument is best used.
[16] The sequence of events on all curves proceeds from left to right.

load, up to full load; nor does the curve of voltage variation across the discharge indicate any appreciable change from what it is for a load of 0.01 ampere. Current curves which show the percentage variation of the reverse current with loads of 0.01 ampere, 0.03 ampere, and 0.08 ampere, are given in Fig. 9. These curves were obtained with a variable shunt and from the practical disappearance of the



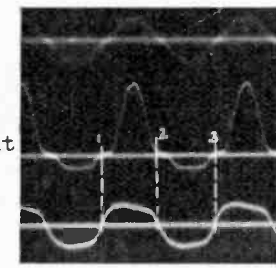


Fig. 12—Curves for 0.0004 Ampere Positive.

Fig. 13—Curves for 0.01 Ampere Positive.

reverse current, for constant positive amplitude, they show the very small variation of the reverse current[17] with load. Fig. 10 shows a typical voltage curve over a range of 0.015 to 0.08 ampere. This was taken at approximately full load. Fig. 11 shows the extent of the negative glow adjacent to the cathode for a load of 0.05 ampere.

II. Two-Way Rectification

In these experiments $F+$ was joined to the secondary of the transformer. The circuit connection is given in Fig. 4. The $F+$ electrode is disconnected from the cathode and is joined to the secondary of the transformer by means of the connection shown dotted. Under this condition the discharge is maintained alternately to the $F+$ and $F-$ electrodes. The reverse current is present but inappreciable.

When the a.c. potential reaches 18.0 volts$_{eff}$,[18] the rectifying discharge strikes with a positive current of 0.0004 ampere. Fig. 12 shows how the voltage and current vary with these currents. The voltage

[17] It is interesting to note that the reverse current can be studied in another way. Instead of shunting the increased current at higher loads, a rectifier tube with $F+$ shorted to the plate (cathode) can be connected into the circuit of Fig. 4 at X. With the cathode of this tube connected to the transformer terminal adjacent to X, the positive current is eliminated. This enables a study to be made of the reverse current for loads beyond the current capacity of the oscillograph. The effect which this may have upon the reverse current, however, makes this procedure questionable.

[18] This is one-half of secondary voltage as in preceding case.

wave shows a double break which is due to the discharge alternating between the $F+$ electrode and the $F-$ electrode. The current wave is taken in the $F-$ electrode circuit and shows a positive current slightly greater than the reverse current. When the current wave was taken in the ammeter circuit, it possessed two positive lobes, each one identified with the positive and negative breaks in the voltage wave. As the potential is raised to 66.0 volts$_{eff}$, the sharp breaks in the voltage wave

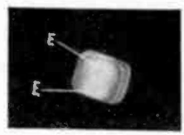


Fig. 14—Discharge at 0.01 Ampere.

disappear. Fig. 13 shows the curves for a current of 0.01 ampere at 66.0 volts$_{eff}$. The photograph of the discharge at this current is given in Fig. 14, which shows a glow at each of the small electrodes.

It is of interest to point out in Fig. 13 that at point 1, where the large electrode has become negative, there is a delay in the striking of the rectifying discharge until the potential has built up to a certain value. At point 2 it is seen that there is a tendency for the current to maintain itself even after the voltage has reversed. This post-arc

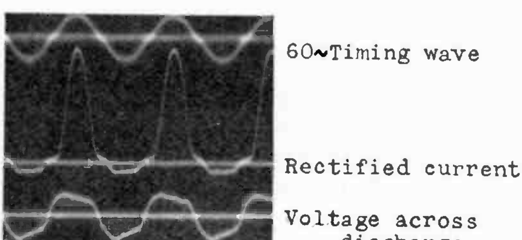


Fig. 15—Curves for 0.02 Ampere Positive.

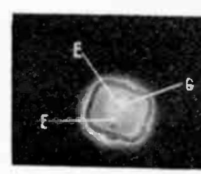


Fig. 16—Discharge at 0.05 Ampere.

conductivity[19] is probably due to a diffusion of positive ions into the large electrode even after the reversal of the voltage. At point 3 the reverse current ceases as soon as the large electrode becomes negative again, at the end of the cycle.

At 90.0 volts$_{eff}$ a current of 0.01 ampere is available. The current and voltage waves are given in Fig. 15. There is very little difference

[19] M. L. Pool, *Phys. Rev.*, 30, 848; 1927.

between the current and voltage waves at 0.01 ampere, and 0.02 ampere, as shown in Figs. 13 and 15. Fig. 16 shows the nature of the glow discharges at 0.05 ampere. With this current the glow extends outside the gauze cover, as would be expected from the theory of the "normal" cathode currents and fall of potential.

III. Two-Way Rectification with Filter Circuit

In these experiments the effect of the filter circuit on the reverse current is studied. The circuit connections are given in Fig. 4. The $F+$ and $F-$ electrodes are connected to the transformer. Ammeter A_1 with the low resistance load is disconnected from $A-B$ and the filter circuit, shown at the right, is connected to terminals $A-B$. This is a standard low-pass filter circuit embracing two condensers of about 2 μf capacity each, and an inductance of 20–30 henries. The load resistance is 3300 ohms.

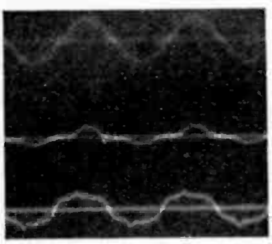


Fig. 17—Curves for 0.0009 Ampere Positive.

60~Timing wave

Rectified current

Voltage across discharge

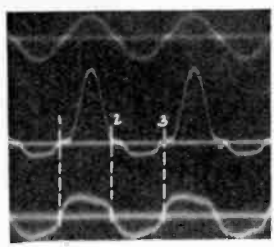


Fig. 18—Curves for 0.01 Ampere Positive and 26 Volts Direct Current.

The initial rectified discharge current appears suddenly and has a value of 0.0009 ampere, as measured at A_2. Before this there is a very small reverse current. The voltage and current waves are shown in Fig. 17. These waves are the same as those shown in Fig. 12, taken without the filter in the circuit. The effect of the filter is more clearly shown at higher current values.

As the a.c. potential is raised, the sharp break in each lobe of the voltage wave is less obvious, until at 68.0 volts$_{eff}$ and a load of 0.01 ampere, it is hardly visible. Under these conditions, the d.c. potential across the load is 26.0 volts. When the a.c. potential is 115.0 volts$_{eff}$ the load current is 0.02 ampere, and the d.c. potential is 50.0 volts. The voltage and current waves under these two conditions are given in Figs. 18 and 19. The discussion of points 1, 2, and 3 in Figs. 18 and 19 is similar to that given in connection with Fig. 13.

In the cases of one-way and two-way rectification without the filter, the voltage across the electrodes in the gas was the a.c. potential applied. With the filter in the circuit the d.c. potential across the load is added to the a.c. potential. The effect of this is to increase the

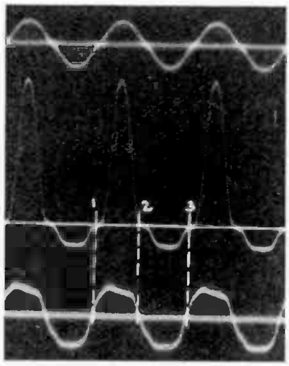


Fig. 19—Curves for 0.02 Ampere Positive and 50 Volts Direct Current.

magnitude of the reverse current as the d.c. voltage increases. This increase in the reverse current is clearly seen in Figs. 18 and 19, for the case of the filter, as compared with the earlier curves in Figs. 13 and 15. Further work remains to be done, using various filter combinations, in order to determine how the reverse current can be minimized, since it is the magnitude of the reverse current that fixes the rectifying characteristics of this type of tube.

Performance as Rectifier

The relative magnitudes of the positive current and the reverse current in a rectified wave are an indication of the degree of asymmetry. In one-way asymmetry, if the reverse current is entirely suppressed, half-wave rectification is complete. In two-way asymmetry, if there

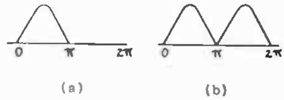


Fig. 20—Theoretical Half- and Full-Wave Rectified Cycle.

is a conversion, so to speak, of the negative lobe of the cycle into a full positive lobe without any reverse current, full-wave rectification is complete. These two conditions are shown in Fig. 20. In Fig. 20a, the interval $0 \rightarrow \pi$ represents the time during which the large electrode is functioning as cathode and the greatest current flow takes place. The interval $\pi \rightarrow 2\pi$ represents the time during which the large electrode is functioning as anode and is suppressing the reverse current. In Fig. 20b, there are two positive lobes resulting from the discharge alternating in only one direction between the cathode and either of the small electrodes.

The degree of asymmetry or degree of rectification is sometimes expressed as a percentage, although this does not clearly represent its meaning. Since the degree of rectification refers more exactly to the proportion of alternating current converted into direct current, Holler and Schrodt[20] prefer to define it as the ratio of the average value of the current, as read on a permanent magnet type of meter, to the root mean square value, as read on a dynamometer or thermal type instrument. In general,

$$\text{Degree of Rectification} = \frac{\text{d.c.}}{\text{a.c.}} = \frac{\text{Average value of current}}{\text{r.m.s. value of current}}$$

In half-wave rectification, for complete suppression of the negative lobe, we have, applying the mean value theorem to Fig. 20a,

$$\frac{\text{d.c.}}{\text{a.c.}} = \frac{\displaystyle\int_0^\pi \frac{I_m \sin\xi\, d\xi}{2\pi}}{\sqrt{\displaystyle\int_0^\pi \frac{I_m^2 \sin^2\xi\, d\xi}{2\pi}}} = \frac{2}{\pi} = 0.636$$

The value of the preceding ratio, 0.636, represents the maximum degree of half-wave rectification possible, when the circuit contains pure resistance and no counter electromotive force. Similarly for full-wave rectification which is theoretically complete we have,

$$\frac{\text{d.c.}}{\text{a.c.}} = \frac{2\displaystyle\int_0^\pi \frac{I_m \sin\xi\, d\xi}{2\pi}}{\sqrt{2\displaystyle\int_0^\pi \frac{I_m^2 \sin^2\xi\, d\xi}{2\pi}}} = \frac{2\sqrt{2}}{\pi} = 0.905$$

The value of this ratio, namely 0.905, represents the maximum degree of full-wave rectification possible under the above conditions.

In order to determine these two ratios, a permanent magnet type of ammeter and a thermogalvanometer are connected in series in

[20] Technologic Papers of Bureau of Stds. No. 265, Oct. 1924, p. 472.

place of ammeter A_1 in Fig. 4, the filter circuit being removed. With this arrangement the following data were collected:

	Half Wave a.c.ma = 100.0		Full Wave a.c.ma = 100.0	
Tube	d.c.ma	d.c./a.c.	d.c.ma	d.c./a.c.
1	50	0.50	78	0.78
2	61	0.61	84	0.84
3	58	0.58	78	0.78
4	59	0.59	80	0.80
5	60	0.60	84	0.84

Jolley defines a so-called rectification ratio as the ratio of the mean current in one direction to that in the other. This ratio is proportional, approximately, to the ratio of the surface areas of the large electrode and the small electrode. Hence the degree of asymmetry is proportional to these surface areas. In the two-electrode tube investigated by Kneser this ratio is 380/1, whereas in Charlton's and the one described in this paper the ratio is approximately 300/1.

The preceding table of data shows that the ratio of the surface areas does affect the degree of rectification since for tube 1, with the gauze cover and hence a smaller cathode area, the ratio of d.c./a.c. is noticeably smaller.

The author acknowledges his great indebtedness to Prof. Dempster, under whose direction this work was carried out, for the suggestion of the problem and for his help in the interpretation of the results. The author is also indebted to Dr. Hoag for his assistance, in many ways, during the course of the work.

Bibliography

This bibliography refers to some of the early literature dealing with the rectifying action of a gas discharge between large and small electrodes.

1. Gaugain, J. M. *Comptes Rendus*, 40, 640–42; 1855. Also consult Poggendorff's Annalen, 95, 163; 1855.
   This article considers the rectifying action between two balls in an evacuated chamber, one of which is covered with an insulating substance except for a small area. Called Oeuf Soupape or Soupape Electrique; that is, Electric Valve.
2. Riess, P. Poggendorff's *Annalen*, 120, 516–17; 1863. Plate IV. Also consult 4th Series Vol. 30.
   This article discusses the deflection of magnetic needles by the discharge of a Leyden jar after the discharge had passed through a rectifier consisting of a small and large electrode in air at a low pressure.
3. Poggendorff. Berliner Akademie der Wissenschaften, 801; 1867.
   The author discusses the idea that all Geissler tubes with electrodes of different form act as rectifiers.
4. Mascart, M. E. Traité d'Électricité Statique, 2, 115–16; 1876.
   In this treatise the author describes experiments which show the possibility of rectifying the discharge from an induction coil by means of the electric valve action of dissimilar electrodes in a gas.

5. Lehmann, O. *Annalen der Physik*, **56**, 325; 1895.
The author considers the rectifying action of a tube in which there is a small and large electrode.
6. Villard, M. *Comptes Rendus*, **128**, 994–96; 1899.
This article discusses the rectifying action of a gas discharge in a vacuum tube with dissimilar electrodes, such as a plate and a spiral, etc.
7. Schröter. Elektrotechnische Zeitung, 679, 689, 696; 1915.
Concerned with gas-filled tubes of modern type using rare gases.
8. Bareiss, M. *Zeitschrift für Technische Physik*, **11**, 449–51; 1927.
The author investigates the operation of several types of gas-filled rectifier tubes of modern design.

Proceedings of the Institute of Radio Engineers
Volume 17, Number 5 *May, 1929*

VACUUM-TUBE VOLTMETER DESIGN*

By
Harry R. Lubcke
(University of California, Berkeley, California)

Summary—*It is shown that for every input range and meter a set of optimum conditions exist, which insure maximum readability, economy, and minimum operating current. Equations are developed (and illustrated with several examples) for the rapid design of a meter for a predetermined range. Optimum conditions are imposed.*

The dependence of the range secured upon plate circuit impedance is shown and its variation with frequency explained. The procedure for eliminating frequency error up to and including radio frequencies is illustrated.

Perhaps no instrument has contributed more toward making the scientific design of radio receivers a practical reality than has the vacuum-tube voltmeter. It fills a position in the communications field of as great an importance as the current-operated voltmeter holds in power work. It has supplied a measuring rod where none before existed. It represents one of man's nearest approaches to the ideal voltmeter.

But despite its excellent characteristics and its extended usefulness, little has been done to make its design a straightforward process. All too often vacuum-tube voltmeter design, if it may be called such, has consisted of calibrating a heterogeneous assembly of parts with little regard for the range secured or the maximum performance obtainable from the setup. Jansky and Feldman[1] have made about the only advance out of the forest of cut-and-try methods with their equation for the maximum peak voltage measurable in a continuous two-range design.

For every desired range and tube a set of optimum circuit conditions exist, a fact not generally appreciated. It is possible to predetermine the circuit constants to give any desired range without extensive experimenting to find them. It is the purpose of this paper to consider optimum conditions in deriving certain equations, and to consider the effect of frequency on the results.

The Optimum Concept

Fig. 1 shows a typical vacuum-tube voltmeter circuit and Fig. 2 a family of curves giving its performance under various operating

* Dewey decimal classification: R 261. Original manuscript received by the Institute, January 18, 1929.

[1] Jansky and Feldman, "A Two-Range Vacuum Tube Voltmeter." *Jour* A.I.E.E., XLII, 126; February, 1929.

conditions. These curves represent the results of a considerable number of cut-and-try tests undertaken in the design of the low reading 199-tube meter shown in Fig. 4. That the range increases with the value of the plate circuit series resistor, R_p', is evident; due, of course, to the greater increase in plate voltage drop across the resistor with current as the R_p' value increases. The circles on curves *C* and *F* show

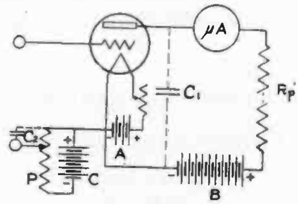


Fig. 1—Wiring Diagram of Vacuum–Tube Voltmeter.

the start of grid-current flow and indicate insufficient grid bias. Reference to the table of voltages accompanying Fig. 2 shows that an excess bias was used for curve *D*, requiring an abnormally large plate voltage to counteract it, and resulting in the plate meter reaching its maximum deflection before the limit of grid bias was approached. For certain other curves, as *A*, *B*, or *E*, the constants were more pro-

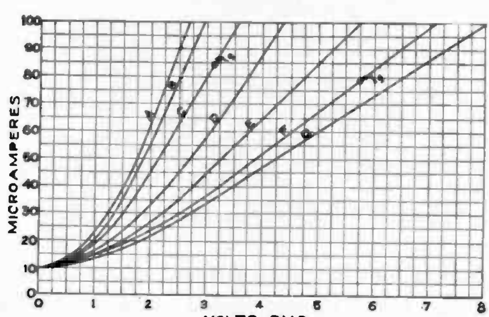


Fig. 2—Variation of Vacuum–Tube Range with Circuit Constants.

perly chosen, the grid bias being approached but not exceeded by the input wave, the plate voltage being normal, and the limit of plate meter deflection reached simultaneously with that of the grid bias.

TABLE OF VOLTAGES

Curve	Range, E	E_g	E_p	R_p'
A	2.7 v	−4.4 v	23 v	10,000 ohms
B	3.0	−4.6	23	25,000
C	3.6	−4.5	23	75,000
D	4.4	−9.0	48	100,000
E	5.7	−9.0	48	200,000
F	7.0	−8.7	48	300,000
G	8.0	−13.0	71	350,000

By reasoning further, the *optimum conditions* are seen to be that set of circuit constants wherein the desired range is spread over the whole indicating meter scale, wherein the minimum plate and grid potentials are employed, and wherein *the grid of the tube at no time becomes positive.* Maximum readability, economy, and true voltmeter action are thus assured. The importance of keeping the grid always negative is often underrated, but the effect of an appreciable operating current on the circuits used in communication work is altogether too potent to be neglected.

Design Equations

Starting with the theorem that the grid must always remain negative and recalling the fact that the peak value of a sine wave is 1.41 times its root-mean-square value we can write:

$$E_g = 1.5E \tag{1}$$

where E_g is the grid bias and E is the maximum r. m. s. voltage to be measured. The constant 1.5 is selected to allow in some measure for wave forms more sharply peaked than the sine wave.

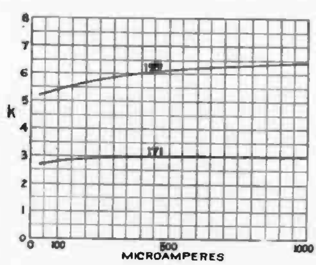


Fig. 3—Values of k for Various Maximum Plate Currents.

From the relation for the plate current of the tube, an expression for the value of the plate circuit series resistor can be secured, i.e., from

$$I_p = \frac{\mu E}{R_p + R_p'} \tag{2}$$

where I_p is the plate current, μ the amplification factor of the tube, R_p the tube plate impedance, and R_p' the plate-circuit series resistance.

Now I_p is the maximum reading of the plate meter minus the steady false zero reading for full scale deflection of the meter

$$I_p = Im - Io = I_p'. \tag{3}$$

Also, let

$$\mu = k \tag{4}$$

where k is the value of the amplification constant for very large values of grid bias.

Substituting (3) and (4) in (2) gives

$$I_p' = \frac{kE}{R_p + R_p'}$$

and

$$I_p' R_p + I_p' R_p' = kE$$

or

$$R_p = \frac{kE - I_p' R_p}{I_p'}. \tag{5}$$

The plate voltage required, E_p, is given quite closely by

$$E_p = kE_g. \tag{6}$$

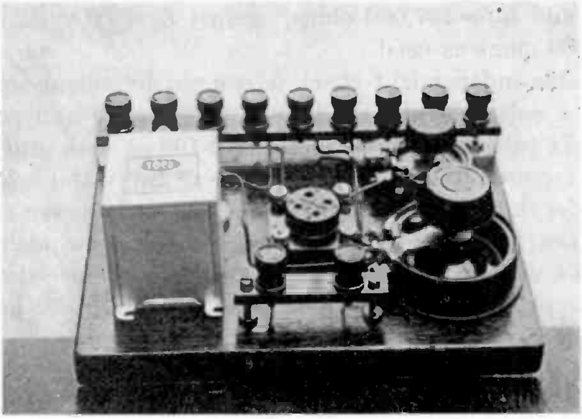


Fig. 4—Low-Range 199 Vacuum-Tube Voltmeter.

Values of k for 199 tubes and 171 tubes are given in Fig. 3 for various values of microammeter maximum range.

Experimental Verification

The validity of the foregoing equations can be established by a consideration of several examples. Take first the A range of Fig. 2 (which is later used in the analysis of the effect of frequency). A 199 tube and 0-100-μa plate meter are used to give an input voltage range of 0-2.7 v.

From (1)

$$E_g = 1.5 \times 2.7$$
$$= 4.05 \text{ v}$$

For the 199 tube and 0-100 microammeter $k=5.4$ from Fig. 3. Also $I_p'=100-10\ \mu a=0.00009a$. $R_p=150{,}000$ ohms. Therefore, in (5):

$$R_p'=\frac{5.4\times 2.7-0.00009\times 150{,}000}{0.00009}$$

$$=12{,}000 \text{ ohms.}$$

From (6)

$$E_p=5.4\times 4.05=21.8 \text{ v}$$

The values used, as given for curve A in the table accompanying Fig. 2, were: $E_g=4.4\ v$, $E_p=23\ v$ and $R_p'=10{,}300$ ohms, a larger plate voltage supplied by a new 22 1/2-v block requiring a correspondingly larger grid bias.

Calculations for curve E, a range of 5.7 volts, give: $E_g=8.7$ v $E_p=47$ v, and $R_p'=197{,}000$ ohms, against $E_g=9.0$ v, $E_p=48$ v, and $R_p'=200{,}000$ ohms as used.

A valuable independent check is secured by calculating the constants for a voltmeter designed by E. T. Dickey and published in 1927.[2] A 171 tube and a plate meter of 0-100 μa with grid biases of 9 and 90 v were used to give voltage ranges of 0-7 v and 0-70 v, respectively. Under the criteria of optimum conditions, however, these ranges are more nearly 0-6 v and 0-60 v, since the grid swings positive for values of 6.4 v and 64 v with a sine wave shape. Since the maximum value of the plate meter is not reached, $I_p'=85-10=75\ \mu a$, and $=80-10=70\ \mu a$.

For the 60-volt range

$$E_g=1.50\times 60=90 \text{ v} \tag{1}$$

$$R_p'=\frac{2.8\times 60-0.00007\times 10{,}000}{0.00007}$$

$$=2{,}390{,}000 \text{ ohms} \tag{5}$$

$$E_p=2.8\times 90=250 \text{ v} \tag{6}$$

The values given are; $E_g=90$ v, $E_p=250$ v, and $R_p'=2{,}400{,}000$ ohms. Calculations for the 0-6 v range give: $E_g=9$v, $E_p=25$ v, and $R_p'=214{,}000$ ohms, as against $E_g=9$ v (max.), $E_p=22.5$ v, and $R_p'=200{,}000$ ohms.

[2] E. T. Dickey, "Notes on the Testing of Audio Frequency Amplifiers," Proc. I.R.E., 15, 687; August, 1927.

The agreement between calculated and actual values is thus seen to be very good, a slight change in grid bias effected by adjusting the potentiometer to give the correct zero reading generally serving to make it exact. The simplicity of the calculations is apparent.

It is interesting to note that the plate impedance at which a tube is worked is very closely a constant for a given plate meter over the range of the plate and grid potentials used. For a 199 tube and 0-100-μa meter R_p is 150,000 ohms, very nearly, for values of negative grid bias from 4.4 to 13 v, corresponding to plate voltages from 23 to 71, and plate circuit series resistors from 10,000 to 350,000 ohms. For a

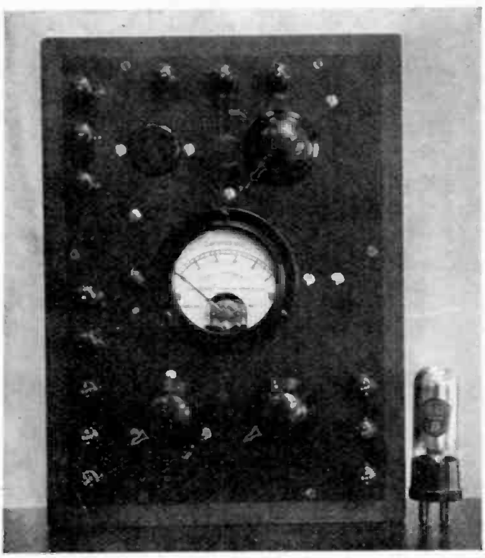


Fig. 5—Panel-Type 199 Vacuum-Tube Voltmeter.

199 tube and 1,000-μa meter R_p is 50,000 ohms, and for a 171 tube and 100-μa meter, 10,000 ohms. These are the values existent for full scale deflection.

Effect of Frequency

The design equations presented give the range secured for a plate circuit path of relatively low impedance, that resulting from resistance alone. Should frequency make the effect of inductive or capacitive reactance appreciable the range secured is noticeably affected. Fig. 6 shows the performance of the voltmeter shown in Fig. 4 at various frequencies without plate circuit bypassing.

It will be noted that changes in frequency from zero to radio frequencies cause variations in the voltage range secured of more than 25 per cent each side of the mean. Omitting for the moment the direct-current calibration, which never can coincide with any alternating-current range, three zones of calibration are observed; one secured with a low-frequency alternating current, the 60-cycle curve; a second secured at higher audio frequencies, the 500-, 5,000-, and 16,000-cycle curves; and a third secured at radio frequencies, the 1,000,000-cycle curve.

The variation of range with frequency is seen to be non-linear, increasing frequency first increasing the range and later decreasing it. This can be explained by considering the plate-circuit meter. A mi-

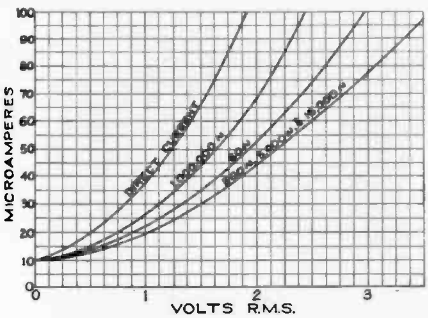


Fig. 6—Variation of Range with Frequency Plate Circuit *Not* Bypassed by Condenser C_1.

croammeter moving coil possesses considerable self inductance because of its many turns and close proximity to considerable iron, and it also possesses an appreciable distributed capacitance as a result of the concentrated nature of the winding and the shellac varnish used to impregnate it. At 60 cycles the effect of capacitance is negligible, but that of inductance has some effect on determining the impedance. At the higher audio frequencies the inductive reactance becomes considerable, and the plate current secured for a given input decreases, as is indicated by the lower position of this curve. This effect continues for higher frequencies, augmented by the parallel resonance effect of the inductance and distributed capacitance, until the resonant frequency of the combination is reached. Beyond this point the coil acts as a condenser and by the time radio-frequency currents are reached it offers little impedance to their flow. Similar effects in the resistor, batteries, and wiring all result in making the impedance a minimum and thus place the radio-frequency curve above the others.

Referring now to Fig. 7, it is seen that with the plate circuit bypassed by C_1 (4μf) and an incidental condenser C_2 (1μf) across the potentiometer of Fig. 1, the range secured is independent of frequency. The various points around the curve represent the plotting of data for 60, 500, 16,000, and 1,000,000 cycles, all of which are so nearly coincident that only a single curve can be drawn through them. The impedance of the plate circuit has been made a constant regardless of frequency by the use of the condenser.

The d.c. calibration differs from all a.c. curves for two major reasons. First, the value of the a.c. input wave read is the *root-mean-square* value as indicated by a.c. meters, whereas the plate-current meter, being a d.c. instrument, gives the *average* value of the plate-current wave, or the integrated semi-constant flow if a bypass condenser be used. The "average" value of a d.c. voltage is indicated by

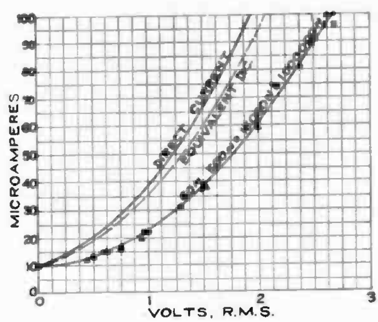


Fig. 7—Variation of Range with Frequency Plate Circuit Bypassed by Condenser C_1.

a d.c. voltmeter, consequently the d.c. voltage impressed is more effective in producing plate meter deflection by the ratio of r.m.s. to average values, or by the *form factor* of the a.c. wave. The "equivalent d.c." curve of Fig. 7 gives this correction. Secondly, the a.c. plate-current waves contain appreciable "negative" loops as a result of incomplete rectification which lowers its average value considerably, i. e., "negative" values below the 10 μa false zero reading. The d.c. input, on the other hand, does not produce any "negative" loops in the plate current but merely a steady d.c. value, which fact accounts for the discrepancy between the equivalent d.c. curve and the a.c. curves of Fig. 7.

Conclusions

Of the various combinations of circuit conditions possible for the attainment of a certain voltage range, there exists *one* set of optimum conditions. This set of conditions spread the desired range over the entire scale of the indicating meter, require the minimum plate and grid battery potentials, and at no time allow the grid of the tube to become positive. Through the use of the design equations developed above, the optimum conditions that will give any desired range are secured at once.

Variation of range with frequency is chiefly due to variation of plate-circuit impedance, a quantity affected mainly by the properties of the plate-circuit meter. Frequency error can be reduced to a negligible quantity by adequately bypassing the plate circuit with a "tank" condenser. Direct-current calibration curves cannot coincide with those for alternating current, because of an inherent discrepancy in the instrument indications amounting to the value of the form factor, and because of "incomplete" rectification, the latter factor usually being the greater of the two.

Proceedings of the Institute of Radio Engineers
Volume 17, Number 5 *May, 1929*

FIELD INTENSITY CHARACTERISTICS OF DOUBLE MODULATION TYPE OF DIRECTIVE RADIO BEACON*

By
Haraden Pratt

(Mackay Radio and Telegraph Company, New York City)

Summary—*Field strength characteristic relationships, applicable to the double modulation type of directive radio beacon when modulation is applied, are developed. Graphs showing the characteristic patterns which govern the indications of the receiving apparatus as it moves around in space about the transmitter are given for three typical sets of transmitter adjustments.*

The publication in the Proceedings[1] of details concerning the double modulation type of directive radio beacon as developed at the Bureau of Standards did not discuss the relationships necessary to obtain field intensity characteristic patterns when modulation is applied to each of the carrier frequency currents of the system.

It is necessary to know what such relations are in order to predict accurately what deflections the indicating device will exhibit at the receiving station for different positions in space around the beacon transmitter.

The writer has worked out these relations and they are presented here to complete the analysis as first set forth in the previous paper.

Reference is made to (4) on page 908,[1] which states that the field intensity observed at a fixed point P is,

$$E_p = AK[E_{s_1} \cos(\theta-\delta) - E_{s_2} \sin(\theta-\delta)] \qquad (1)$$

where E_{s_1} and E_{s_2} are the voltages supplied by the amplifiers to the two input coils of the antenna system goniometer, respectively.

When modulation is introduced, these two voltages can, for the general case, be written:

$$E_{s_1} = (E_0 + d_1 E_0 \sin \omega_1 t) \sin \omega t \qquad (2)$$

$$E_{s_2} = r(E_0 + d_2 E_0 \sin \omega_2 t) \sin(\omega t + \beta) \qquad (3)$$

Where E_0 is the maximum value of the carrier voltage supplied by the first amplifier.

r is the ratio of the maximum value of the carrier supplied by the second amplifier to that supplied by the first amplifier.

* Dewey decimal classification: R 526.1. Original manuscript received by the Institute, January 21, 1929.

[1] J. H. Dellinger and Haraden Pratt, Proc. I. R. E., 16, 890; July, 1928.

d_1 is the ratio of the maximum value of the voltage of modulation frequency $\omega_1/2\pi$ to E_o.

d_2 is the ratio of the maximum value of the voltage of modulation frequency $\omega_2/2\pi$ to rE_o.

β is the phase angle between the two carrier voltages.

These values when placed in (1) result in

$$E_p = AKE_0\Big\{\sin\omega t[\cos(\theta-\delta) - r\sin(\theta-\delta)\cos\beta]$$
$$-r\cos\omega t\sin\beta\sin(\theta-\delta)$$
$$+\frac{d_1}{2}[\cos(\omega-\omega_1)t - \cos(\omega+\omega_1)t]\cos(\theta-\delta) \qquad (4)$$
$$-\frac{rd_2}{2}[\cos(\omega t+\beta-\omega_2 t) - \cos(\omega t+\beta+\omega_2 t)]\sin(\theta-\delta)\Big\}$$

which is the general expression for the field intensity at the receiving point.

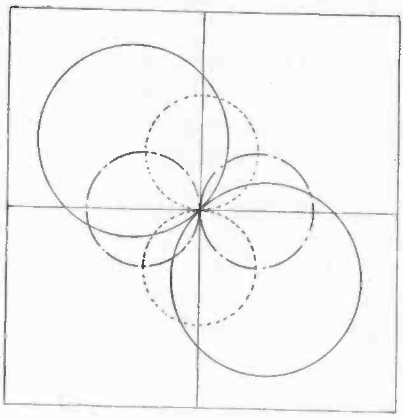


Fig. 1—Field Intensity Patterns Showing Carrier and Both Sets of Sidebands of Double Modulation Beacon for the Case Where the Two Carrier Voltages Supplied to the Antenna Systems Are Equal and in Phase.

Several special cases of this general relationship are of interest, particularly those representing possible operating conditions. One usual operating condition is offered by the case where the two carrier voltages have the same amplitude and are in phase. Then $r=1$, $\beta=0$, and

$$E_p = AKE_0 \left\{ \sqrt{2} \sin \omega t \sin \left(-\delta - \frac{\pi}{4} \right) + \frac{d_1}{2} [\cos (\omega - \omega_1)t - \cos (\omega + \omega_1)t] \cos (\theta - \delta) - \frac{d_2}{2} [\cos (\omega - \omega_2)t - \cos (\omega + \omega_2)t] \sin (\theta - \delta \right\} \quad (5)$$

Fig. 1 shows the field intensity patterns for this case, the radius vector being proportional to the field intensity for any angle in space referred to the radio-beacon transmitter. The solid line graph represents that of the carrier which is indicated by the first term of the equation, and the dot-dash and dotted graphs those of the sidebands resulting from the two modulating frequencies respectively, indicated by the two other terms of the equation.

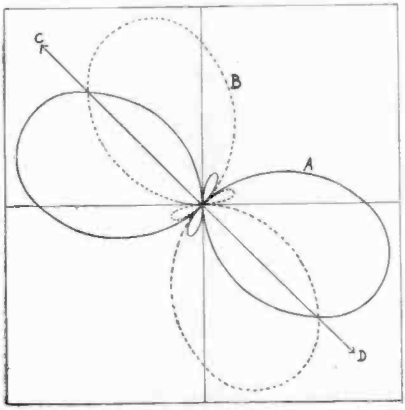


Fig. 2—Field Intensity Patterns Showing Reed Indicator Deflections for the Conditions Shown in Fig. 1.

Since the reed course indicators developed for use with this type of radio-beacon signal operate as a result of the low-frequency voltages produced by the beating in the radio receiver of the sideband frequencies upon that of the carrier, they will respond to space pattern characteristics as shown in Fig. 2, which is easily derived from Fig. 1. The solid graph corresponds to the voltage available for the operation of one reed, and the dotted graph that for the other reed. No corrections have been allowed to care for any non-linearity which the radio receiver circuits may introduce, for example by a non-linear detector. The courses are shown at C and D. Practically no deflections occur in the directions at right angles to these courses. The sharpness of the course indications can be estimated from the patterns.

This operating condition appears to be the most favorable so far investigated. The simplification resulting from only two courses being produced is of great advantage.

The case where the two carrier frequency voltages are unequal and in phase is of interest. Then $r<1$, $\beta=0$, and

$$E_p=AKE_0\Big\{[\sin\omega t[\cos(\theta-\delta)-r\sin(\theta-\delta)]$$
$$+\frac{d_1}{2}[\cos(\omega-\omega_1)t-\cos(\omega+\omega_1)t]\cos(\theta-\delta)$$
$$-\frac{rd_2}{2}[\cos(\omega-\omega_2)t-\cos(\omega+\omega_2)t]\sin(\theta-\delta)\Big\}. \quad (5)$$

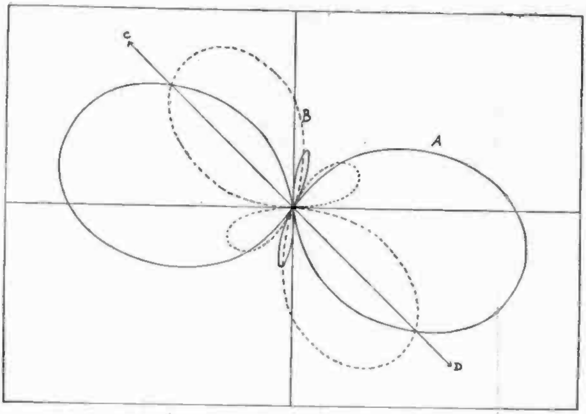


Fig. 3—Field Intensity Patterns Showing Reed Indicator Deflections for the Case Where the Two Carrier Voltages Supplied to the Antenna Systems Are Unequal but in Phase.

Fig. 3 shows the patterns for reed deflections for a typical set of conditions coming under this case. It will be noted that this results in an unsatisfactory operating condition, the courses not being well defined from the standpoint of reed deflections.

By suitable coupling means from the master oscillator to the two output circuits, one of the carrier voltages can be advanced in phase beyond that of the other. The case where the two carrier voltages are equal in amplitude but in phase quadrature results in a different field intensity pattern, the resultant radio carrier voltage vector rotating in space so that at all points equidistant from the transmitter, the field intensity changes periodically in time at radio frequency, but at the same amplitude. Here $r=1$, $\beta=\pi/2$, and,

$$E_p = AKE_0\left\{ [\sin \omega t \cos (\theta-\delta) - \cos \omega t \sin (\theta-\delta)] + \frac{d_1}{2}[\cos (\omega-\omega_1)t - \cos (\omega+\omega_1)t] \cos (\theta-\delta) - \frac{d_2}{2}[\sin (\omega+\omega_2)t - \sin (\omega-\omega_2)t] \sin (\theta-\delta) \right\}. \quad (7)$$

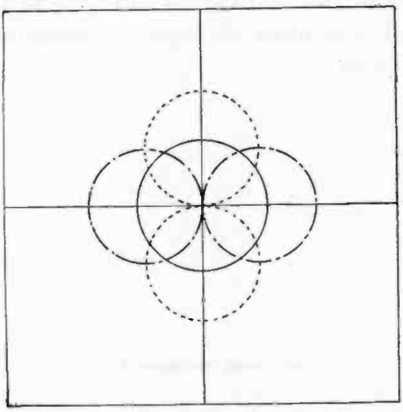


Fig. 4—Field Intensity Patterns Showing Carrier and Both Sets of Sidebands of Double Modulation Beacon for the Case where the Two Carrier Voltages Supplied to the Antenna Systems Are Equal but in Quadrature Phase.

The space pattern for this case is shown in Fig. 4, and the variation of the audio-frequency intensities producing the reed deflections derived from it is shown in Fig. 5. Four courses result. It is interesting

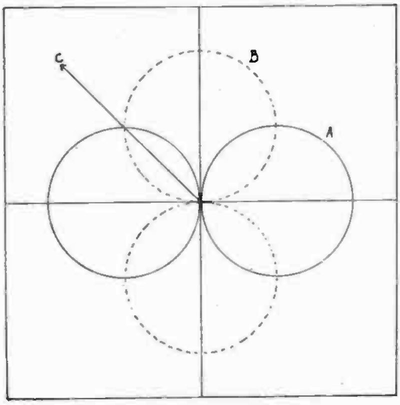


Fig. 5—Field Intensity Patterns Showing Reed Indicator Deflections for the Conditions Shown in Fig. 4.

to note that since the carrier is of equal strength at all points, this arrangement might also permit the use of the beacon for some other purpose, for example with direction finders installed on aircraft, using the heterodyne method of reception.

The relations given for the last case are, of course, subject to the variations discussed in (17) and (18) of the original paper for which allowance must be made.

Relations between the two carrier currents other than those discussed can be readily studied through examination of the resulting field intensity patterns.

Proceedings of the Institute of Radio Engineers
Volume 17, Number 5 *May, 1929*

LOGARITHMIC SCALE FOR BEAT-FREQUENCY OSCILLATOR*

BY
E. R. MEISSNER
(Federal Telegraph Company, Palo Alto, California)

Summary—*The equation governing the shape of a condenser's plates, which if placed in a beat-frequency oscillator would give a logarithmic frequency scale, is developed.*

BECAUSE of the ease with which their frequency can be varied and because they make it continuously variable, beat-frequenyc oscillators are rapidly gaining favor. A change in frequency is accomplished by simply changing the capacity setting of one variable air condenser. Its scale can be calibrated directly in frequency. This saves the operator a great deal of time and the chances of error are greatly reduced.

It has become general practice to plot audio-frequency curves and sound pressure curves on semi-log coordinate paper. This is in order that the low end of the frequency scale will be spread out. By doing this the low frequencies can be plotted to the same number of significant figures as a frequency ten or a hundred times higher. Likewise in setting the frequency of a beat-frequency oscillator it is very desirable to be able to set say ninety cycles to the same number of significant figures as nine hundred or nine thousand. This will be possible if the frequency scale is a logarithmic one.

Let us consider the shape of a condenser plate which will give a logarithmic frequency scale. The condition to be satisfied is

$$\frac{d(\log f)}{d\theta} = K \qquad (1)$$

Where θ = the angle through which the condenser is rotated
K = a constant
and f is the audio frequency
Now $f = f_1 - f_2$ (2)
where f_1 equals a constant frequency and f_2 is a variable frequency. The frequency f_2 will depend upon the circuit constants.

$$f_2 = \frac{1}{2\pi\sqrt{LC}} \cdot \qquad (3)$$

* Dewey decimal classification: R344.8. Original manuscript received by the Institute, December 6, 1928.

As C will be the only variable we can write

$$f_2=\frac{D}{\sqrt{C}} \qquad \text{where} \qquad D=\frac{1}{2\pi\sqrt{L}}. \tag{4}$$

Substitute (4) in (2)

$$=f_1-\frac{D}{\sqrt{C}}. \tag{5}$$

Substitute (5) in (1) and integrate

$$\log\left(f_1-\frac{D}{\sqrt{C}}\right)=K\theta+k. \tag{6}$$

The constant of integration k can be determined from the relation
When $\theta=0$
$C=C_0$
C_0 equals the effective capacity in the circuit when θ equals zero.
Hence $(f_1-D/\sqrt{C_0})=f_0=$ the lowest audio frequency the oscillator is designed to produce.

Thus
$$k=\log\left(f_1-\frac{D}{\sqrt{C_0}}\right)=\log f_0. \tag{7}$$

Solve (6) for C

$$f_1-\frac{D}{\sqrt{C}}=\epsilon^{K\theta+k} \tag{8}$$

or

$$C=\frac{D^2}{\left[f_1-\epsilon^{K\theta+k}\right]^2}. \tag{9}$$

Let us now turn our attention to the capacity C. It is composed of the capacity of the variable condenser plus the rest of the effective capacity in the circuit which has been defined above as C_0
Let $C_c=$ Capacity of variable condenser.

Then $C=C_c+C_0.$ (10)

Now the capacity of a flat plate condenser is proportional to its area

$$C_c=BA \tag{11}$$

neglecting edge effects, where A is the area of the plates and B is the proportionality factor.

Where the movable plates are attached to a shaft the active plate area is: (See Fig. 1)

$$A = \frac{1}{2} \int [r^2 - r_1^2] d\theta . \tag{12}$$

Substituting (11) and (12) in (10) gives

$$C = C_0 + \frac{1}{2} B \int [r^2 - r_1^2] d\theta . \tag{13}$$

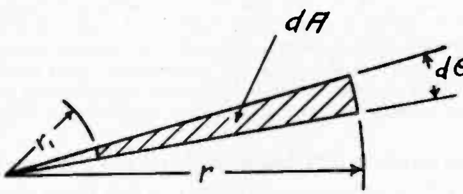


Fig. 1

Differentiate (13) with respect to θ

$$\frac{dC}{d\theta} = \frac{B}{2} [r^2 - r_1^2] . \tag{14}$$

Differentiate (9) with respect to θ

$$\frac{dC}{d\theta} = \frac{2KD^2 \epsilon^{K\theta+k}}{[f_1 - \epsilon^{K\theta+k}]^3} \tag{15}$$

We can now equate (14) and (15) and solve for r

$$r = \sqrt{\frac{4KD^2 \epsilon^{K\theta+k}}{B[f_1 - \epsilon^{K\theta+k}]^3} + r_1^2} . \tag{16}$$

Thus the radius of the plate for any value of θ is determined.

Proceedings of the Institute of Radio Engineers
Volume 17, Number 5 *May, 1929*

RADIO INTERFERENCE*

By
JAMES G. ALLEN
(Avalon, Penna.)

Summary—*The radio interference situation is rapidly becoming so serious as to make improvements in both methods of detection and methods of elimination absolutely imperative.*

The most effective method in interference detection is that combining the good features of the intensity method, with the circuit selection features of the directional method, coupled with extensive experience, both in the field and in the laboratory.

A light, self-contained, compact, unidirectional receiver equipped with a visible indicating audibility meter is the proposed instrument most desired for this work.

The design of filter systems intended to drain interference from circuits should incorporate suitable impedances at points where reflection is likely to occur.

RADIO interference has been with us ever since the inception of radio, but it is only recently that it has been receiving intensive study by the majority of central station engineers.

The first receiver, having few tubes and inefficient design, would not pick up noises from any great distances. Operators were hindered at times by interference, but the broadcast listeners regarded the radio noises in a very tolerant manner on account of the novelty of the entire radio idea. The novelty rapidly wore off and demands were made for the elimination of all noises. This demand has built up in proportion to the number of receiving sets in use, times average set sensitivity, and times a certain factor representing the proportion increase in the use of electrical appliances capable of producing oscillating discharges or surge effects.

The problem of radio interference has grown at such a rate that adequate consideration and development work have been impossible. Radio reception has become one of the greatest sources of enjoyment in life for the average person, and as an inevitable result higher standards of clear reception will soon be demanded.

Radio interference is a general term applied to anything which prevents perfect radio reception.

It is primarily applicable to noises from external sources, but it is also applied by some writers to other factors which interfere with receptions, such as fading, noises produced by receiver defects, and noises produced in eliminators and run down batteries, loose ground clamps, or bad antenna contacts.

* Dewey decimal classification: R170. Original manuscript received by the Institute, February 15, 1929. Presented before meeting of Pittsburgh section, January 15, 1929.

Of the noises from external sources there are several classes:

(a) Static or atmospheric
(b) Station heterodyning
(c) Regenerative squeals
(d) Sparking apparatus

The work of interference detection and elimination is concentrated on the latter class. There is a great difference between an arc or uninterrupted current flow as used in welding, arc light circuits, and electric furnaces and the interrupted arc-overs across insulating mediums encountered in nearly all noise producing apparatus. The first group

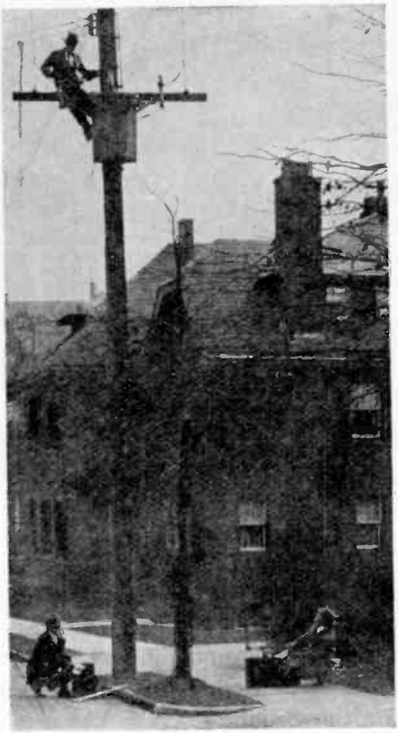


Fig. 1

uses a steady electronic flow with practically no tendency toward oscillations and few surge effects. The latter group has interrupted electronic movements productive of damped or sustained oscillations or of surge effects, the character of these depending on the constants of the connected circuits, the strength of currents broken, and the gap distance. The constants of the circuits include all nearby capacities, the high-frequency surge impedance of each line, adjacent inductances, and the included resistances. These are found in practice to be of such complex nature that only in the simplest cases can the results be predicted.

It may help one to visualize a minute spark as producing a terrific racket in your radio by thinking of it as a small spark transmitter similar in principle to those used on nearly all ships a few years ago. Though the spark is perhaps much smaller the distance is so much less,

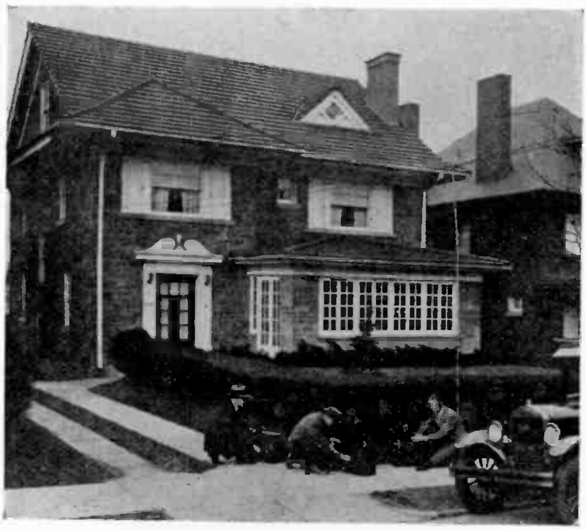


Fig. 2

and instead of signal strength diminishing as the square of the distance as in radiation over short distances, the signals are carried along the supply wires with much less diminution. This is very noticeable on some power lines where the noise level is within 40 per cent of average value at any point on the circuit.

A common idea among radio investigators was that the correct method of running down interference should be the same as that used in locating a spy's transmitter in wartime, namely to use a loop set and plot lines of maximum signal on a map. The common point of convergence should then be the source of disturbance. No such simple scheme can be used in 95 per cent of the cases. A loop picks up most of its signal by magnetic induction from the nearest lines. Whenever the wires turn a corner, the maximum effect turns the corner with it, thereby hopelessly confusing the investigator.

The second method tried is still in use by many investigators, and is generally known as the intensity method. In this system a careful survey is made of the suspected region and the intensity of field noticed

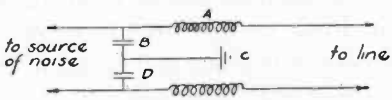


Fig. 3—Universal Filter Circuit Applicable in 80 Per Cent of All Cases.

at each point. Any apparatus found at the point of maximum intensity is then carefully inspected to determine the cause of trouble. Fig. 5 shows the dropping off in field strength as the receiver is moved away from the line carrying the disturbance.

Serious difficulties encountered with this method are:

1. Resonant points along the circuits give false clues and multiply the required work. This is shown in Fig. 6.

2. Circuits paralleling the producing circuit spread the noise over a huge area in certain instances.

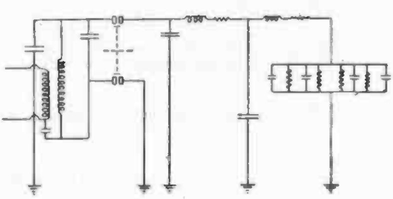


Fig. 4—Equivalent Circuit of a Precipitator.

3. The variation of the distance to ground under the wires causes corresponding variations in field intensity.

4. The presence of metal structures or masses along the line produces unaccountable variations.

5. Reflection phenomena are noted at all ground leads and at the ends of circuit branches.

To locate interference sources expeditiously you must use a combination of intensity method and direction method, and the results of experiences with similar situations.

In this method, use is made of the directional properties of the loop to differentiate between the various circuits. Thus if a house service circuit and a telephone circuit are under suspicion, a test is made at points where the wires diverge; by swinging the loop around the noise-producing circuit is indicated by the line of maximum intensity. This is useful in all situations regardless of the number of lines present, and fails only on the border between territory effected by one noise-producing fault and that effected by a similarly toned source.

A knowledge of the peculiarities of radio interference as learned from extensive experience in this field is most useful in making a quick determination of the trouble, and no set of rules can be formulated to take the place of such experience.

Interference travels in three ways, namely, direct radiation, conduction along metallic circuits, and combinations of conduction and radiation. Examples of the first class are ignition noises, station hetero-

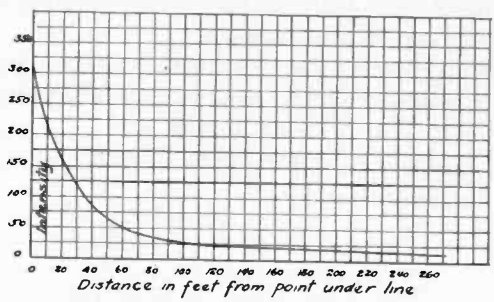


Fig. 5—Variation of Intensity Measured along Perpendicular.

dyning, and small independent plant apparatus where no incoming circuits can carry the noise out by conduction. Examples of the second class include noises carried directly to a.c. sets along the house service lines. The third class is represented by such examples as all noise originating in appliances used on the house service lines and carried along on them to be transferred by induction or radiation to the antennas of receiving sets.

Every service man should know the following simple directions for locating radio interference:

1. Remove the antenna and ground wires and notice the change in noise intensity. If the noise continues undiminished, look for set trouble. If the noise is cut down not more than 50 per cent, look for the trouble in the complainant's own house wiring and appliances as this indicates that most of the noise is entering the set by conduction. If nearly all of the noise goes when the antenna is removed, look for outside interference.

2. Find out what electrical equipment is being used in the neighborhood. If any appliances are suspected, have them turned on and off several times while listening to the receiver.

3. If all your observations indicate that the public utility's equipment is probably the source of trouble and if you are not able to locate the exact source, then call upon the utility company for assistance.

In any city there is normally a high noise level. Extremely quiet reception from a supersensitive receiver must not be expected in such places. If sensitivity is raised each year, people must be instructed in what to expect from these supersensitive sets or general dissatisfaction results. Many dealers are losing sales by overselling the customer

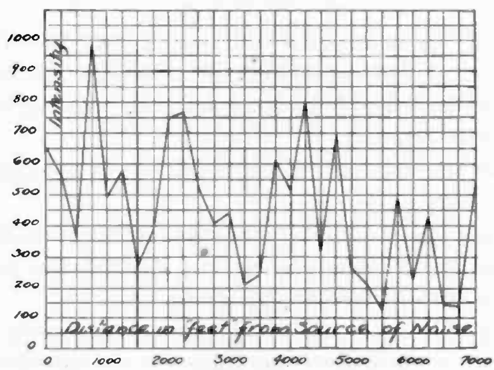


Fig. 6—Variation of Intensity Measured at Various Points along Power Circuit.

on what to expect from a new set. Sets are being turned back even after large deposits have been paid on them. Every such case is a loss to the dealer's reputation.

Some service men and salesmen are taking the easiest way out in cases where the customer is not satisfied. They say, "Call the Power Company and tell them there is a power leak, and they will be glad to know about it, as it will save lots of money by catching it before much power leaks away." The nearest thing to a power leak on overhead lines is a tree ground or broken insulator, and that amounts to a very small trickle. The results of our investigations of thousands of complaints of this nature show that in the great majority of cases the noise originates in some neighbor's electrical appliance.

A favorite expression among salesmen is "leaking transformer." This idea has caught like wildfire and extends from coast to coast. There have been transformers that leaked and gave radio interference, but they are rare enough to deserve a place in a museum.

There would be little to gain by the work on interference if it merely proved who was to blame for the disturbances, but fortunately many of these noises can be stopped at the source or en route. Today there are a variety of filters made commercially to fit every need. Do not expect the simplest filter to take care of the more difficult forms of interference. This refers particularly to violet-ray, x-ray, electro-therapeutic machines, precipitators, and others of that class.

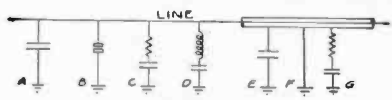


Fig. 7—Use of Impedance in Grounding.

Some idea of the complexities involved may be had by studying the equivalent circuit of a precipitator. See Fig. 4. Such equivalent circuits had to be analyzed before any progress was made in eliminating precipitator interference.

Fig. 3 shows the ordinary filter circuit which is applicable to most cases of interference.

Space will not permit a detailed explanation of the filter treatment of the many sources of interference, but a suggestion in line filter design will not be out of place at this point.

In the study of interference draining more attention should be paid to the fact that a steep wave-front surge causes reflections at the ends of circuits and also at the grounding points whether metallic grounds or through condensers.

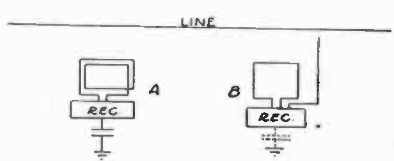


Fig. 8—Unidirectional Trouble Finder.

If the grounding impedance is equal to the high-frequency surge impedance of that portion of the line, there will be little tendency to reflection and the interference will be successfully eliminated by grounding.

Fig. 7 shows various grounds applied to a line having radio interference on it. (a) shows a direct condenser ground which produces reflection, under most conditions, which defeats the purpose of the condenser. (b) indicates grounding through small gap in low-voltage line. Very poor results are attained. (c and d) show respectively an impedance ground and a resistance ground, either of which may successfully eliminate the noise. However, an impedance ground may be effective for only one particular band of frequencies, while the resistance ground will be equally effective on any frequency or steepness of wave front. The remaining grounds (e, f, and g) show the same conditions applied to a cable sheath having induced interference on it.

Equipment for locating interference sources consists of superheterodynes (self-contained), low-frequency amplifiers, exploring coils, audibility meter, and miscellaneous meters. The most useful is the

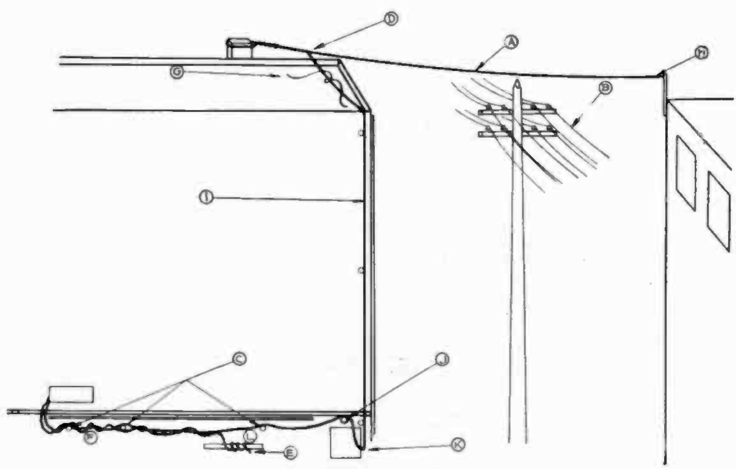


Fig. 9—Typical Faults in Antenna Installation.

suitcase model super. The set testers come in very handy on the numerous false complaints where the real trouble lies in the set, and the owners are most obstinate and troublesome. Care must be taken that this does not lead to free service work.

One piece of apparatus which will prove invaluable when once perfected is the unidirectional receiver, such as indicated in Fig. 8. The necessary development work will require much time which has not been available. Some obstacles to the use of this device at present are: bulk, lack of ground connections, and necessity of transporting delicate meters. A direct indicating audibility meter should be used in connection with this instrument.

Fig. 1 illustrates the use of a low-frequency amplifier in tracing a noise along the house service wires, and also shows a superheterodyne being used to check whether the disturbance is originating on the 110-volt supply or on the telephone lines.

The low-frequency amplifier is very useful when near the source of trouble, as it picks up the disturbance only when at a short distance from the source and avoids the false indications met with while using a more sensitive receiver.

Fig. 2 shows various receivers being used in tracing a noise on the house service lines. Portability is essential for this work.

Fig. 9 shows antenna conditions typical of those found in half the homes today, causing not only poor signal pick-up but lack of selectivity, high interference pick-up, and the production of noises at points of contact with metal and masonry and at loose joints and clamps.

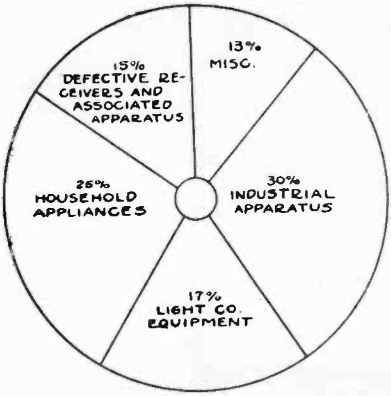


Fig. 10—Responsibility Classification.

(a) Total length of antenna and ground lead is double the correct value in the average installation.

(b) Many antennas are found passing over or under lines carrying current at high voltages. This is extremely dangerous to life and property. A broken wire or accidental contact during a storm or at the time of installation may mean death to all touching the wire or the radio.

(c) Antenna lead-ins laid over various pipes and brackets.

(d) Unsoldered and corroded joints.

(e) Ground wire loosely wrapped around corroded pipe or loose ground clamp.

(f) Lead-in and ground wire wrapped together.

(g) Lead-in tangled with loose wires or scraping against metal scraps or spouting.

(h) No insulators.

(i) Down lead along drain pipe.

(j) Turn taken around pipe to hold wire in place.

(k) Against damp masonry.

(l) Parallel to 110-v wires and to telephone lines.

Fig. 10 shows the ultimate classification of a year's interference cases brought to a power company as their trouble. This of course does not mean that the power company was responsible for 17 per cent of all the noise in that territory, but that of all the cases where claim was made that the cause was without doubt the company's, only 17 per cent actually turned out to be such.

Radio interference work is at present being carried on mainly by the power companies to promote good will and to clear all trouble of their own before it comes to the public attention.

It is a pioneering project in several ways, and consequently is looked upon with certain misgivings by conservatives. The policy which will be followed in this work will depend largely upon the attitude of the public as given expression in letters of commendation, the public press, and in requests for this service.

This field will offer unlimited opportunities for research and constructive development when the public and the affected manufacturers realize the possibilities of improved reception conditions.

Conclusions

It is urgent that all companies or groups interested in any phase of radio should aid in the investigation and elimination of radio interference.

Many lines of investigation are open in this work, such as

(a) Unidirectional source finders.

(b) Substantial and reliable audibility meters of the indicating type, possessing high sensitivity.

(c) More thorough filter design study, with special attention to draining noises from power lines, trolley wires, and feeders and telephone lines.

(d) The manufacture of "interference proof" electrical appliances.

Proceedings of the Institute of Radio Engineers
Volume 17, Number 5 *May, 1929*

Discussion on
RECEPTION EXPERIMENTS IN MT. ROYAL TUNNEL*

A. S. Eve, W. A. Steel, G. W. Olive, A. R. McEwan, and J. H. Thompson

Carl R. Englund:[1] During the delivery of his paper, Dr. Eve referred several times to radio methods of ore prospecting, and it has occurred to me that the attenuation in the ground which he reports as observed for ordinary radio signals is not necessarily the same attenuation as that which the ore prospector would encounter in applying radio to subterranean ore finding. This point is worth making even if, as the computations show, the attenuations of different wave motion types are not radically different.

In subterranean ore finding it would seem that ordinary transverse waves are the preferable type, such for example as would best be produced and observed by using buried antennas. In these waves the electric and magnetic vectors are not in time phase[2] but are at right angles to the Poynting vector, and the only serious difference from ether waves is the presence of an attenuation factor. We therefore express these waves as either the real or the imaginary part of the complex expression

$$E = E_0 e^{-\delta r + i\omega(t - r/V)} \quad \text{where}$$

$$\delta_T = \frac{2\pi\sigma}{c} \cdot \sqrt{\frac{\mu}{\epsilon}} \cdot K \qquad K = \sqrt{\frac{2}{\sqrt{1+\left(\frac{2\sigma}{f\epsilon}\right)^2}+1}}$$

$$V = \frac{c}{\sqrt{\epsilon\mu}} \cdot K$$

ϵ = dielectric const.

σ = conductivity

μ = permeability

c = vel. of light

$$f = \frac{\omega}{2\pi}$$

and for small conductivities or high frequencies the factor K is nearly unity or δ independent of the frequency.

Ordinary radio transmission is another type of wave motion, a longitudinal one in fact. The equiphase surfaces no longer coincide with the equiamplitude surfaces, and there is attenuation in directions both along and perpendicular to the ground. In a recent discussion Fry[3] has broadly treated these wave motions; they have been termed by him "hybrid" waves. That the attenuation along the direction of propagation of transverse waves should be the same as that perpendicular to the ground in a hybrid wave is neither necessary nor evident and a distinction is clearly to be made.

The simple Cohn-Zenneck[4] theory of transmission along a material boundary is based on several plausible assumptions which result in the differential equation for the magnetic field as

$$\frac{\partial^2 H_y}{\partial Z^2} + \frac{\partial^2 H_y}{\partial X^2} = \frac{i\omega\mu(4\pi\sigma + i\omega\epsilon)}{C^2} H_y,$$

the electric field being derived via Maxwell's equations from the magnetic field satisfying this equation. The plane material surface boundary is here the x, y

* Proc. I. R. E. 17, 347; February, 1929. Presented before New York meeting of the Institute, December 5, 1928.

[1] Bell Telephone Laboratories, Cliffwood, N. J.

[2] Because of the earth's conductivity.

[3] Fry, *Jr.* Opt. Soc. Amer. 15, 137, 1927; 16, 1, 1928.

[4] Cohn, "Das Elektromagnetische Feld" (book), p. 449, 1900; Zenneck, *Ann. d. Phys.*, 23, 846, 1907.

plane, and the fields are assumed independent of the y coordinate. These are the geometrical settings, the two assumptions which have been made are: the y component of the electric field is non-existent and the time factor enters as $e^{i\omega t}$. The simplest solution of the differential equation is

$$H_y = H_{0y}e^{mx+nz}$$

with $m^2+n^2=i\omega\mu/C^2\,(4\pi\sigma+i\omega\epsilon)$ as the only condition placed upon the unknowns m and n. When, however, we consider the boundary conditions at $z=0$, we obtain additional equations making m and n determinate. We can thus obtain an expression for the electric field in the material medium as the product of an amplitude factor and a combination amplitude and phase term, this latter being a simple exponential function of both x and z. The electric field vector is of course not vertical, and the wave motion is not a transverse one as already stated.

When $\mu=1$ and the media are air and leaky dielectric, respectively, the exponential amplitude phase factor in the z direction is

$$e^{\pm\omega/c\sqrt{\epsilon}}\sqrt{\frac{\left(i\frac{2\sigma}{f\epsilon}-1\right)^2}{\left(i\frac{2\sigma}{f\epsilon}-1-\frac{1}{\epsilon}\right)}}$$

and the attenuation coefficient itself is the real part of the complex exponent or

$$\delta_H=\frac{\omega}{c}\sqrt{\epsilon}\sqrt{\frac{\left(\frac{4\sigma^2}{f^2\epsilon^2}+1\right)}{\sqrt{\frac{4\sigma^2}{f^2\epsilon^2}+\left(1+\frac{1}{\epsilon}\right)^2}}}.$$

It may be remarked that the existence of a physical counterpart of the simple Cohn-Zenneck solution is not provable by any mathematical device; its selection is moreover an act of judgment by the theorist and must be checked by physical tests. However, no transverse wave can satisfy the differential equation, and more general solutions can be built up from the simple one so that its use is doubtless legitimate.

The values of δ_T and δ_H, the attenuation coefficients for the transverse and hybrid waves, respectively, are thus different functions of the frequency and it is of interest to calculate them in particular cases. I am indebted to Mr. Sterba, of the Bell Telephone Laboratories, Inc., for the following values of earth constants, measured at broadcasting frequencies at Deal Beach, N. J.

Condition	ϵ	ohms per. cm cube	σ
Dry earth	30	600,000	1.5×10^{6}
Wet earth	80	6,000	1.5×10^{8}

and from these the table follows, the attenuations being per cm distance in every case.

	Dry Earth		Moist Earth	
Freq.	δ_T	δ_H	δ_T	δ_H
10^3	0.81×10^{-5}	1.147×10^{-5}	0.81×10^{-4}	1.15×10^{-4}
10^4	2.44×10^{-5}	3.64×10^{-5}	2.56×10^{-4}	3.62×10^{-4}
10^5	5.21×10^{-5}	13.4×10^{-5}	8.0×10^{-4}	11.47×10^{-4}
10^6	5.72×10^{-5}	113×10^{-5}	22.5×10^{-4}	36.9×10^{-4}
10^7	5.73×10^{-5}	1130×10^{-5}	34.5×10^{-4}	192.9×10^{-4}
10^8	5.73×10^{-5}	11300×10^{-5}	35.1×10^{-4}	1861×10^{-4}

Evidently as the conductivity increases the disparity between δ_T and δ_H decreases, but the frequency change of δ_H remains more pronounced than that of δ_T, and hence observations of the type reported by Professor Eve on the hybrid wave of ordinary radio transmission at and near the surface of the earth do not apply directly to the electromagnetic wave of transverse type which should be used for ore surveying.

A. S. Eve:[5] It is certainly true that there is marked dissimilarity between underground radio detection and ore prospecting, even when the same frequency is used.

In searching for ore by electrical methods a horizontal loop, of well insulated cable, is placed on the ground, or a vertical loop is supported on a frame. An alternating current is passed round the loop, and the frequency may be in the audible range, about 500 cycle, or of radio range, about 30 kc. The current in the loop induces an electromotive force around a good conductor underground, if not too far from the loop. This conductor reradiates energy which must be detected by a suitable detector on the surface. The fact that the loop is near and almost above the conductor, the fact that this conductor has to affect the field, and the fact of the measurement of the reradiation or secondary disturbance certainly differentiates geophysical prospecting from mere underground radio detection.

Both schemes do, however, involve the question of penetration of rocks by electromagnetic waves of varied frequencies under conditions of many different types. Mr. Englund's discussion is useful in calling attention to the difficulties surrounding this subject. In the original paper by Major Steel no reference was made to ore detection, but in my lectures at New York I certainly alluded to the subject of ore detection, which indeed first directed my attention to the absorption of radio by rocks.

[5] Director of Physics Dept., McGill University, Montreal, Canada.

Proceedings of the Institute of Radio Engineers
Volume 17, Number 5 *May, 1929*

Discussion on

FACSIMILE PICTURE TRANSMISSION*

V. Zworykin

Alfred N. Goldsmith:[1] This evening there has been presented an interesting paper on "Facsimile Picture Transmission." Those of us who can remember back to the early days of radio communications are aware that spark transmission was the order of that already remote day. Modulation, as such, was a strange term to radio engineers, because modulation implies taking something which was rather steady and then impressing something else upon it. But there was not anything so definitely dependable and constant about a spark gap; it broke down in spasmodic and erratic fashion with the utmost violence and considerable noise, and gave rise to trains of damped waves which by the most charitable interpretation could not be regarded as a modulation of a continuous wave. The effect of such waves on the receiving set and the patience of the person trying to avoid interference was very marked. Thus modulation in those days was practically without significance as a radio engineering term. Then came the quenched spark transmitter and sometimes wave trains from such transmitters even overlapped, although with random phase relationship between the successive groups of waves and therefore still without any very clear meaning to the term "modulation" as employed in present day practice.

Finally, there came the era of the continuous-wave transmitting set, of the telegraph type first, where modulation or control of a continuous wave was accomplished slowly but surely (very slowly over the average circuit, and sometimes none too surely).

As the years went on, radio telephony, with a more complex form of modulation, came into existence and the problems of control of the transmitter and adequate reception of the extended sidebands corresponding to this form of modulation required a period of years for adequate development.

Today we stand on the threshold of the newest, most remarkable and unusual types of modulation, the modulation of electromagnetic waves to correspond to the still picture or to the changing contours of a motion picture. We are endeavoring to impress upon the flying wave the likeness of persons or things, either stationary or mobile. These new fields are engaging the serious attention of radio workers because clearly facsimile transmission has something of the quality of intimate contact with the original which telephony has not and which is lacked, necessarily, by the more cold telegraphically-transmitted word. Television requires even more complicated modulation, and we are beginning to think in terms of sidebands which would have been truly disconcerting in their width to the telegraphic communication engineer of a few months ago. Nevertheless much has been accomplished and a description of a substantial and practical contribution to the subject is presented by Dr. Zworykin.

M. B. McCullough:[2] What applications does a system of this type have?

V. Zworykin:[3] I would say that the application of a system of this type would be to any sort of facsimile transmission; in other words, it may be used to transmit and broadcast newspaper pictures, transmit commercial telegraphs, transmit orders from one factory branch to another, and so forth.

N. E. Bonn: How much power must the tuning fork supply the motor to keep it in synchronism with the fork?

V. Zworykin: As much power as possible, and the more the better. Ten watts is sufficient to keep the picture quite stable, but this is about the lower limit.

N. E. Bonn: You have constant power and constant voltage?

V. Zworykin: Not necessarily. We are using the regular power supply.

* Proc. I. R. E., **17**, 536; March, 1929. Presented before New York meeting of the Institute, January 2, 1929.

[1] Chief Broadcast Engineer, Radio Corporation of America, New York, N. Y.

[2] Sales Department Radio Corporation of America, New York, N. Y.

[3] Research Department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

A. Nyman:[4] I notice that the method used for introducing the alternating-current component in the picture is by interrupting the light. I wonder if the alternative method of using alternating current supplied to the photo-electric cell has been considered; and if so, what are the objections to it?

V. Zworykin: Yes, it has been considered, and we have been working for a number of years with this method. It is a very alluring method, I would say, because the elimination of the light interrupter is very desirable. The trouble is that you have to use quite a high frequency, at least 3000 cycles. In this case the capacity of the photo-electric cell becomes quite important, for at such frequencies the capacity leakage is relatively large.

E. C. Ballentine:[5] I would like to ask Dr. Zworykin if he has actually found that the helium lamp is as good as the neon? Since we developed our neon lamps about a year ago, we have been experimenting with different types, and it has been our experience that helium is actually inferior to neon, for the reason that neon has some violet bands in the spectrum which are hardly visible, but very actinic.

V. Zworykin: I admit that this question is still not quite settled. I think the spectrum of the glow discharge in this kind of tube depends not only on the gas used but also on the character of the glow discharge. You can make the constricted glow discharge by using either a positive column discharge or a negative column discharge. In two different cases there will be two different results, and since no close investigation was made, I cannot give you a definite answer on that.

E. C. Ballentine: I would like to make just one remark, if I may. I would like to impress on the Institute at this time a feature of facsimile which Dr. Zworykin has not mentioned in his paper and which I think is quite important. That is one thing about facsimile that the General Electric Company has been experimenting with for the last two years—the radio circuit. We have found that the short waves are very variable things to work with. We find that no matter how good our terminal apparatus may be, or how perfect it may be, the major problem still remains in radio of getting the high speed telegraphic signals across and through the ether. I think that still remains the major problem in radio facsimile work.

Alfred N. Goldsmith: There can be no question, of course, that once the terminal apparatus has been brought to a degree of perfection greater than that imposed by variations of attenuation throughout the transmission band, any improvement of terminal apparatus is merely something to be stored up against the happier day in the future when the radio circuit is smoothed out or improved in its transmission characteristic.

Taking a transoceanic circuit capable of carrying, say 100 cycles or 200 cycles per second, it obviously would not be of any direct commercial advantage today to be able to receive 1000- or 10,000-cycle modulation in a receiver or to send it out from a transmitter, because such modulated waves would be too badly mangled in transmission. However, the inherent advantages of the improved equipment will appear as soon as the radio circuit is correspondingly improved. Fortunately we are gradually improving our radio links as well. The limitation of some radio circuits is a feature which is neglected at times, and which frequently accounts for the amazing results obtained both in so-called facsimile and so-called television transmissions where the transmitting medium consists of an extremely accommodating and very solid length wire from one room to another.

H. H. Haglund: I understand that the synchronism maintained by having the two tuning forks vibrating at a different speed is about 1 beat in 20 seconds; that is, the second receiving tuning fork is corrected once every revolution of the drum. I would like to know how this correction is applied to the fork.

V. Zworykin: The tuning fork is driven by a vacuum tube and a resistance is included in the grid circuit of this tube. Every time that the correcting impulse comes to the terminals of the resistance it changes slightly the oscillation of the tube and this corrects the tuning fork. We have found this is sufficient to correct the second tuning fork, if the frequency difference between tuning forks does not exceed about 1 beat in 20 seconds.

[4] Radio Patents Corporation, New York, N. Y.
[5] Radio Engineering Department, General Electric Company, Schenectady, N. Y.

T. P. Dewhirst: I would like to ask what is the average life of the helium glow lamp as compared with the neon lamp, and the limitations of flash and voltage?

V. Zworykin: I do not see why there should be any difference in the life of the helium lamp as compared with the neon lamp. The limitation is mostly from the sputtering of the electrodes, which is about the same, in both cases.

T. P. Dewhirst: What power is available across the polarizing resistance?

V. Zworykin: One lumen gives about 20 microamperes through 0.5 megohm, with caesium.

T. P. Dewhirst: How about the potassium cells?

V. Zworykin: In our measurements we found the caesium cell was about 100 times as sensitive as the potassium cell.

J. E. Shannon: How does the photographic image at the receiving end compare with the original? Take, for instance, a perfect photograph at the transmitting end: how does that compare at the receiving end?

V. Zworykin: It depends, of course, on how many picture elements you transmit. As you know, for newspaper work they use about 50 lines per inch. In our case we use 64 lines per inch, and we have found it quite satisfactory. On the other hand, in some other facsimile machines they use a much higher number of lines. For instance, the General Electric engineers use 100 lines per inch and for the fine details, of course, it is better. In Europe I saw systems using 130 lines per inch. I do not see much difference from 100 lines up and believe that further increase is a waste of time and of the width of the band of transmission.

R. H. Ranger: I would just like to emphasize what Mr. Ballentine has brought out. Not only are you limited in facsimile transmission by the radio circuit, but it does seem to me that you have to make your apparatus conform to the radio circuit. In other words, there are many ways of solving any particular problem, and the one that you should select is the one that will get through the complete circuit from one point to the other with the least power through the most interference, and that is why there is such a discrepancy between some short link laboratory results and those that go through the air.

The great bugbear that we have found in all our work is the change in the level of the received signal. Most of the very high-speed facsimile test work, on the contrary, has been on a basis where the change level is very important in order to get the tones. All the work that we have done in the Radio Corporation has been on the "on and off" basis with the interpretation of the halftone values in terms of dots spaced at different distances apart, because we have found that that is the only reliable method of getting current values that will register correctly over great distances. That all means, of course, that you have to slow down the rate at which you scan, because you have to interpret your intensity values in terms of separation and length of the dot elements, and therefore your scanning speed goes down proportionately.

In regard to the number of scanning lines which you use, there again you are tied to the radio circuit. If you use 60 lines to the inch, you will get along very nicely, if you have a perfect radio circuit. On the other hand, if interference, fading, or any other irregularities enter, you will find your chances for getting through with a double number of lines per inch vastly improved. For example, on some of our work where we use 120 lines to the inch we can miss a whole line through fading or other causes and still get a perfectly legible typewritten copy, and that of course is our goal.

In regard to the pick-up system with the light and parabolic reflector, I am quite in accord that that is a novel and efficient way of picking up light from a spot. However, strange as it may seem, it may not be the most efficient way to pick up black from a spot. In other words, what we are concerned with in picture transmission is getting the greatest differentiation between black and white. Therefore, you have to pick the optical system which will give you that greatest differentiation. To get the greatest differentiation, you want as fine a pencil of light shot at the paper as possible, and you likewise want as fine a pencil of light focussed back from the paper. In other words, if you send a pencil of light straight at the piece of paper, you get diffuse reflection on all sides, and if you pick it up from all sides you will find that as your image crosses in front of that pencil of light, first the area will be darkened on one side and then on the other. Therefore, you may not get clean-cut differentiation as the pencil of light passes through the type or other picture matter. However, all these matters are compromises and therefore what you have to select is the one that best fits your whole proposition. The real answer of the effectiveness of this particular compromise is the excellent pictures that Dr. Zworykin has shown.

In regard to the synchronizing, again it is the proposition of realizing that you have to work imperfectly through space. If you depend upon the radio circuit to see to it that your rotating drums are in absolute step, you are just requiring that much more from your poor link through space. If you can get synchronism in any other way than by radio, therefore, it is very wise to concentrate on that other way and leave the radio channel to get the lights and shades across. At the present time, for example, we find it quite possible to maintain separate tuning forks on opposite sides of the continent, within two parts in a million and the drift which that means in any picture is certainly very slight; in fact, you would not be able to notice it. I feel that we have to concentrate on the things that fit the conditions as we meet them in the air, and while I feel that the Chairman's statement is correct, that the greater abilities of the terminal equipment will come into their own when the radio circuit is improved, nevertheless we have to take things as they are and make the most of them by adapting our terminal equipment to those conditions.

Alfred N. Goldsmith: There can be no doubt that 100 per cent modulation, and not too rapid modulation, is desirable when you are transmitting through an "ether" that has variable transmission characteristics, different zero levels for all frequencies, and a fairly high interference level.

I had occasion recently to point out that in the early days of happy simplicity in radio transmission, we believed that we were transmitting through a homogeneous, non-absorbing medium, but that we have since learned that we actually transmit through a swirling fog of varying colors, in which are imbedded numerous rapidly moving, irregularly surfaced mirrors, and crude lenses or prisms.

BOOK REVIEW

Handbuch der Experimentalphysik. EDITED BY WEIN-HARMS. Vol. xiii, Part 2. Glühelektroden und Technische Elektronenröhren, BY W. SCHOTTKY, H. ROTHE, and H. SIMON; p. 492, 179 figs. Akademische Verlagsgesellschaft M.B.H. Leipzig; price bound 46 RM.

This volume is in reality a collection of three monographs, each dealing with a different phase of the radio vacuum-tube problem.

The first part, entitled "Physik der Glühelektroden," and occupying well over half the volume, is written by Schottky and Rothe. The authors develop the present status of theoretical and experimental thermionics, principally in the language of the Gibbs thermodynamic potential. Following preliminary orientation chapters covering a treatment of the thermodynamic principles on which this part of the volume is based, chapters on electron vapor pressure and emission, thermionics, thermal effects of ionic emission and the surface activation problem, are among those included. A final chapter deals with phenomena not approachable by thermodynamic methods, in particular the Schottky effects. Experimental work and theory are well coordinated throughout the monograph.

The second part of the volume, a short section of less than sixty pages, presents "The preparation of the Hot Cathode," by Simon. Experimental methods are described for filament preparation and mounting for consistent behavior as an electron emitter, rather than the actual commercial practice of any particular tube manufacturer. The behavior of the different types of hot cathode and the methods of evacuation and of temperature measurement are also dealt with in this survey of the literature on hot cathode technique.

The radio engineer will wish that the third monograph were longer and more complete: "Technical Electron Tubes and their Application," by Rothe. While the two previous parts are of primary interest to physicists and to the specialist in filament development, there is found in this latter part, comprising somewhat less than a third of the volume, a review of the literature on fields more familiar to the radio engineer. Following a treatment of vacuum-tube characteristics and of circuits for their measurement come sections on amplifier, oscillator, modulator, and detector, with emphasis on circuits which have actually come into practical use. Neutralizing and feed-back arrangements in amplifiers occupy several pages. Two pages are found for the four-element tube and its circuits, and fifteen pages for the quartz resonator and its control of oscillating circuits. Here, as is apparently also true with other subjects covered in the monograph, the author has given a good introduction to the piezo-electric resonator, but has not had space available for the treatment of details. Developments which have not so far come to have practical importance, such as the dynatron and the magnetron, are omitted entirely.

The entire volume is well prepared. The reviewer finds a number of inconsistencies in the manner of citing periodicals, some journals being referred to in as many as three different ways. It would make for convenience in such a reference work if each page bore either the title or the number of the monograph to which it belongs.

K. S. VAN DYKE

Proceedings of the Institute of Radio Engineers
Volume 17, Number 5 *May, 1929*

MONTHLY LIST OF REFERENCES TO CURRENT RADIO LITERATURE

THIS is a monthly list of references prepared by the Bureau of Standards and is intended to cover the more important papers of interest to professional radio engineers which have recently appeared in periodicals, books, etc. The number at the left of each reference classifies the reference by subject, in accordance with the scheme presented in "A Decimal Classification of Radio Subjects—An Extension of the Dewey System," Bureau of Standards Circular No. 138, a copy of which may be obtained for 10 cents from the Superintendent of Documents, Government Printing Office, Washington, D. C. The articles listed below are not obtainable from the Government. The various periodicals can be secured from their publishers and can be consulted at large public libraries.

R100. Radio Principles

R113 Barfield, R. H. The attenuation of wireless waves over towns. *Jnl.* Institution of Elec. Engrs. (London), 67, pp.253–270; February, 1929.

(Shows that the rate of change of attenuation with wavelength of the radiated field over towns is rather great. A theoretical discussion is given by means of Sommerfeld's numerical distance and the same applied to the absorbing effect of vertically grounded conductors which exist in the towns in many forms. Also a theoretical discussion on selective absorption due to tuned antennas and their reradiation. Sommerfeld's theory seems to confirm the high rate of attenuation over towns.)

R113 Sacklowski, A. Die Ausbreitung der Elektromagnetischen Wellen. (The propagation of electromagnetic waves). Book. Published by Weidmannsche Buchhandlung, Berlin, 1929. Noted in *Experimental Wireless and Wireless Engr.* (London), 6, p. 83; Feb., 1929.

(Review of work which was published by the author in the *Elektrische Nachrichten Technik*, 1927.)

R113 Eve, A. S., Steel, W. A., Olive, G. W., McEwan, A. R., Thompson, J. H. Reception experiments in Mount Royal Tunnel. Proc. I. R. E., 17, pp. 347–376; Feb., 1929.

(Experiments presented which were carried out in the Mt. Royal Tunnel of Canadian National Railways at Montreal in order to determine how radio waves reach the receiving set.)

R114 Yokoyama, E. and Nakai, T. A note on the directional observations on grinders in Japan. Proc. I. R. E., 17, pp. 377–79; Feb., 1929.

(Direction of grinders taken in Japan during 1927 showed diurnal and seasonal changes in the direction of atmospherics.)

R125.6 Transmitting aerials (editorial). *Experimental Wireless and Wireless Engr.* (London), 6, pp. 59–61; Feb., 1929.

(Discusses the features of the beam system developed by A. Meissner (f=15000 kc) and that due to P. P. and T. L. Eckersley and H. L. Kirke for the broadcast range. Shows the importance of emphasizing the ground ray.)

R125.6 Eckersley, P. P. and T. L., and Kirke, H. L. The design of transmitting aerials for broadcasting stations. *Experimental Wireless and Wireless Engr.* (London), 6, pp. 86–92; Feb., 1929.

(It is brought out that the radiation along the tangent of the earth's surface should be emphasized and any appreciable intensities upwards suppressed. It is shown that this can be accomplished with high antennas working with more than quarter wavelength distribution (for instance full wavelength distribution utilizing phasing coils). The attenuation due to ground absorption is also studied by means of Sommerfeld's formula.)

R132 Garton, C. G. and Lucas, G. S. An apparatus for the projection of frequency output characteristics. *Experimental Wireless and Wireless Engr.* (London), **6**, pp. 62–70; Feb., 1929.

(Description of a system for studying frequency amplitude characteristics of audio-frequency amplifiers.)

R132 Nelson, J. R. Circuit analysis applied to the screen grid tube. Proc. I. R. E., **17**, pp. 320–338; Feb., 1929.

(General radio-frequency circuit theory is discussed in this paper. Amplification equations for impedance and transformer coupling using an untuned primary whose period is above the highest frequency considered are derived and discussed for the case of a screen-grid tube.)

R133 Hollmann, H. E. On the mechanism of electron oscillations in a triode. Proc. I. R. E., **17**, pp. 229–251; Feb., 1929.

(Considers the different types of electron oscillations which occur in the Barkhausen and Kurz retarding field of a triode having a high positive potential applied to its grid, and zero or small negative potential applied to its plate.)

R134.4 van der Pol, B. The effect of regeneration on the received signal strength. Proc. I. R. E., **17**, pp. 339–346; Feb., 1929.

(Theory of the effect of regeneration using the solution of a non-linear differential equation. Experimental verification of the theory given.)

R144 Cockcroft, J. D. Skin effect in rectangular conductors at high frequencies. *Proc.* Royal Soc. A (London), **122**, pp. 533–542; Feb. 4, 1929.

(Deduction of formulas for the high-frequency resistance of conductors with rectangular cross section.)

R200. Radio Measurements and Standardization

R210 Hull, L. M. and Clapp, J. K. A convenient method for referring secondary frequency standards to a standard time interval. Proc. I. R. E., **17**, pp. 252–271; Feb., 1929.

(Method is described for obtaining a convenient low frequency from a high-frequency standard by means of harmonic control of distorted wave oscillators (multivibrators).)

R210 Hall, E. L. A system for frequency measurements based on a single frequency. Proc. I. R. E., **17**, pp. 272–282; Feb., 1929.

(Method is described which is suitable for calibration of either piezo oscillators or frequency meters in terms of an accurately standardized temperature controlled piezo oscillator.)

R300. Radio Apparatus and Equipment

R320 Landon, V. D. A multiple receiver antenna system. *Radio Broadcast*, **14**, pp. 291–293; March, 1929.

(System for apartment houses.)

R333 Weaver, K. S. A high-power output tube—The 250. *Radio Broadcast*, **14**, pp. 329–330; March, 1929.

(Characteristics of tube.)

R333 What is a good tube? *Radio Broadcast*, **14**, pp. 335–45; March, 1929.

(Data given on the Cunningham, Sylvania, Ceco and Raytheon tubes.)

R343 Hull, R. A. Improving short wave phone reception. *QST*, **13**, pp. 9–20; March, 1929.

(Description of a modern superheterodyne for short-wave phone, code, and general broadcasting.)

R376.3 Bostwick, L. G. Acoustic considerations involved in steady state loud speaker measurements. *Bell System Tech. Jour.*, 8, pp. 135–158; January, 1929.

(Describes certain difficulties encountered in acoustic measurements of performance of loud speakers. Data given for two representative types of loud speakers when measured in space free from reflections and when measured under varying conditions in a special acoustic laboratory.)

R381 Siegmund, H. O. The aluminum electrolytic condenser. *Bell System Tech. Jour.*, 8, pp. 41–63; January, 1929.

(Action of the aluminum electrolytic condenser and method of avoiding the rectification effect. Shows that the life of such condensers is high, some having been in use for seven years.)

R500. Applications of Radio

R521 Pickerill, E. N. A modern radio aircraft installation. *Radio Engineering*, 9, pp. 46–48; Feb., 1929.

(Description of new transmitter and receiver designed for airplane communication.)

R521 Drake, F. H. An aircraft radio receiver for use with rigid antenna Proc. I. R. E., 17, pp. 306–319; February, 1929.

(Outline is given of physical and electrical requirements of an aircraft receiver suitable for reception of radio beacons and telephone service on a small rigid antenna. Describes the design of a special unicontrol receiver calculated to fulfill these requirements.)

R521 Pratt, H. and Diamond, H. Receiving sets for aircraft beacon and telephony. Proc. I. R. E., 17, pp. 283–305; February, 1929.

(Design details for three receiving sets of slightly different types with characteristic and performance curves are discussed. Reprint of Bureau of Standards Research Paper No. 19, Bureau of Standards Journal of Research, October, 1928.)

R526.4 Alexanderson, E. F. W. Height of airplane above ground by radio echo. *Radio Engineering*, 9, pp. 34–35; Feb., 1929.

(Preliminary work on a radio altimeter.)

R531.2 Schedule of short wave programs. Radio Broadcast, 14, p. 298; March, 1929.

(List of short-wave stations.)

R800. Non-Radio Subjects

534 MacKenzie, D. Sound recording with the light valve. *Bell System Tech. Jour.*, 8, pp. 173–183; Jan., 1929.

(The light valve of Wente is described. It is an electromagnetic shutter made up of a loop of duralumin tape formed into a slit at right angles to a magnetic field. Amplified currents from a microphone flow in the duralumin and open and close the loop. An incandescent filament is focussed on the light valve the slit of which is focussed by a lens on the sound negative film. When sound currents flow the film receives a varying exposure.)

534 Norris, R. F. The acoustimeter. *Radio Engineering*, 9, pp. 36–37; February, 1929.

(An electrical means for measuring sound intensity.)

621.319.2 Guillemin, E. A. and Glendinning, W. On the behavior of networks with normalized meshes. Proc. I. R. E., 17, pp. 380–393; Feb., 1929.

(Theory of normalizing meshes in electrical networks is verified and illustrated by examples and figures relating to two and three-mesh circuits.)

621.385 Osborne, H. S. The principles of electric circuits applied to communication. *Bell System Tech. Jour.*, 8, pp. 3–20; Jan., 1929.

(Discussion of method of presenting fundamental electrical principles. Outline of problems arising in application of electric principles to telephone systems.)

Proceedings of the Institute of Radio Engineers
Volume 17, Number 5 *May, 1929*

CONTRIBUTORS TO THIS ISSUE

Allen, James G.: Born May 16, 1897 in Cumberland, Maryland. Research in electro-metallurgy at Westinghouse Electric and Manufacturing Company, East Pittsburgh, Penna. Graduated in electrical engineering, Carnegie Institute of Technology, 1920. Special courses in illumination and telephony from other institutes. General Electric course, 1920–21. Telephone engineer, Western Electric Company, Chicago, 1921–23, editing specifications for both manual and machine switching exchanges. Radio engineer and illuminating engineer, Duquesne Light Company, Pittsburgh, Penna., since January 10, 1924. Author of a number of papers relating to radio reception and radio coordination. Associate member A.I.E.E. and I.E.S. Associate member, Institute of Radio Engineers, 1928.

Bayly, B. deF.: Shrewsbury School, England, specializing in mathematics and physics, 1917–19; studied law in Saskatchewan, worked on communications, CPR telegraphs, telephones, also signal officer in militia, 1920–25; studied engineering, Toronto University, 1926–28; instructor in radiotelegraphy, University of Toronto, 1929. Associate member, Institute of Radio Engineers, 1927.

Fisher, Elmer Howard.: Born November 21, 1906. Studied at California Institute of Technology, 1923–26. Construction electrician, 1926–27. Received A.B. degree, Stanford University, 1928. At present research assistant, Stanford University, California.

Lubcke, Harry R.: Born August 25, 1906 at Alameda, California. Received B.S. degree, University of California, Berkeley, 1929. Writer for technical publications, 1922 to date. Consultant in amplifier design, Carl Rhodehamel Studios, Hollywood, 1928–29. Associate member, Institute of Radio Engineers, 1926.

Mögel, Hans E.: Born May 31, 1900 at Leipzig, Germany. Educated at Dresden High School. Received E.E. degree, 1922, and Dr. Eng., 1926 from Dresden High School. Assistant to Prof. Barkhausen, 1921; research engineer, laboratories of the Huth Company at Berlin, development of transmitters, receivers, and amplifiers, 1922–26; consulting engineer, Transradio A. G., Berlin, working especially at the receiving station in Geltow, 1926 to date.

Pratt, Haraden: Born July 18, 1891 at San Francisco, Calif. Graduated from College of Mechanical and Electrical Engineering, University of California, 1914. Radio operator and installer, United Wireless and Marconi Companies, 1910–13. Expert radio aide to Navy Department, 1915–20. Engineer with Federal Telegraph Company in charge of research factory and design and construction of chain of radio stations, 1922–27. In charge of development of radio aids to air navigation, Bureau of Standards, Washington, D. C. At present chief engineer, Mackay Radio and Telegraph Company, New York City. Associate member, Institute of Radio Engineers, 1914; Member, 1917; Fellow, 1929.

Quäck, Erich: Born July 27, 1890 at Bischofsheim bei Mainz, Germany. Studied at the Technical High School, Darmstadt. Served as volunteer at the Maschinenbau and Mühlenanstalt Luther, Darmstadt und Schuckert, Nürnberg. Entered the Telefunken Laboratory in 1905; chief engineer. Amalgamated

Wireless Telegraph and Telephone Company, Berlin-London (Poulsen system) 1907–09; chief engineer, Telefunken Company, 1910; acting member of the management of the Transradio A. G. für drahtlosen Überseeverkehr, 1921–.

Shaw, A. E.: Assistant to the consulting engineer, Q.M.C., at the Army Base, Brooklyn, N. Y. for fourteen months; then entered Polytechnic Institute of Brooklyn and received E.E. degree, 1923. With Bell Telephone Laboratories for several years, then entered University of Chicago; received M.S. degree, 1928. At present a Fellow in the Dept. of Physics, University of Chicago, carrying on research work.

Soucy, Chester I.: Born July 21, 1904 at Troy, N. Y. Received B.A.Sc. in electrical engineering, University of Toronto, Canada, 1926. Lecturer in radio engineering and in charge of radio laboratory, University of Toronto, 1926–28; also research work on radio- and audio-frequency measurements and measuring apparatus. Installation engineer of synchronized sound motion picture equipment, Northern Electric Company, Canada, 1928 to date. Associate member, Institute of Radio Engineers, 1926. Assistant secretary, Canadian section, 1926–27; vice-chairman, 1927–28.

Terman, Frederick Emmons: Born January 7, 1900, at English, Indiana. Received A.B. degree, Stanford University, 1920; E.E. degree, Stanford University, 1922. D.Sc. degree, Massachusetts Institute of Technology, 1924. At present assistant professor of electrical engineering, Stanford University, in charge of communication and analytical work. Associate member, Institute of Radio Engineers, 1925.

your money's worth
. . . in musical performance

TONE Fidelity . . . the master salesman of radio . . . is the constant companion of the Thordarson equipped receiver. A snap of the switch . . . a turn of the dial . . . and his message begins. He collects no commissions . . . has no expense account, yet works unceasingly, delivering his message of quality reproduction to everyone within earshot. Without his effortless activity the set manufacturer's days are numbered, for the public will accept no substitute for Tone Fidelity.

It is significant that the manufacturers of the world's finest radio receivers almost universally have selected Thordarson power supply and audio transformers to carry this message of tonal purity into millions of homes.

Whether you are engaged in building, selling or buying radio receivers, remember this: Thordarson power supply and audio equipment spells quality reproduction.

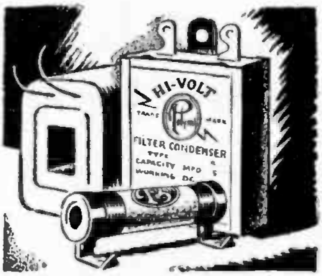
THORDARSON ELECTRIC MANUFACTURING CO.
TRANSFORMER SPECIALISTS SINCE 1895
Huron, Kingsbury and Larrabee Sts., Chicago

EQUIPPED WITH

THORDARSON
RADIO
TRANSFORMERS

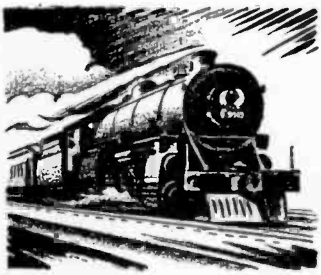
S U P R E M E   I N   M U S I C A L   P E R F O R M A N C E

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

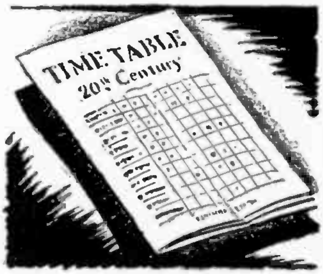


WHEN YOU BUY POLYMET PRODUCTS YOU GET

QUALITY PRODUCTS



where you want them



ON SCHEDULE

YOUR order in the stock room of some manufacturer 100 miles away is not going to help you much to maintain your production schedule. Neither will a shipment three weeks late, nor a shipment, hurried out, of questionable uniformity and quality.

Polymet enjoys the advantages of the most up-to-date manufacturing methods, permitting large-scale production and quickly increased volume, without detriment to quality or uniformity.

We are now supplying 80% of the radio industry with Polymet electric set essentials. Their good-will for Polymet has been grounded on Dependability — the Dependability of Polymet Products and the Dependability of delivery.

POLYMET MANUFACTURING CORP.
829-A East 134 St, NEW YORK CITY

POLYMET PRODUCTS

MASTER INSTRUMENTS
for Radio Laboratory Use

Pattern 171
For Direct Current

Pattern 172
For Alternating Current

Pattern 173
Wattmeter

FOR radio laboratory service such as designing, checking shop instruments, and in fact master testing of all kinds, Jewell Master Portable Instruments afford an unequalled value.

Jewell Master Instruments comprise the first complete line of intermediate size instruments in cases of uniform dimensions. The compact size of Jewell Masters makes them easily portable, yet they possess all the refinements necessary to dependable, accurate testing. Their neat, clean-cut appearance instills confidence.

Rugged bakelite cases with non-shatterable glass windows stand up under hardest service. Knife-edge type pointers of seamless aluminum; anti-parallax mirrors; large scale openings; exceedingly long hand-drawn scales stepped and calibrated with a potentiometer or with standards of unquestioned accuracy, combine to make reading easy and accurate.

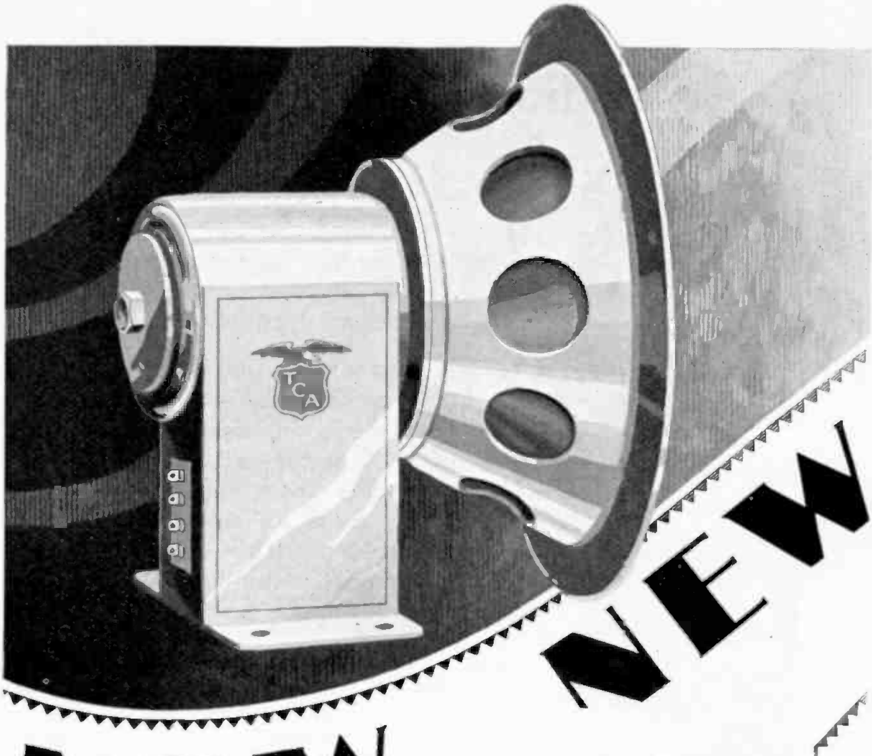
Master Instruments are available in a large number of ranges. For example, D. C. Voltmeters may be had in resistances as high as 5000 ohms per volt, and A.C. Instruments for low filament voltages are available in special ranges.

Every radio engineer should have the Jewell Master Instrument Bulletin No. 2012. Write for your copy today.

JEWELL ELECTRICAL INSTRUMENT COMPANY
1650 WALNUT ST., CHICAGO, ILLINOIS

29 YEARS MAKING GOOD INSTRUMENTS

JEWELL



NEW

NEW heights in Electrodynamic reproduction are reached by this latest development of the T. C. A.—a unit that offers a fidelity of tone and a rich full amplification that must be heard to be appreciated.

Intensive research has shown the necessity for several important modifications from common dynamic speaker practice. These improvements are offered to the industry for the first time. Details and data on request.

All external metal parts are cadmium plated. All terminal lugs are grouped on a rear panel of bakelite, improving appearance and making cabinet installation fast and easy.

Complete line of types and sizes on dependable quantity delivery.

THE TRANSFORMER CORPORATION OF AMERICA, CHICAGO, ILLINOIS

NEW NEW

NEW products, of which this Electrodynamic speaker is the latest, make the T. C. A. line a peculiarly helpful source of supply to the quality set manufacturer.

Dependability in T. C. A. power packs and chokes is no accident. Interchangeability in T. C. A. Transformers is not a matter of luck or chance.

For every manufacturing operation has been perfected through the production of thousands, and in some cases, millions of identical units.

NEW production facilities made possible by the plant illustrated below will further emphasize T. C. A.'s claim to leadership.

Here basic raw materials, such as wire and sheet steel, will be converted into finished receiver units, ready for installation in the radio set.

The thoroughness of the T. C. A. engineering laboratory has enabled it to render valuable service and assistance to many set manufacturers. Inquiries invited.

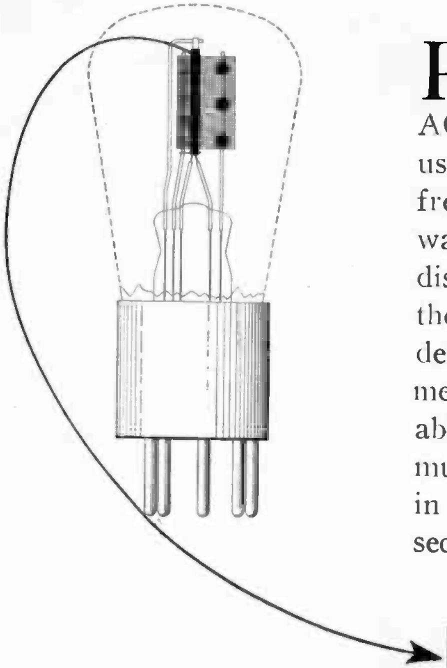
2301-2319 South Keeler Avenue

THE TRANSFORMER CORPORATION OF AMERICA, CHICAGO, ILLINOIS

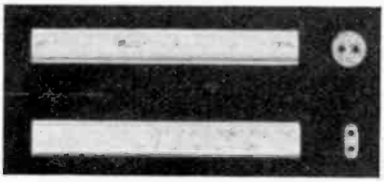
Fused Pure Silica

Vitreosil

The Ideal Insulation



PROGRESSIVE manufacturers, making the better kind of AC heater-type radio tubes use Vitreosil insulation for its freedom from gas and uniform wall which produces even heat distribution. It easily meets the thermal conditions of sudden heating and cooling, is mechanically strong, and available at low cost in single or multibore styles, and twin bore in either oval or circular cross section.

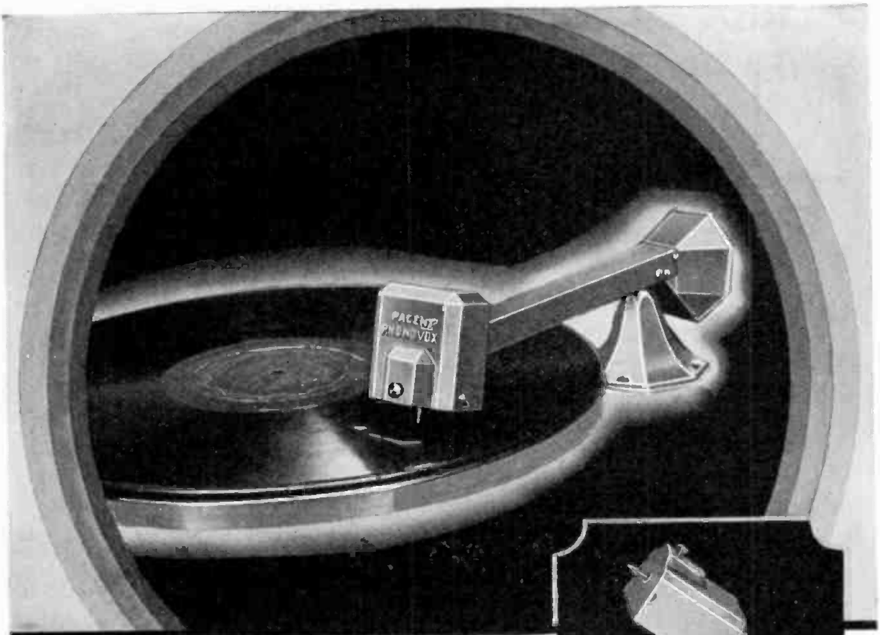


You can identify this Vitreosil product by its smooth satin finish as illustrated herewith. Let us send samples and quote on your requirements.

PURE FUSED SILICA VITREOSIL REGD TRADE MARK THE THERMAL SYNDICATE LTD WALLSEND-ON-TYNE

THE THERMAL SYNDICATE, Ltd.

1716 Atlantic Avenue Brooklyn, New York



No. 106-B Type *List price, $15.00*

The Super Phonovox head hinges backward, allowing easy insertion of the needle — eliminating any external support.

A New Pick-Up

That Offers Astonishing Improvement in the Electrical Reproduction of Records!

Again a startling advance in pick-up design and as usual by Pacent—the new Super Phonovox . . . . offering a degree of naturalness and tone beauty hitherto unknown . . . . new standard improvements, refinements, and finishes.

Among the new features are the elimination of rubber bearings which are the cause of variations between pick-ups, new perfectly balanced tone arm, fold-back hinge for easy insertion of needle, SPECIAL ENGLISH 36% COBALT MAGNETS and many others.

Write today for complete information, discounts, etc.—three models—$12, $15, and $25.

Prices slightly higher west of the Rockies.

PACENT ELECTRIC CO., Inc., 91 Seventh Avenue, New York

Pioneers in Radio and Electric Reproduction for Over 20 Years

Manufacturing Licensee for Great Britain and Ireland: Igranic Electric Co., Ltd., Bedford, England

Licensee for Canada: White Radio Limited, Hamilton, Ont.

PACENT Super Phonovox

PYREX Insulators make records at the North Pole, at the South Pole

. . . *and everywhere between*

THE stream of messages from Commander Byrd when he flew across the North Pole traveled out from an antenna equipped with PYREX Insulators.

Now for his Antarctic expedition, the Commander uses PYREX Insulators exclusively for all antennae and also employs them where possible at other locations in his equipment.

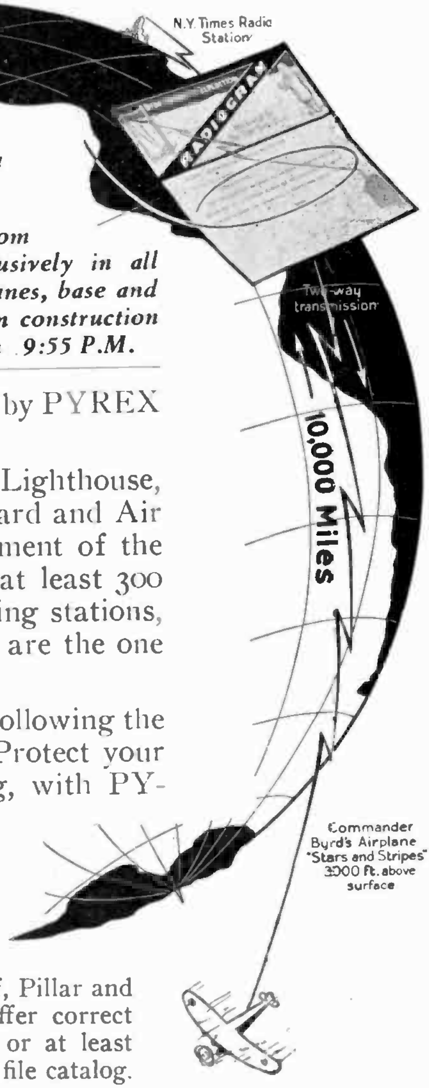
PYREX Insulators are therefore one of the most important factors in the dependability of his communication system between the various ships, base, portable and airplane stations, and in giving us our interesting daily news from the Antarctic regions.

Commander Byrd—and PYREX Insulators—recently set a new world's record in aviation radio, when his plane "Stars and Stripes," 3000 feet above Antarctic ice, established perfect two-way communication with the New York *Times* station in New York City, 10,000 miles away, and the occupants conversed at will with F. F. Meinholtz, the local Radio Consultant of the Expedition.

Write for this FREE BOOKLET

The transmitting and receiving equipment in the "Stars and Stripes" is small, weighs only about 40 lb., and is of the short-wave (34-meter) type with a power of only 50 watts. Plane radio sets are always of low power because of weight limitation. The attainment of 10,000-mile range of short-wave signals from such a small set indicates the height of insulation achievement, and by many radio experts is considered the greatest feat ever performed by radio.

The Corning Glass Works congratulates the Commander and is



Little America, Antarctica
Feb. 3rd, 1929

Uniformly excellent satisfaction from PYREX Insulators employed exclusively in all antenna systems all our ships, airplanes, base and portable stations, also extensively in construction various transmitters. —Hanson 9:55 P.M.

justly proud of the part played by PYREX Insulators.

In the United States Navy, the Lighthouse, Atlantic Ice Patrol, Coast Guard and Air Mail Services, in the development of the Directional Beam System, in at least 300 of America's finest broadcasting stations, PYREX Insulators were and are the one and only choice.

You will make no mistake by following the judgment of these leaders. Protect your set, transmitting or receiving, with PYREX Insulators, and your first installation will soon tell you why these insulators occupy their unique position of supremacy.

Antenna, Strain, Entering, Standoff, Pillar and Bus-bar Types of various sizes offer correct selection. Buy from your dealer or at least write to us for complete illustrated file catalog.

CORNING GLASS WORKS, DEPT. 63
Industrial and Laboratory Division
CORNING, NEW YORK

T. M. REG. U. S. PAT. OFF.

CGW **PYREX**

A MARK OF CORNING GLASS WORKS

RADIO INSULATORS

PRECISION FILAMENT RIBBON AND WIRE
FOR RADIO VACUUM TUBES
IS A PRODUCT OF
SIGMUND COHN
44 Gold Street New York

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

Announcement

***Attention:* Owners of Broadcasting Stations**

We wish to announce that we are in a position to supply you with a Thermostatically Controlled heater unit for housing your Piezo Electric Crystals, said unit guaranteed to maintain a *constant temperature to within a tenth of one degree Centigrade.* This unit is easily adjusted, and when once set is entirely automatic..

Description: This unit has provision for mounting two crystals (one as spare) with instantaneous changeover. Crystal leads brought out through ISOLANTITE bushings. Black crystalline finish with nickel trim and fireproof construction; operates from 110 volts supply.

This unit is absolutely guaranteed and should be a necessary addition to make your station up-to-date. Delivery can be made within 10 days after receipt of your order. Price $400.00.

Attention: Radio Laboratories and Universities

We have a limited amount of crystals which can be ground for *low frequency standards.* We can grind for you such a crystal to 25,000 cycles to plus or minus one hundredth of one per cent. Prices quoted upon application.

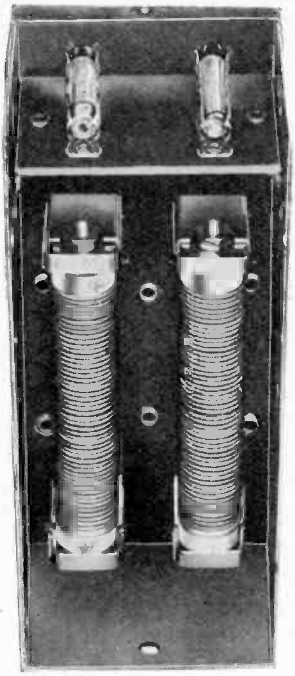
Scientific Radio Service

P. O. Box 86 Dept. R-2

MOUNT RAINIER, MARYLAND

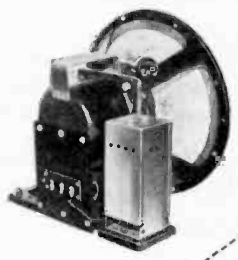
When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

This New Elkon Rectifier Eliminates the Power Transformer in Dynamic Speakers



AGAIN Elkon leads the field. The new Elkon D-29 Power Supply is the outstanding development of the year in rectifiers for dynamic speakers. This remarkable rectifier operates directly from the AC power line eliminating the Power Transformer and reducing the cost of assembly.

Supplied complete, ready to install, or the rectifier units (two required on each speaker) can be sold separately. Wonderfully efficient, quiet in operation. The units can be replaced when necessary as easily as a tube is changed in a socket.



If you have not already sent us a sample of your new speaker, do so at once. We will equip it with the new Elkon rectifier and return it to you promptly.

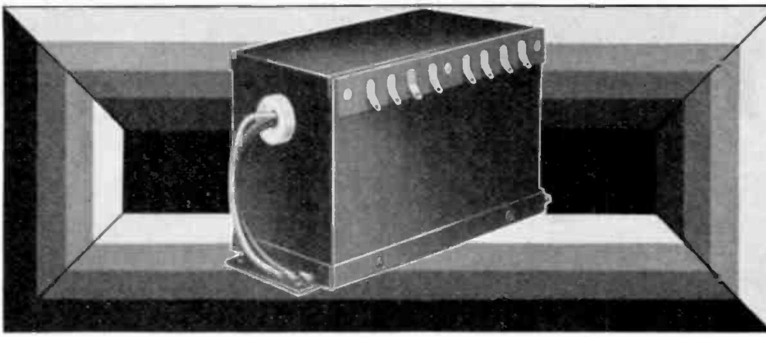
ELKON, Inc.
Division of P. R. Mallory & Co., Inc.
350 Madison Ave.
New York City

COUPON

ELKON, Inc., Radio Dept. E-71
350 Madison Ave., New York City
Please send us complete information on your new ELKON D-29 Power Supply for Dynamic Speakers.

Name..........

Address..........



New Jefferson Power Pack for use with the new 245 and A.C. 222 power tubes.

Transformers and Chokes *for* New Power Tubes

Specially Engineerd by Jefferson

AGAIN Jefferson Engineers have anticipated the need of the Radio Industry. The transformer and choke problems which will be met in building sets around the newly developed power tubes have already been solved by Jefferson Engineers.

A new power transformer has been designed, perfected, and thoroughly tested for use with the new tubes No. 245 and No. A.C. 222 shield grid tube.

A wide choice of choke units are ready—heavy single duty chokes, double chokes of the conventional design—or staggered choke units consisting of one heavy and one light choke. The last is an especially economical method which minimizes hum and allows maximum voltage on the tubes without overloading the rectifier.

Special audio transformers have been developed with improved design to make use of all the possibilities of these new tubes.

Jefferson reputation, backed and maintained by Jefferson engineering, is your guarantee of quality, service, and satisfaction on these new units. And the foresight of Jefferson Engineers together with the Jefferson production capacity are your insurance of prompt deliveries now and throughout the season.

Take advantage of this engineering work already done for you by writing us your problems. Complete electrical specifications and quotations will be supplied on request.

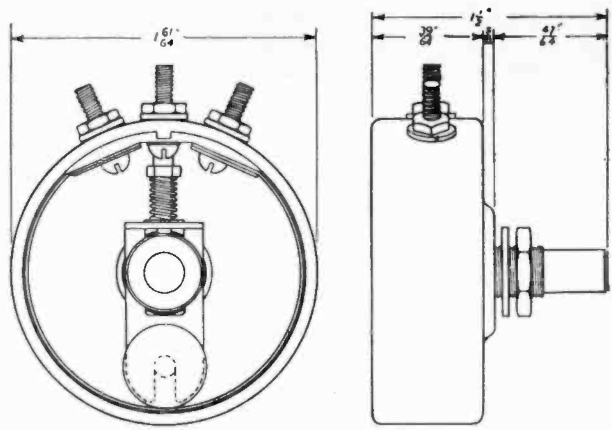
JEFFERSON ELECTRIC COMPANY
1591 West 15th Street, CHICAGO, ILLINOIS

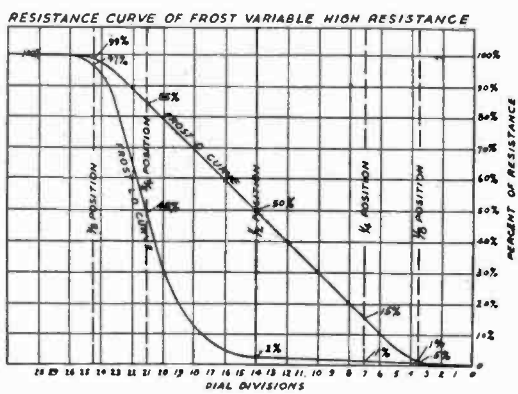
JEFFERSON

AUDIO and POWER TRANSFORMERS and CHOKES

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

For Satisfactory
Specify Frost





Frost makes the size you want with the resistance progression to suit your needs

Volume Control

Here's Why

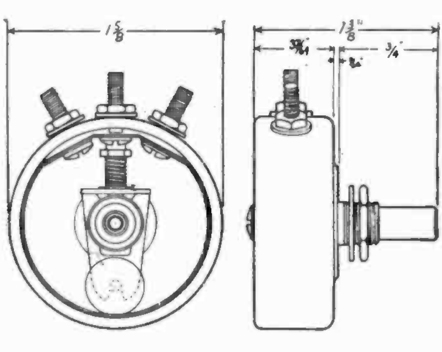
Frost Variable Resistance Elements are smooth-running, non-inductive, not affected by temperature or humidity changes. The roller contact on the arm insures long and accurate service.

Standard housing dimensions are as follows:

Diameter	*Depth*	*Type*
1 61/64 in.	39/64 in.	Bakelite
1 7/8 in.	43/64 in.	Metal
1 7/8 in.	3/4 in.	Metal
1 5/8 in.	37/64 in.	Bakelite
1 1/2 in.	43/64 in.	Metal

Bushing, threads per inch, shaft lengths and diameters, as illustrated, are standard. For other than standard units, please indicate in your request for samples any special dimensions, terminal positions, curve desired, and watt load. In requesting tandem unit samples, please include maximum permissible mounting depth. Supplied in two or three terminal type, as you desire; clockwise or counter-clockwise resistance increase.

FROST-RADIO



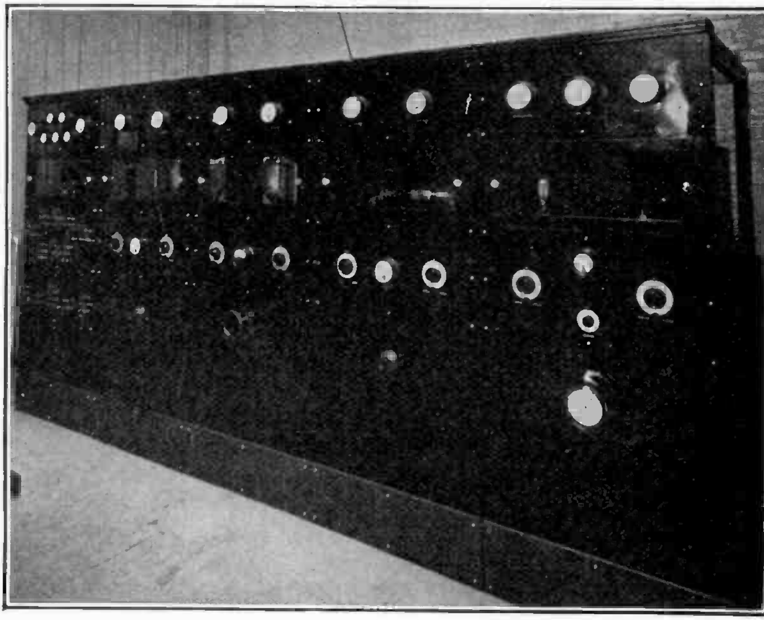
HERBERT H. FROST, Inc.

***Main Offices and Factory:* ELKHART, INDIANA**

160 North La Salle Street

CHICAGO

A Typical R-S Instrument Installation



THIS modern 2000 watt broadcasting transmitter has just been put in service by Station WAAM owned and operated by I. R. Nelson Company, Newark, N.J. It is said to be the most powerful non-chain transmitter in the New York district.

Panel #1 at the left contains a crystal oscillator and a 50 watt amplifier; Panel #2 a 250 watt amplifier; Panel #3 two 1000 watt amplifier tubes; Panel #4 a 1000 watt modulator and Panel #5 all power controls and battery charging apparatus. The measuring instruments are R-S Types TD and TW, 3½" diameter and Types FA, FD and FW, 4" diameter, for A.C., D.C. and R.F.

As a matter of interest, the high voltage plate circuit is protected by a special R-S air break overload circuit breaker rated at 2500 volts.

These instruments are shown in Bulletins K-400, K-420 and K-810, which we will be glad to send on request.

"Over thirty years' experience is back of Roller-Smith"

ROLLER-SMITH COMPANY

Electrical Measuring and Protective Apparatus

Main Office:
2134 Woolworth Bldg.
NEW YORK

Works:
Bethlehem,
Pennsylvania

Offices in principal cities in U. S. A. and Canada.

Representatives in Australia, Cuba, Japan and Philippine Islands.

TEMPERATURE CONTROL UNITS

designed for

PIEZO CRYSTAL OSCILLATORS

Catalogue No. 211

Automatic thermostatically controlled heater compartments, designed to house from one to three piezo crystals—Jacks are provided to fit any type of crystal holder (When ordering give dimensions and type of holder employed)—Uniquely constructed adjustable thermostat units, which are guaranteed to keep the temerature constant to within 0.1 of one degree at the desired setting—Adjustable working limits 30° to 50° C—Fitted with precision thermometers having large graduated scales capable of indicating tenths of a degree centigrade—The cases are constructed along scientifically correct lines, having an inner lining of special asbestos board; an intermediate non-circulating air chamber and air exterior covering of heavy sheet aluminum—Supported with aluminum end castings.

Easily adapted to present day transmitters—Operates direct from any 110 volt A.C. or D.C. line—Current consumption only one-half ampere—Furnished with pilot light which gives instantaneous check on operation.—Dimensions 7½" x 11½" front x 12" deep.

Broadcasting, commercial, experimental and other stations, which are required to keep within 100 cycles of a specified frequency, will find these REL Cat. 211 units very necessary—Quantity production has enabled us to offer these at a very reasonable price.

Information and Prices on Application

REL

MANUFACTURES A COMPLETE LINE OF APPARATUS FOR SHORT WAVE TRANSMISSION AND RECEPTION.

RADIO ENGINEERING LABORATORIES

100 Wilbur Ave. Long Island City, N.Y., U.S.A.

Radio Electrical **Potter** Products of Merit

Condensers

The Investment that Pays Dividends

QUALITY in the Potter Condenser is given by the use of highest grade paper, foil and impregnating wax.

LONG LIFE has been attained by manufacture in a factory devoted to the exclusive production of condensers by special processes.

UNIFORMITY is essential to give best results in any radio receiver or power amplifier and is given by careful and skilled workers. A series of tests during the making and rigid inspection controls the production.

ECONOMY does not always come with the purchase at the lowest price. The additional cost is an investment that pays dividends by reducing the repair charges which are sure to grow if condensers fail under operating conditions.

Potter Condensers include a full line of By-Pass, Filter and Filter Block Condensers for all of the required capacities and working voltages.

POTTER DYNAMIC SPEAKER FILTER WILL

REDUCE the hum in A.C. operated dynamic speakers, using low voltage rectifier

A Condenser Assembly for Every Use

The Potter Co.

North Chicago, Illinois

A National Organization at Your Service

RCA

RCA Radiotrons embody all the world's knowledge of vacuum tube design. Back of the mark RCA are the engineering resources of General Electric, Westinghouse and the Radio Corporation of America.

RADIO CORPORATION OF AMERICA

NEW YORK CHICAGO ATLANTA DALLAS SAN FRANCISCO

RCA RADIOTRON

MADE BY THE MAKERS OF THE RADIOLA


"THE STANDARD OF COMPARISON"
"As furnished the U.S. NAVY"
reads an order for condensers from the Byrd Expedition.
Every CARDWELL condenser meets the rigid requirements of the Navy and other branches of the Service—your guarantee of quality and satisfaction.
Transmitting Condensers for powers up to 50 K.W.
Receiving Condensers in all Standard capacities.
Send for Literature
THE ALLEN CARDWELL MFG. CORPN.
81 Prospect St.
BROOKLYN, N. Y.
Cardwell Condensers

PRECISION

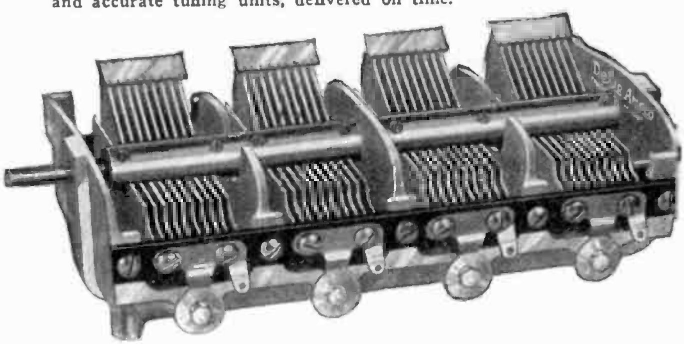
In Manufacturers'

CONDENSERS

Is Assured By

DeJur-Amsco

These famous "Bath-Tub" Condensers are available in Single, Double, and Quadruple types in all capacities. They are the products of a plant manned by experts and equipped with laboratories and machinery to assure set manufacturers precise and accurate tuning units, delivered on time.



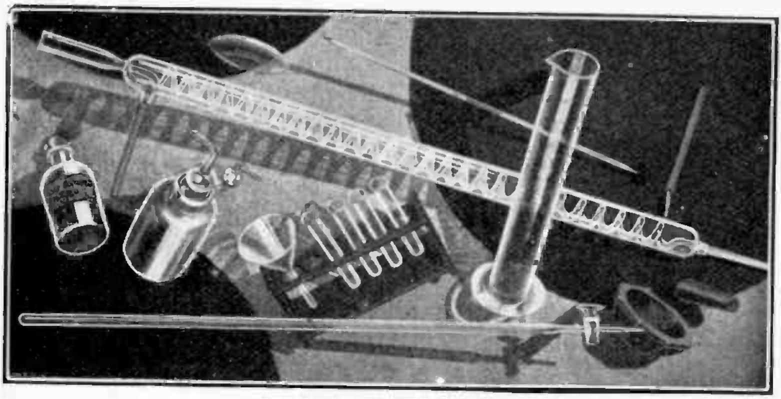
Covered by Patents and Patents Applied For.

Send us your specifications and let us quote on your requirements.

DeJur-Amsco Corp

Condenser Headquarters

Broome & Lafayette Sts., New York City



Uniformly Good ~

LIKE a seething 'melting pot', with science ceaselessly checking each crucible—the Arcturus Laboratory, as a result of its research and pioneering, gives the radio world, in Arcturus A-C Long Life Tubes, a product that is uniformly good.

Rigid tests and specifications, jealously guarding an enviable reputation, do not cease with one type of tube—*they go on and on for every tube.*

. . . oxides that are put through sieves, so fine they hold water . . . parts that are proven with 'go and no-go gauges', where even a hairline makes a vast difference . . . special production units diligently supervised by efficient laboratory engineers . . . specified filament, metal and glass construction . . . the most minute evacuating process known to science . . . *to give the world uniformly good A-C tubes.*

Critical set engineers have been quick to grasp the value of such service and its significance in set efficiency.

Arcturus has struck the keynote in perfect tube production—with ARCTURUS A-C LONG LIFE TUBES.

ENGINEERING FACTS HAVE A UTILITY SIGNIFICANCE TO THE BROADCAST LISTENER.

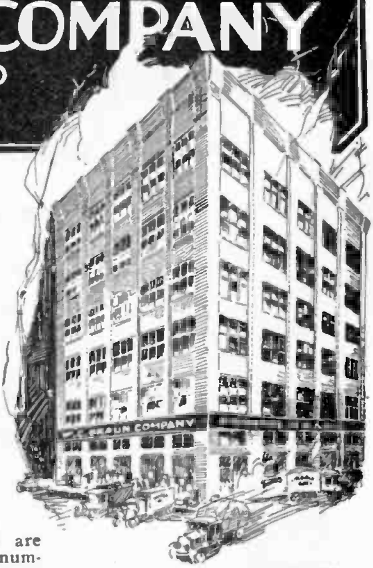
ARCTURUS RADIO TUBE CO. NEWARK, N.J.

ARCTURUS

BLUE A-C LONG LIFE TUBES

W.C. BRAUN COMPANY

WHOLESALE RADIO HEADQUARTERS



Keeping up with the Developments in Radio

No industry in the world's history has attracted so many inventors and experimenters as the radio industry. Something new is always on tap. Contrast the old wireless days with the modern electrically operated talking radio. Think of what is still to come when perfected television, telephony, short wave control, etc., are fully realized.

In keeping with the policies of *Wholesale Radio Headquarters* (W. C. Braun Company), our service lies in testing out and determining which of these newest marvels are practical, salable and usable for the greatest number. Our task is to study the multitude of new merchandise, select those items that are thoroughly proved and reliable, and make it easy for the public to secure these while they are still new.

A huge and varied line of standard radio merchandise is carried in stock for quick shipment to all parts of the country. This service assures the dealer and set builder of *everything he needs*, all obtainable from one house, without shopping around at dozens of different sources. It saves considerable time, trouble and money. For example, when you want a complete radio set or parts for a circuit, you also will want a cabinet, loud speaker, tubes and other supplies and accessories. You know that at Braun's you can get everything complete in one order, and thus save days and weeks of valuable time, besides a considerable saving in money.

New Lines for Spring and Summer

Here, all under one roof, is carried the world's largest stocks of radio sets, kits, parts, furniture, speakers and accessories for the radio season, portable radios and phonographs for summer trade and a complete line of auto tires, tubes and supplies, electrical and wiring material, camping and outing equipment, tents, golf goods, sporting goods; in fact, a complete merchandise line to keep business humming every day, every week and every month in the year.

NEW LINES SPRING and SUMMER

RADIO SETS, KITS, PARTS SHORT WAVE, TELEVISION, SPEAKERS, SUPPLIES, PORTABLE RADIOS and PHONOGRAPHS AUTO TIRES and ACCESSORIES

ELECTRICAL GOODS
Wiring Fixtures, Etc.

SPORTING GOODS
Outing Clothing, Baseball, Golf Goods, Etc.

HOUSEHOLD SPECIALTIES
Vacuum Cleaners, Phonographs, Electrical Toys

Do You Get Our Catalog?

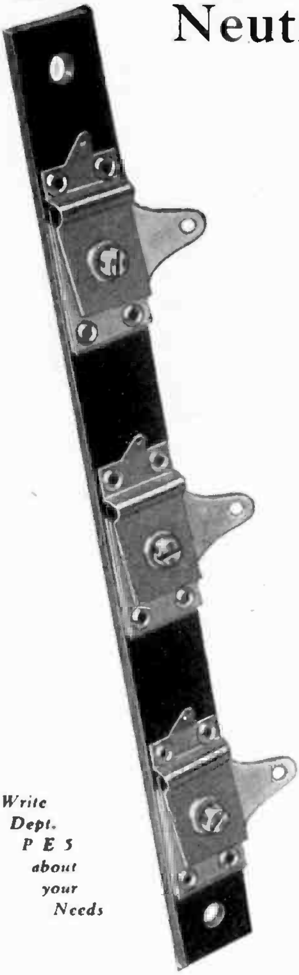
If you don't receive our catalog, by all means send us a request on your letterhead to insure getting each new edition as promptly as it comes out. Braun's Big Buyers' Guide is crammed full of bargains and money-making opportunities that you cannot afford to pass up.

W. C. BRAUN COMPANY

Pioneers in Radio

600 W. Randolph St., Chicago, Illinois

Special Equalizing and Neutralizing CONDENSERS



WHEN the standard Hammarlund Equalizing and Neutralizing Condensers do not quite fit into your receiver design, we are prepared to make special models, either single or in gang, to your specifications. The Hammarlund Equalizing and Neutralizing Condenser is superbly made—compact, accurate, efficient.

Bakelite base; brass stator plate; mica dielectric; phosphor bronze spring plate; convenient adjusting screw and connecting lugs.

The standard models range in capacity value from 2 mmfds. minimum to 70 mmfd. maximum.

Write Dept. P E S about your Needs

HAMMARLUND MANUFACTURING COMPANY
424-438 WEST 33rd STREET, NEW YORK, N. Y.

For Better Radio
Hammarlund
PRECISION
PRODUCTS

COILS BY ROME signifies the establishment of a complete coil winding department,—already busy winding coarse coils, fine coils, magnet coils, paper cell coils. . . .

COILS BY ROME signifies engineering that begins with fundamental coil design and carries through to application. It may well be considered an adjunct to your own design and experimental departments.

COILS BY ROME signifies a new precision process in winding coarse wire coils that achieves an otherwise impracticable factor of space utilization.

COILS BY ROME signifies manufacturing methods and capacity that are eager to match coils and costs with you, whether you wind your own coils or buy them.

COILS BY ROME is both a challenge and an invitation.

. . . We ask an opportunity to prove the significance of COILS BY ROME.

ROME WIRE COMPANY
Division of General Cable Corporation
ROME, NEW YORK

ROME PRECISION COILS

A Message to Manufacturers of Vacuum Tubes

FOR years, Isolantite has been recognized by vacuum tube engineers as the premier insulator for use in the internal construction of the vacuum tube. For receiving and transmitting tubes alike, Isolantite has met the severe electrical and mechanical requirements demanded by the leading tube laboratories and factories of the country.

Isolantite has advanced side by side with the vacuum tube art and industry, offering a perfected product from an early date. This time-tested and approved insulator is made available today by an organization of skillful and painstaking engineers. They are pledged to the duty of making Isolantite toe the mark of reliability, technical excellence of product and economy.

Entrust your experimental and production problems to this experienced Isolantite organization, makers of tried, tested and perfected Isolantite products.

Isolantite Company of America, *Inc.*

New York Sales Offices—551 Fifth Ave., New York City

TIME

THERE IS STILL TIME TO SECURE OUR QUOTATIONS *and* SAMPLE BLOCKS FOR THIS SEASON'S REQUIREMENTS.

OUR OIL CONDENSERS ARE LEADING THE FIELD IN QUALITY AND THE PRICES ARE RIGHT.

DO NOT OVERLOOK THIS OPPORTUNITY. FORWARD YOUR LATEST SPECIFICATIONS TO US AT YOUR EARLIEST CONVENIENCE.

CONDENSER CORPORATION OF AMERICA

259-271 CORNELISON AVE. JERSEY CITY, N. J.

DUBILIER Devices
Reg. U.S. Pat. Off.

Dubilier
Transmitting
Condensers

1 mfd. condenser $5.00
2 " " $8.00

DUBILIER type 686 condensers have the usual Dubilier high safety factors for use in transmitter filter net works. 1000 volt DC rating.

May be connected in series where the working voltage exceeds 1000. Through series parallel connections practically any working voltage and capacity can be obtained.

DC voltage must not exceed 1000; or in AC supply filter circuits the transformer voltage must not exceed 7.50 volts per rectifier plate.

Ask about Dubilier paper condensers also,—the standard of the leading manufacturers.

We make condensers for every purpose

Illustrated below is but one of the many hundred types of Condensers Dubilier is producing for radio manufacturers. Many thousands of these condensers are being used in well-known and nationally advertised radio sets.

Consult us in reference to your problems
Address Dept. 88

Dubilier
CONDENSER CORPORATION

10 East 43rd Street, New York City

You can forget the Condensers if they are Dubilier's

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

Announcing the

SYMINGTON

Super-Dynamic Reproducer

FOR many years Valley Appliances, Inc., has been manufacturing electrical equipment. Most of its recent work has been in the radio field.

Included among shipments we made to the trade last year were 250,000 sets of parts for dynamic loud speakers.

Our position is somewhat unique. We make everything under our own roof. In addition to a strictly modern tool room and machine shop we have our own coil winding department as well as complete facilities for plating, enameling, baking, heat treating and annealing.

The result—a one profit sales price.

The design being presented is the joint effort of an experienced shop and laboratory to give highest quality operation at low cost.

VALLEY APPLIANCES, *Inc.*

634 Lexington Ave., Rochester, N. Y.

W. S. Symington, *President*

I. G. Maloff, *Vice-President*

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

Tone Quality-Sensitivity Volume *and* Clarity

all this and more by using

CeCo
RadioTubes

In the CeCo research laboratories, both the *quality* of today's achievement and the vision of tomorrow's radio needs fill the minds of CeCo engineers.

That is why there will always be a CeCo tube for every radio requirement.

An interesting discussion of CeCo methods and materials is sent free on request. Ask for the booklet "Radio Vacuum Tubes."

Hear the CeCo Couriers every Monday night at 8:30 Eastern Daylight Saving Time over WOR and the Columbia Broadcasting System.

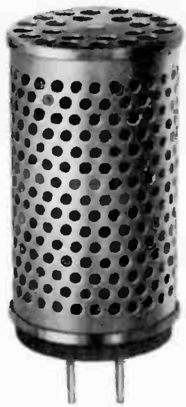
CeCo Manufacturing Co., *Inc.*

Providence, R.I.

Announcing the LINE BALLAST CLAROSTAT

YOUR 1929 A-C sets are incomplete if they do not include automatic line-voltage control. And you run the danger of losing many potential sales, experiencing plenty of service troubles, and having your engineering—and your merchandising—judgment seriously questioned. All of which you cannot afford in a highly competitive market.

After a year or more of research and development, the Clarostat Engineering Staff takes pleasure in announcing the LINE BALLAST CLAROSTAT—a practical, automatic, foolproof, inexpensive line-voltage control.



½ Actual Size

This device is sturdily built. Will provide long and trouble-proof service. Sealed in stout metal casing to avoid tampering. Functions over wide limits, such as between 100 and 135 volts, with resultant secondary voltages varying less than plus or minus 5 per cent—or well within the specifications of A-C tube manufacturers. Plugs into standard receptacle.

The LINE BALLAST CLAROSTAT is inexpensive. You can well afford the slight added cost. Furthermore, by doing away with a tapped transformer primary, together with switching mechanism or terminals and extra wiring, the LINE BALLAST CLAROSTAT goes far toward paying for itself. And on the basis of merchandising advantages, the device pays for itself a hundred-fold.

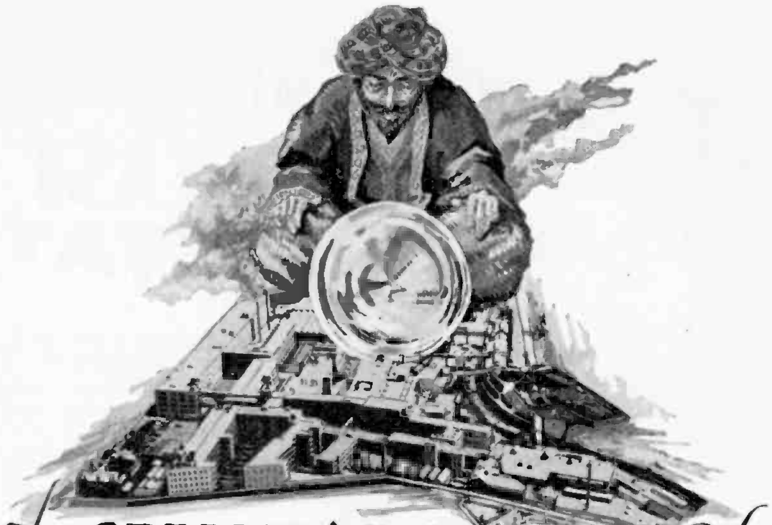
Don't fail to look into the merchandising features quite as well as the engineering advantages. Remember, the LINE BALLAST CLAROSTAT makes it possible for you to sell sets in low-voltage areas, because of full volume and tone, and in high-voltage areas, because of no extra strain on the tubes. All of which means more sales, more good will, and more dealer interest.

Write for technical bulletin on the LINE BALLAST CLAROSTAT. Better still, send us a sample power transformer with an 85-volt primary, and we shall submit to you the proper LINE BALLAST CLAROSTAT for your inspection and test. Meanwhile, don't forget that there is a CLAROSTAT for every purpose—variable, fixed and automatic resistance.

Clarostat Manufacturing Company, Inc.

Specialists in Radio Aids

289 North Sixth Street :: Brooklyn, N. Y.

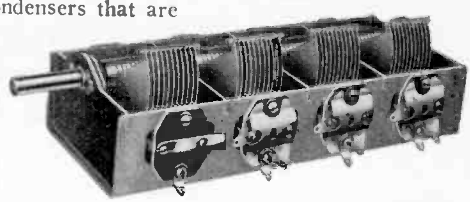


The CRYSTAL BALL *of the* MODERN RADIO MAKER

THE modern radio manufacturer keeping abreast of the latest developments in radio endeavors to gauge the market requirements, and produce a set which has all of the qualities the public demands.

The task is not a light one. Market changes are rapid these days of keen and capable competition. The set of today may not sell to the enlightened public of tomorrow. Sometimes the crystal ball of the clairvoyant would help—if only to enable a view of tomorrow's market.

Many important radio manufacturers depend upon Scovill to keep them abreast of the latest developments in the manufacture of Radio Condensers—an integral and important part of every good radio set. They place their confidence in this pioneer for Radio Condensers that are the last word in development. Instead of peering into a crystal ball, they summon a Scovill representative to help with their problems. Let Scovill aid you with your Condenser problems.



Visit the Scovill Exhibit—Booths 22 and 23—Radio Manufacturers' Association Trade Show, Week of June 3, Stevens Hotel, Chicago

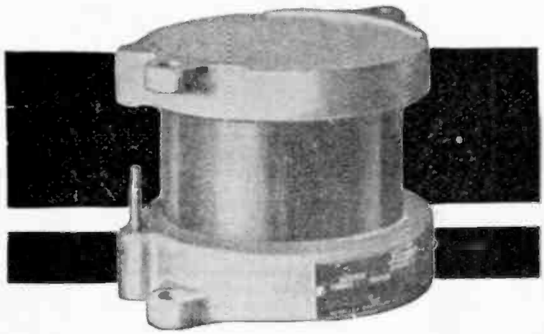
MEMBER COPPER & BRASS RESEARCH ASSOCIATION

SCOVILL

MANUFACTURING COMPANY
WATERBURY, CONNECTICUT

NEW YORK	SAN FRANCISCO	CHICAGO
PROVIDENCE	BOSTON	CLEVELAND
LOS ANGELES	PHILADELPHIA	CINCINNATI
ATLANTA		DETROIT

In Europe—THE HAGUE, HOLLAND



Faradon

Dependable as recognized
for more than twenty
years

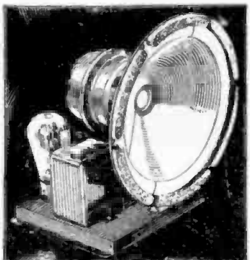
WIRELESS SPECIALTY
APPARATUS COMPANY
Jamaica Plain, Boston
(Est. 1907)

ELECTROSTATIC CONDENSERS FOR ALL PURPOSES

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

SM

New Reduced Prices on S-M Amplifiers



Matched Impedance Dynamic Speakers

Equipped with S-M 229 Output Transformer with impedance-matching taps, for any standard power tubes singly or in push-pull. Type 851 (110v. d.c.) $29.10 *net*. Type 850 (110v. a.c.) using 1-'80 type tube with high-efficiency filter, $35.10 *net*.

Increased popularity of Silver-Marshall high-power amplifier panels now makes possible a very substantial reduction in price—simultaneous with removal of the S-M organization to a new plant of far greater capacity. "PA" type rack-and-panel amplifiers are not sold through the trade, but direct only to engineers. Properly installed, they compare favorably with any competitive American equipment at any price.

The a.c. power amplifier in the photograph includes (from top to bottom) the following:

One PA-60A Volume Indicator (vacuum tube voltmeter) Panel $80

One PA-50A Input Control, to precede PA-20B Input $90

One PA-20B Input Amplifier: a.c.-operated, 3-stage push-pull. To supply up to 16 output amplifiers $85

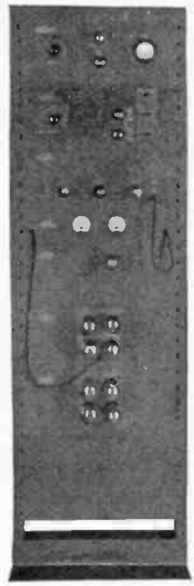
One PA-10A Meter Panel: two milliammeters, desirable for all installations $45

One PA-40B Input Power Supply Panels $90

Two PA-30A Output Amplifier Panel—1-stage 250 push-pull; about 15 watts output per panel; each $80

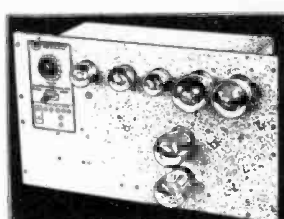
One PA-1A Panel Rack with master switch $40

Total price of above $590



The Famous 690 Self-Contained Amplifier at a New Low Price

S-M Type 690 Amplifier operates entirely from the a.c. light socket, and, using the famous S-M Clough-system audio transformers in all stages, insures a straight-line characteristic from 5000 cycles down to 70 cycles or below. It has three stages, the last two push-pull; will supply 6 to 12 or more dynamic speakers. Fading control is provided on the panel, and a three-point switch for record, microphone and radio input selection. Requires 1-'27, 2-'26, 2-'50, 2-'81 tubes. Will reach 2000 or more people. New net price, $147.00.

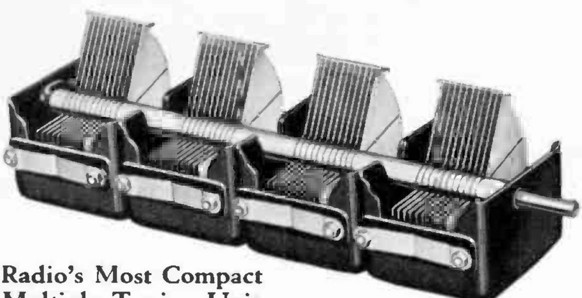


The Silver-Marshall laboratories, continuing the advisory service which they have for years offered to all experimental engineers, will furnish detailed recommendations promptly and without charge for any contemplated sound installation. Address inquiries to Chief Engineer, Power Amplifier Division.

SILVER-MARSHALL, Inc., 6411 W. 65th Street CHICAGO, U. S. A.

TRADE MARK
UNITED SCIEN. LAB
INC.

New Type B. T. 4 Gang
ARMORED CONDENSER



**Radio's Most Compact
Multiple Tuning Unit**

Set Manufacturers will find in this new Type B.T. Armored Condenser, the solution to their tuning problems. It will measure up to your most rigid tests for precision. You will also find it rigid and sturdy, assuring a long life of uniform efficient performance. Its compactness makes this new Type B.T. Armored Condenser a great space saver. In its design and construction there are many exclusive features which your engineering department will appreciate and approve. Write for sample.

These new type B.T. Armored Condensers are made in single, two gang, three gang, and four gang units of .00035 mfd capacity and lower.

**Samples now ready for delivery.
Write for prices and full information.**

UNITED SCIENTIFIC LABORATORIES, Inc.
115-C Fourth Avenue, New York City
Branch Offices for Your Convenience in

St. Louis
Chicago
Boston
Minneapolis
Cincinnati

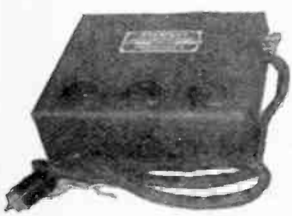
RADIO MANUFACTURERS' ASSOCIATION
RMA
MEMBER

Los Angeles
Philadelphia
San Francisco
London, Ontario

"Isn't it about time, Dad, you eliminated the 'ADENOIDS'?"

ANY set with inferior transformers has adenoids. Why not have your set give you what it is capable of—it's a mighty simple thing to eliminate the adenoids from your set—and to substitute true tones as given by AmerTran radio products.

AmerTran audio systems will give you every tone broadcast with all of the overtones and shadings from the lowest stop on the organ to the piercing note of the piccolo. A pair of DeLuxe transformers, or the superb power amplifier (push-pull for 210 tubes) and the ABC Hi-Power Box. No matter what AmerTran audio system you choose, your set will be free from adenoids.



Complete 2 stage audio amplifier. First stage AmerTran DeLuxe for UX 227 AC and second stage AmerTran Push-Pull for two 171 or two 210 Power Tubes.
Price, East of Rockies—less tubes—$60.00.

See your dealer or write to us.

AMERTRAN

TRADE MARK REG. U.S. PAT. OFF.

AMERICAN TRANSFORMER CO.

Builders of Transformers For More Than 29 Years

84 Emmet St. Newark, N. J.

AEROVOX
BUILT BETTER
CONDENSERS AND RESISTORS

How Do You Buy Condensers?

MOST filter condensers, condenser blocks and bypass units are bought merely on the basis of price, voltage ratings and their ability to withstand ordinary short-time tests, without sufficient consideration to the fact that these are not dependable indicators of the ability of a condenser to stand up under all conditions of service, during the entire life of the receiver or power unit.

Nothing is apt to prove as costly as a cheaply made, over-rated condenser or resistor. Whether you are a manufacturer, professional set builder or experimenter, you cannot afford the high cost luxury of a cheap condenser or resistor.

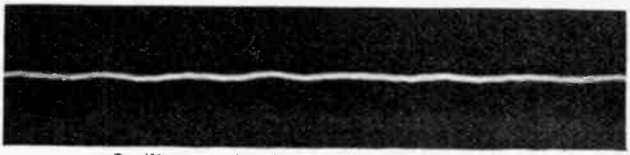
Aerovox condensers and resistors are conservatively rated and thoroughly tested. The Aerovox Wireless Corporation makes no secret of the Insulation Specifications of their filter condensers and filter condenser blocks. This information is contained in detail in the 1928-29 catalog.

The next time you are in the market for filter condensers or filter condenser blocks, make your comparison on the basis of Insulation Specifications. Aerovox condensers are not the most expensive, nor the cheapest, but they are the best that can be had at any price.

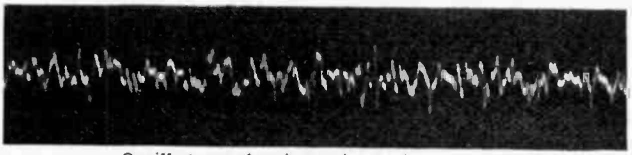
Send For Complete Catalog

Complete specifications of all Aerovox units, including insulation specifications of condensers, carrying capacities of resistors and all physical dimensions and list prices are contained in a fully illustrated, 20-page catalog which will be sent free of charge on request.

AEROVOX WIRELESS CORP.
80 Washington Street, Brooklyn, N. Y.
RMA
PRODUCTS THAT ENDURE



Oscillogram showing noiseless performance of BRADLEYUNIT resistors.

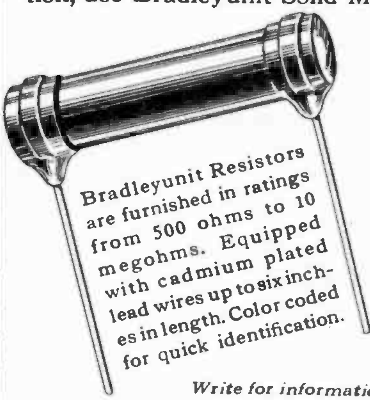


Oscillogram showing noisy performance of other types of resistors.

A New Resistor

that assures noiseless reproduction

COMPARE the extraordinary quietness of the Bradleyunit Resistor with the noisy performance of other resistors. Many resistors cause disagreeable hissing noises in the loudspeaker. For pure, clear reproduction, use Bradleyunit Solid Molded Resistors. They are unaffected by temperature, moisture or age.



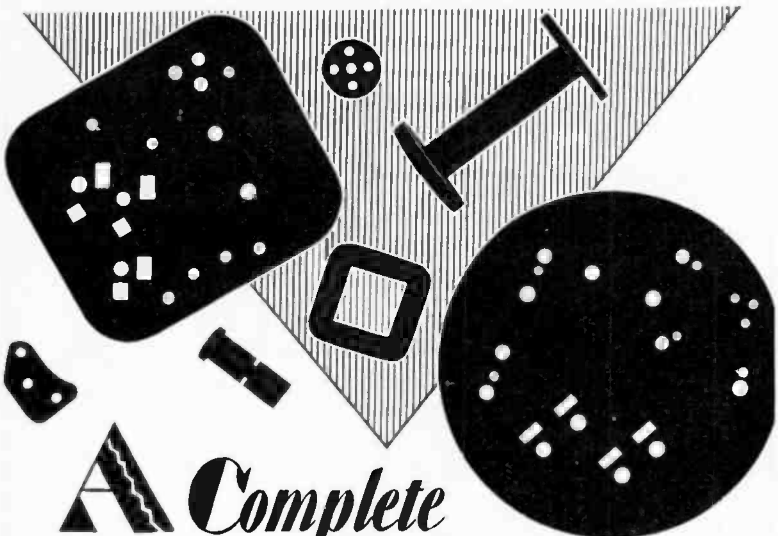
Leading set manufacturers are standardizing on the new Bradleyunits for grid leaks in detector circuits and for resistors in resistance coupled amplifiers. The Bradleyunit is your assurance that noises in the loudspeaker cannot originate in your equipment.

Write for information and prices today

ALLEN-BRADLEY CO., 282 Greenfield Avenue, Milwaukee, Wis.

Allen-Bradley

PERFECT RADIO A-B **RESISTORS.**



A Complete and Prompt Insulating Service

FORMICA provides promptly uniform and high quality phenol laminated insulating sheets, tubes and rods, and parts of any type that it is possible to machine from them.

The equipment both for producing the fundamental shapes and for machining them to your blue prints is the largest and most complete in the industry.

The Formica plant is centrally located where the promptest delivery is possible to the largest number of factories.

Send your drawings for quotations

THE FORMICA INSULATION CO.
4626 Spring Grove Avenue, Cincinnati, Ohio

FORMICA
Made from Anhydrous Bakelite Resins
SHEETS TUBES RODS

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

A New Book

Modern Radio Reception

By CHARLES R. LEUTZ

384 Pages—250 Illustrations—6x9 Fully Bound

SOME OF THE SUBJECTS COVERED

Radio Laboratory Apparatus
Super Heterodynes
A Current Supplies
Short Wave Reception
Vacuum Tubes
Power Packs
Radio Definitions
A/C Tubes
Resistance in Radio
Power Amplification
Radio Frequency Amplification
Long Wave Reception
Radio Measurements
Trouble Finding
Oscillators
Shield Grid Tubes

An ideal book for the radio experimenter, engineer, service man or anyone interested in broadcast reception.

Price $3.00 Postpaid

Unless you are entirely satisfied, the book can be returned within five days after receipt and your money will be refunded immediately.

C. R. LEUTZ, *Inc.*

LONG ISLAND CITY, NEW YORK, U.S.A.

Volume Controls

TO vary the intensity of the faithful reproduction built into radio receivers without introducing noise or distortion, can only be accomplished by a careful and complete consideration of both mechanical and electrical features of the volume control.

Mechanically—The Centralab exclusive and patented rocking disc contact precludes any possibility of wear on the resistance material. This feature adds to the smoothness of operation since the contact shoe rides only on the disc. The shaft and bushing are completely insulated from the current carrying parts—eliminating any hand capacity when volume control is placed in a critical circuit.

Manufactured in three sizes
Standard
Junior
Midget
Also Double Standard
and *Double Junior*

Electrically — Centralab engineers have evolved tapers of resistance that produce a smooth and gradual variation of volume. These tapers have been thoroughly tried and tested for each specific application for current carrying capacity and power dissipation.

Centralab volume controls have been specified by leading manufacturers because of their quality and ability to perform a specific duty—Vary the intensity of faithful reproduction—faithfully.

Write for full particulars of specific application.

Centralab

CENTRAL RADIO LABORATORIES

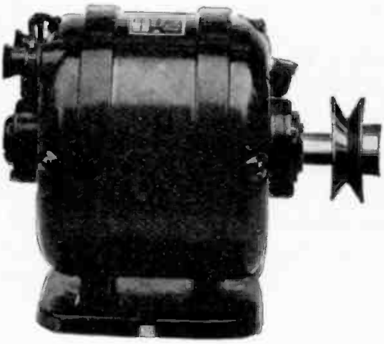
36 Keefe Ave. Milwaukee, Wis.

A CENTRALAB VOLUME CONTROL IMPROVES THE RADIO SET

"ESCO"

Synchronous Motors for Television

In addition to building reliable and satisfactory motor generators, "Esco" has had many years of experience in building *electric motors* for a great variety of applications.



Synchronous motors, small, compact, reliable, self starting are now offered for *Television* equipment. They require no direct current for excitation, are quiet running and fully guaranteed.

Other types of motors suitable for Television may also be supplied.

Write us about your requirements.

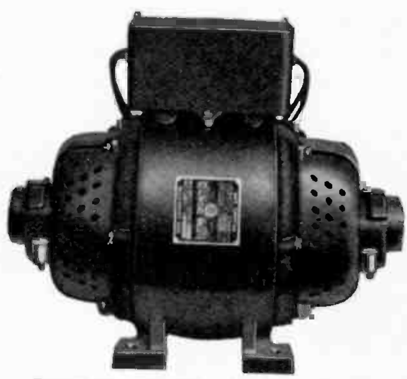
Machines for operating 60-cycle A. C. Radio Receivers, Loud Speakers and Phonographs from Direct Current Lighting Sockets Without Objectionable Noises of any Kind.

The dynamotors and motor generators are suitable for radio receivers and for combination instruments containing phonographs and receivers. Filters are usually required. The dynamotors and motor generators with filters give as good or better results than are obtained from ordinary 60-cycle lighting sockets.

They are furnished completely assembled and connected and are very easily installed.

These machines are furnished with wool-packed bearings which require very little attention, and are very quiet running.

Write for Bulletin No. 243-C.

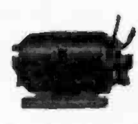


Dynamotor with Filter for Radio Receivers

How can "ESCO" Serve You?

ELECTRIC SPECIALTY COMPANY

TRADE "ESCO" MARK

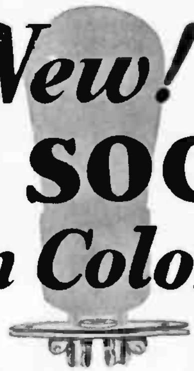


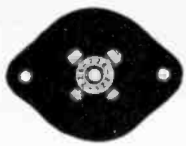
300 South Street **Stamford, Conn.**

New!

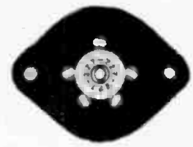
EBY SOCKET

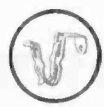
In Colors

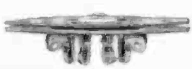


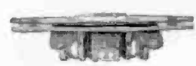


Illustrating the action of the guide for the tube prongs. The tubes *have* to go in *right*—no slipping or fumbling.









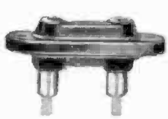
This is a close-up view of the new Eby double contact prong. Spring tension evenly divided between top and bottom of both sides.

Model 6 Socket is new and *much better*. Designed for manufacturers' use exclusively. Popular Eby features have been retained and new ones added.

- Four different colors numbered—for identification of tubes.
- Long two-sided prongs—for positive contact.
- Guide for tube prongs—a famous Eby feature.
- Rivet assembly—for economy.

New in performance, new in appearance—and a new low price.

Moulded



Tip Jacks

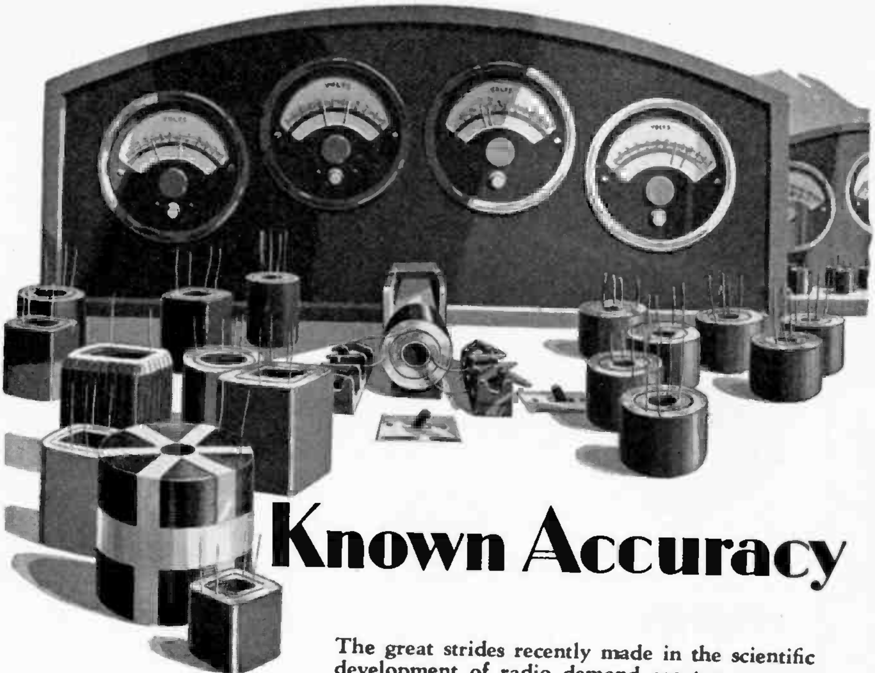
A pair of tip jacks moulded as inserts in a brown bakelite strip marked speaker, Phono or Field. No insulating washers—no nuts.

Combination

Strips

Ground post automatically grounded and Antenna post insulated. No washers.

The H. H. EBY MFG. CO., Inc.
4710 Stenton Ave. Philadelphia
Makers of Eby Binding Posts



Known Accuracy

The great strides recently made in the scientific development of radio demand greater accuracy in coils.

To insure the utmost accuracy, Dudlo is equipped with every necessary instrument for their testing and inspection.

The meter panel pictured above . . . only one of the tests to which Dudlo coils are subjected . . . measures output voltages, detects short-circuits and breakdowns. Other instruments check many other requirements to insure strict adherence to customers specifications.

This is one of the reasons why Dudlo coils are designed right, built right, and give uniformly good results wherever used.

If you are having coil troubles, send them to us. Dudlo engineering resources are at the service of the radio industry.

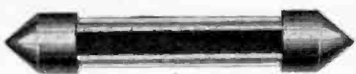
DUDLO MANUFACTURING COMPANY, FORT WAYNE, INDIANA
Division of General Cable Corporation

DUDLO

THE COIL'S THE THING IN RADIO

Continental Resistors

Durable dependable, simple in structure and give a minimum of resistor trouble.



A

Type A for grid leaks and light power purposes. Will dissipate ½ watt safely.

W

Types W and X for greater power dissipation.

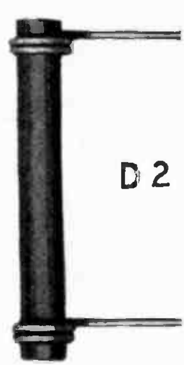
X

All types furnished in any resistance value desired.

In use continuously for a number of years by the largest manufacturers.

Types E2 and D2 furnished with wire leads soldered to coppered ends, are for soldering permanently into position in apparatus where they are to be used.

E 2



D 2

Samples for test sent on receipt of specifications.

CONTINENTAL CARBON INC.

WEST PARK, CLEVELAND, OHIO

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

A *Remarkable* New 5-WATT VOLUME CONTROL and a *Superior* COVERED RESISTANCE

Complete assembly of the new ELECTRAD VOLUME CONTROL; showing neat compact design, predominance of metal for rapid heat dissipation; firmly riveted for strength. Size: 2 3/16" x 2 13/16" x 5/8" deep. One-hole panel mounting.

THE radio profession has waited for these two new Electrad achievements—but it has not waited in vain.

First: A volume, control entirely different in principle, that easily dissipates a full five-watts without breaking down or varying in resistance. Laboratory tests, equal to more than 10 years' normal service, prove its extraordinary accuracy and lasting qualities.

The resistance element is a highly-developed graphite paint fused to an enameled metal base. The contact is pure silver; designed literally to float over any slight inequalities of surface. Result: A smooth, stepless flow of current which improves with use owing to microscopic deposit of silver from the contact on the resistance element.

Can be made in any desired range for usual requirements with a resistance curve of uniform variation, or tapered to your specifications.

Second: A new standard in covered resistances. May be run at rated capacity without burnouts. Heavier than usual Nichrome resistance wire—hence cooler.

The contact bands and soldering lugs are Monel metal. Costs more—worth it. No unequal expansion—no broken connections.

Last, but not least—covered by an elastic insulating enamel; baked on at only 400 degrees F. Less chance for injury to resistance wire and contacts.

The bands, tube, wire and enamel expand and contract alike under load, insuring against breakage of wire at contact points and along the tube. Can be made in practically any resistance values and wattage ratings desired. What are your needs?

ELECTRAD, INC., Dept. PE5, 175 Varick St., New York.
Send complete data on your new 5-Watt Volume Control and Covered Resistance—also samples for test.

Name .... Title ....
Firm .... Street ....
City .... State ....

ELECTRAD
INC.

Evolution in A. C. Tube Design

FLOATING FILAMENT TYPE

(No spacing Insulator)

Quick heating — but heater often touches Cathode causing burnout or HUM. Position of filament not rigidly fixed

COVERED FILAMENT TYPE

(Spacing Insulator in contact with full length of filament)

Slow heating — but insulation wears out filament. Short life

THE RAYTHEON TYPE

(Spacing Insulators not in contact with filament)

Heats up quickly — position of filament rigidly fixed—long life

Why Raytheon Tubes are "Healthy"

4-Pillar Construction, Cross-anchored Top and Bottom.

Ra – 227

UNLIKE any and all other radio tubes, the relative positions of all the elements are permanently maintained in Raytheon Tubes and the fragility has been conquered and eliminated. Raytheon "Healthy" Tubes cost you no more—and by longer life, they should reduce your maintenance cost by one-half. Most important of all—their performance never varies.

RAYTHEON MANUFACTURING CO.
CAMBRIDGE, MASS.

Raytheon
LONG LIFE RADIO TUBES

Meet that Production Schedule!

EVER since the beginning of radio, *Fast* has specialized in one thing only—Condensers. In the development of an organization to meet the rapidly expanding requirements of radio set manufacturers, special machinery had to be designed, production methods standardized and labor and time-saving equipment utilized to the utmost.

How well we have been able to meet these conditions, is attested by the fact that millions of condensers are produced here annually for the country's leading set manufacturers.

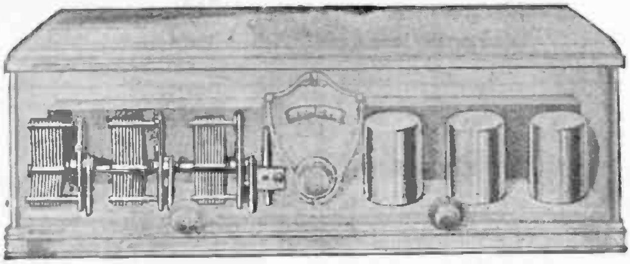
An example of *Fast* production methods is shown in the illustration of our winding room in which scores of dual machines perform intricate operations rapidly and dependably on a tremendous production schedule.

Don't take chances of having broken delivery promises ruin your production schedule. Establish a reliable, if need be, auxiliary source of supply to meet every contingency.

Send us your specifications and let us show you how your condenser worries can be overcome.

JOHN E. FAST & CO. MEMBER RMA

3982 Barry Avenue, Chicago, Illinois



Aluminum Shielding

A notable contribution to radio design

SINCE the beginning of 1929, five more prominent manufacturers have adopted Aluminum Shielding. Twenty-seven leading sets are now designed for Aluminum Shielding—an almost universal acceptance.

The reason is evident. Aluminum is highly efficient electrically—especially at radio frequencies. It works easily and well in the shop. It appeals to both purchaser and producer—because it is attractive in appearance, light in weight and non-corrosive.

And Aluminum Shields are economical, from the standpoint of first cost—in production—and in finishing. We solicit your inquiries.

ALUMINUM COMPANY OF AMERICA
2470 Oliver Building, Pittsburgh, Pa.
Offices in 18 Principal American Cities

ALUMINUM

The mark of quality in Radio

PROFESSIONAL ENGINEERING DIRECTORY

For Consultants in Radio and Allied Engineering Fields

The J. G. White Engineering Corporation

Engineers—Constructors

Builders of New York Radio Central

Industrial, Steam Power, and Gas Plants, Steam and Electric Railroads, Transmission Systems.

43 Exchange Place New York

Amy, Aceves & King, Inc.

Consulting Engineers

DESIGN—TEST—DEVELOPMENT

Radio Transmitters, Receivers and Sound Reproducing Apparatus

Research Laboratories

55 West 42nd Street, New York
Longacre 8579

ROBERT S. KRUSE

Consultant for development of Short-wave Devices

103 Meadowbrook Road

WEST HARTFORD, CONN.

Telephone, Hartford 45327

BRUNSON S. McCUTCHEN

Consulting Radio Engineer

17 State Street

NEW YORK

Electrical Testing Laboratories

RADIO DEPARTMENT

also

Electrical, Photometric, Chemical and Mechanical Laboratories

80th Street and East End Ave.
NEW YORK, N. Y.

PATENTS

WM. G. H. FINCH

Patent Attorney

(Registered U. S. & Canada)

Mem. I. R. E. Mem. A. I. E. E.

303 Fifth Ave New York
Caledonia 5331

For EXPORT of material made by:

Allen D. Cardwell Mfg. Corp.
Clarostat Mfg. Co.
Corning Glass Works
Dubilier Condenser Corp.
Elkon, Inc.
Radio Engineering Labs.
Raytheon Mfg. Co.
United Scientific Labs.
Weston Electrical Inst. Corp.

apply to

AD. AURIEMA, INC.

116 Broad Street, New York, N. Y.

JOHN MINTON, Ph.D.

Consulting Engineer

for

Developing — Designing — Manufacturing

of

Radio Receivers, Amplifiers, Transformers, Rectifiers, Sound Recording and Reproducing Apparatus.

Radio and Electro-Acoustical Laboratory

8 Church St. White Plains, N. Y.

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

PROFESSIONAL ENGINEERING DIRECTORY

For Consultants in Radio and Allied Engineering Fields

(Continued)

4th Edition

Thoroughly Revised—Up-to-Date

"RADIO THEORY AND OPERATING"

992 Pages 800 Illustrations

By MARY TEXANNA LOOMIS

President and Lecturer on Radio Loomis Radio College

Member Institute of Radio Engineers

Price $3.50—Postage Paid

LOOMIS PUBLISHING CO.

Dept. 6, Washington, D.C.

EDGAR H. FELIX

Broadcast Consultant

Federal Radio Commission cases—Broadcasting Station sales problems—Special investigations in visual transmission—Utilization of broadcasting by advertisers.

8 Doremus Avenue

Ridgewood, N. J.

TRANSLATIONS

Translation from French and German of Electrical and Radio Scientific articles and Patents, with idiomatic rendering of Technical Terms. Research undertaken.

A. ALEXANDER SINGER

246 W. 12th Street

NEW YORK CITY

RADIO ENGINEERS

Ten dollars will introduce you directly to over 6,000 technical men, executives, and others with important radio interests. For details write to

Advertising Dept., I.R.E.

Complete Line of

RADIO PANELS, TUBING, RODS AND INSULATING MATERIALS

Drilling, Machining and Engraving to Specifications

TELEVISION KITS, DISCS, NEON TUBES, PHOTO ELECTRIC CELLS AND ALL PARTS

Write for Catalog

Insuline Corp. of America

78-80 Cortlandt St., N. Y.

Cortlandt 0880

Ramsey's Experimental Radio

Third Edition

(xii-229 pages, $5\frac{1}{2} \times 7\frac{1}{4}$, cloth, 152 figures)

A Radio Frequency Manual Fundamental measurements and tests.

Review in June 28 Proc. Inst. Rad. Eng. p. 851

Price $2.75 postpaid

Ramsey Publishing Co.

615 E. 3rd St., Bloomington, Indiana

RADIO ENGINEER AVAILABLE

University graduate in Physics and Electrical Engineering. Post graduate course in Radio Engineering. Eight years instructor of Physics and Engineering at a recognized University. Fifteen years theoretical and practical experience in all phases of radio. Desires connection with some research or development laboratory, preferably in the Middle West territory. Excellent references furnished. Member I.R.E. Address Box 147, I.R.E.

WANTED

PROCEEDINGS OF THE I.R.E.

Complete Volumes 1 to 4 inclusive

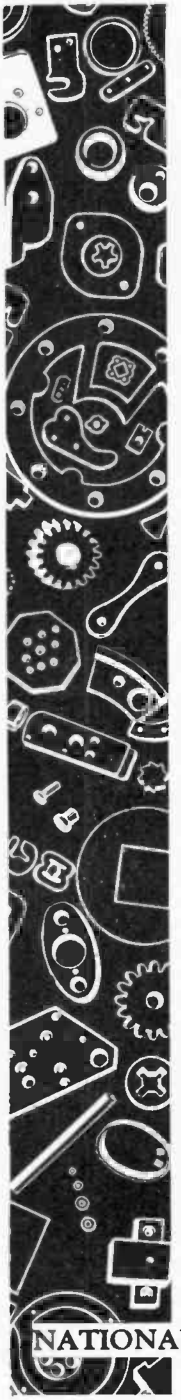
L. P. GRANER

421 Canal Street

NEW YORK, N.Y.

Tel. Walker 0898

Alphabetical Index to Advertisements

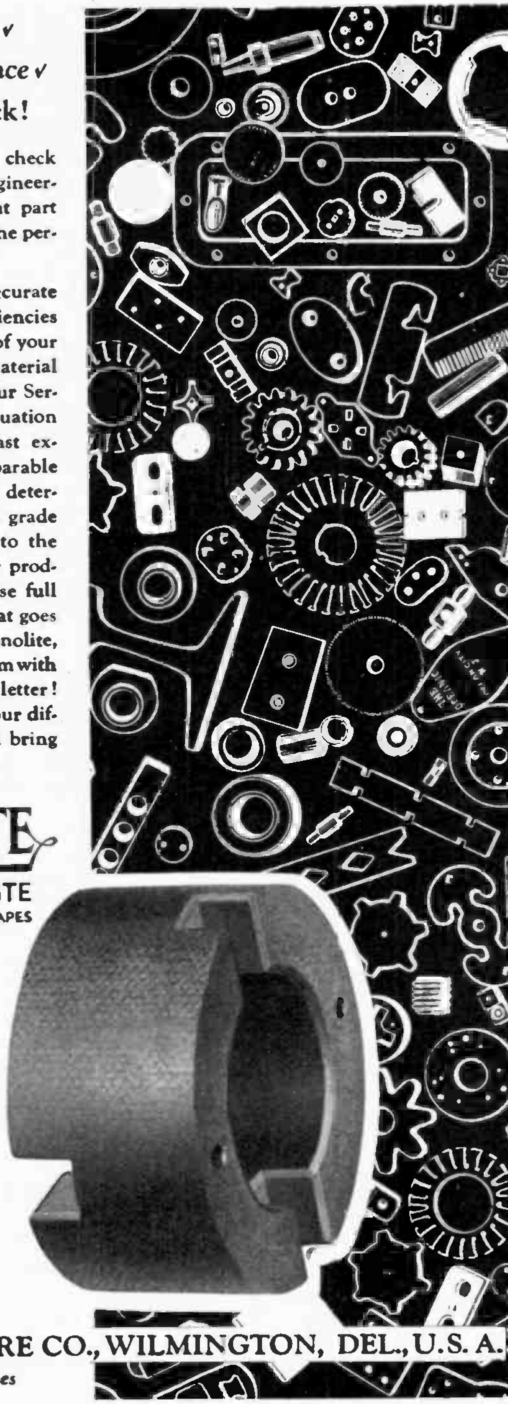


Your Requirements ✓
Phenolite's Performance ✓
—They Must Check!

—and they can be made to check 100 per cent if our Service Engineering Department knows what part laminated bakelite plays in the performance of your product.

Wastes in fabricating, inaccurate assembling or other inefficiencies are not necessarily the faults of your mechanics. Look to the material itself—or better still, have our Service Engineers study the situation from every angle. Their past experience in problems comparable to your own enables them to determine by actual tests which grade of Phenolite is best suited to the service requirements of your product. And because we exercise full control over every process that goes into the manufacture of Phenolite, your future orders will conform with these specifications to the letter! Correspondence regarding your difficulties or requirements will bring immediate action.

PHENOLITE
Reg. U.S. Pat. Off.
Laminated BAKELITE
SHEETS : RODS : TUBES : SPECIAL SHAPES

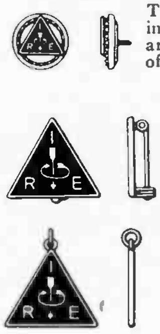


To be specific—here is a coupling disc fabricated by "National" from a grade of Phenolite developed in our laboratory for the known requirements of this particular part. It possesses unusual tensile strength and resistance to wear. It is unaffected by oil or moisture, and due to its fabric base, this coupling has valuable shock-absorbing properties.

NATIONAL VULCANIZED FIBRE CO., WILMINGTON, DEL., U.S.A.
Offices in Principal Cities

INSTITUTE SUPPLIES

EMBLEMS



Three styles of Institute emblems, appropriately colored to indicate the various grades of membership in the Institute, are available. The approximate size of each emblem is that of the illustrations.

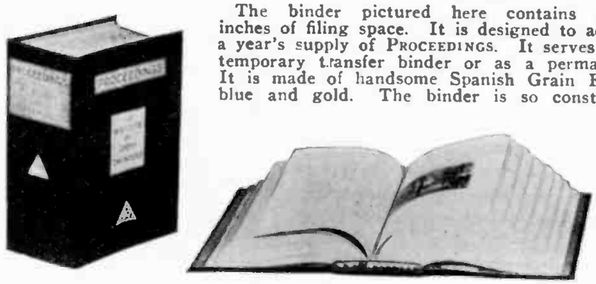
The lapel button is of 14k gold, the background being enamelled in the membership color, the lettering being gold. The button is supplied with a screw back with jaws which fasten it securely to the coat. This style emblem can be obtained for $2.75, postpaid, for any grade.

The pin is also of 14k gold. It is provided with a safety catch and is appropriately colored for the various grades of membership. Price, for any grade, $3.00 postpaid.

The watch charm is handsomely finished on both sides and is of 14k gold. The charm is equipped with a suspension ring for attaching to a watch fob or chain. Price for any grade, $5.00 postpaid.

BINDERS

The binder pictured here contains over three inches of filing space. It is designed to accommodate a year's supply of PROCEEDINGS. It serves either as a temporary transfer binder or as a permanent cover. It is made of handsome Spanish Grain Fabrikoid in blue and gold. The binder is so constructed that



each individual copy of the PROCEEDINGS will lie flat when the pages are turned. Copies can be removed from the binder in a few seconds and can be permanently preserved in undamaged condition. Hundreds of these binders are sold each year. Price, $1.50 each, or $2.00 with the member's name or the PROCEEDINGS Volume Number stamped in gold.

BACK ISSUES OF THE PROCEEDINGS

Back issues of the Proceedings are available in unbound form for the years 1918, 1920, 1921, 1922, 1923, and 1926 at $6.75 per year (six issues). Single copies for any of the years listed to 1928 are $1.13 each. For 1928 (where available) the single copy price is $0.75. Foreign postage on the volume is $0.60 additional. On single copies $0.10.

A number of individual copies for years other than those listed above are available. For a list of these, members should apply to the Secretary.

Bound volumes in Blue Buckram binding are available for the years 1920, 1921, 1922, 1923, 1925, and 1926 at $8.75 per year. The bound volume for 1928 is priced at $9.50. Foreign postage is $1.00 per volume.

Bound volumes, for the above years, in Morocco Leather binding are available at $11.00 each.

These prices are to members of the Institute.

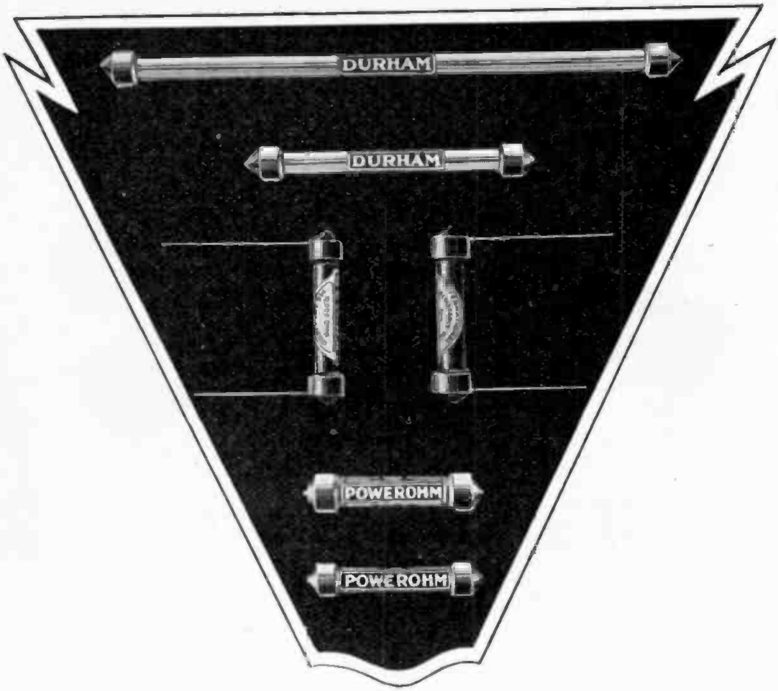
FOURTEEN YEAR INDEX

The PROCEEDINGS Index for the years 1909-1926, inclusive, is available to members at $1.00 per copy. This index is extensively cross indexed.

YEAR BOOK

A copy of the current year book will be mailed to each member, when available. The 1927 and 1928 year books are available to members at $0.75 per copy, per year.

When ordering any of the above, send remittance with order to The Secretary, The Institute of Radio Engineers, 33 West 39th Street, New York, N.Y.



The New Improved

DURHAM POWEROHMS

Each succeeding year, more and more important manufacturers of radio, television and talking movies are standardizing on DURHAMS —the resistances which are dependable, accurate in rating, and can be relied upon for long continued and uninterrupted service.

Supplied in 1 and 2 watt types in standard, pig-tail or special tips; temperature rise at 1 watt is 45°c and at 2 watts 74°c; all types are flash tested at double the rated power load as an extra precaution against electrical or mechanical weaknesses; extremely rugged construction; supplied in all ranges from 500 to 200,000 ohms in power types and from 1 to 100 megohms in resistor types.

Samples for testing gladly sent upon request, together with engineering data sheets. Please state ratings in which you are intereted.

DURHAM METALLIZED

RESISTORS & POWEROHMS

International Resistance Company, 2006 Chestnut Street, Philadelphia, Pa.

NEW AERO

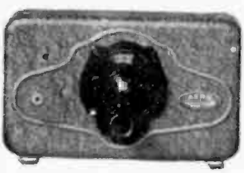
WAVEMETER

THE AERO WAVEMETER was designed for the radio amateur and the experimenter. It is of rugged mechanical and good electrical construction and meets the exacting requirements of the properly conducted amateur station.

Using the principle of the "series gap," and having a definite fixed minimum capacity, the amateur wavelength bands are spread over a great many dial divisions. The velvet vernier dial has 100 divisions, each of which may be read to one-tenth of a division. The 5-meter band covers 40 dial divisions; the 10-meter, 40 divisions; 20-meter, 17 divisions and the 40-meter band, 25 divisions. For the 80-meter band, two coils are used. One (72 to 82 meters) covers 45 divisions, and the other (80 to 90 meters) covers 65 divisions..

Each coil, excepting the 5-meter, uses No. 18 enameled wire tightly wound into grooves of the bakelite tubing. The tubing has a ⅛ in. wall and is 2 in. in diameter. The Aero heavy duty plugs and jacks make positive contact. The heavy brass case has a black crackle finish. The 3/16 in. black bakelite top is hexagonal shape to prevent rolling. The indicator is a standard neon lamp. Each wavemeter is individually hand calibrated. Standard coils are 20, 50 and 80 meters. 5- and 10-meter coils extra. Furnished with or without neon lamp indicator. Write for prices.

Aero Listening Monitor



The Aero Listening Monitor enables any amateur transmitter to check his own note, to know whether it is pure D.C. or not. It is a safe, sure and accurate way of knowing your station without depending upon the reports of others. Watching the ammeter won't help you—you need the Aero Monitor to be absolutely positive. The Aero Monitor is a completely shielded unit encased in a black metal cabinet, size 9 x 5½ x 2½ in. Filament and B supply is included. It operates with a UX-199 type of tube and employs a stable circuit, delivering a signal intensity of about R-4 or 5. Equipped with automatic filament control. The battery supply is thoroughly shielded from the R.F. A reliable, scientific instrument. Ship. wt., about 2½ lbs.

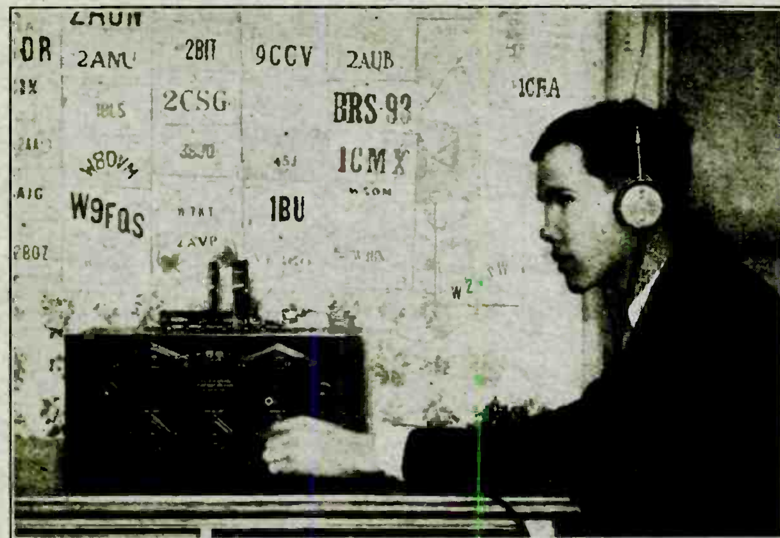
Model M-29 Aero Monitor. Including Dry Batteries, but no tube. List Price. $15.00

Send for new Short-wave supplement showing new 1929 products. It is free.

AERO PRODUCTS
INCORPORATED

MEMBER R.M.A.

4611 E. Ravenswood Ave., Dept. 2359, Chicago, Ill.



Eric Palmer, Jr., with the Grebe CR-18-Special—an important part of the radio equipment on the Pinchot Expedition.

Short Waves in the South Seas

One of the purposes of the Gifford Pinchot Expedition, now on its way to the South Seas, is a study of short wave reception. And one of the important items of equipment is a Grebe CR-18-Special Short Wave Receiver. With two stages of audio amplification, adaptable to the use of a power tube, the CR-18-Special makes an ideal set for short wave reception. A loud speaker may be used, and a single adjustment controls volume from headset level to full audio output.

A. H. GREBE & CO., INC.
Richmond Hill, N. Y.
Western Branch:
443 So. San Pedro Street, Los Angeles, Calif.

GREBE
SYNCHROPHASE
RADIO

MAKERS OF QUALITY RADIO SINCE 1909

An A.C. - Operated Portable R.F. Oscillator

A portable source of radio-frequency signals has numberless uses in the radio laboratory. The Type 584 A.C. Portable R.F. Oscillator is operated from the 110-volt alternating current supply, and, by the use of plug-in coils it covers the entire spectrum between 10 and 20,000 kilocycles.

DETAILS

One cabinet houses oscillator and plate supply.

Uses a 227-type tube as an oscillator, a 210A-type tube as a plate-supply rectifier.

Eight stock coils cover the range from 10 kilocycles to 20,000 kilocycles.

Only one control (with an auxiliary for fine adjustment) for each coil band.

Provision made for audio-frequency modulation.

Weight without tubes and coils, 22½ pounds.

Licensed for Radio Laboratory Experimental Use Only Where No Business Features Are Involved. U. S. Pat. No. 1113149.

GENERAL RADIO COMPANY

30 STATE STREET CAMBRIDGE, MASSACHUSETTS

GEORGE BANTA PUBLISHING COMPANY, MENASHA, WISCONSIN