VOLUME 16 OCTOBER, 1928 NUMBER 10

PROCEEDINGS

of

The Institute of Radio Engineers

Published Monthly By

THE INSTITUTE OF RADIO ENGINEERS

Publication Office: 450-454 Ahnaip St., Menasha, Wis.

BUSINESS, EDITORIAL AND ADVERTISING OFFICES

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

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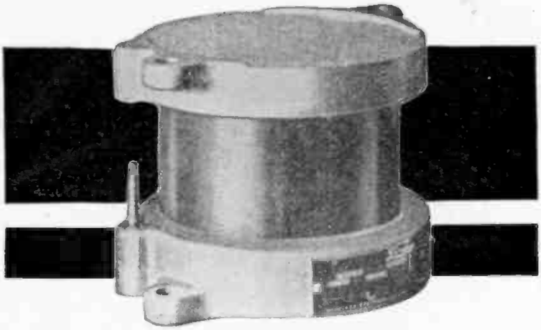

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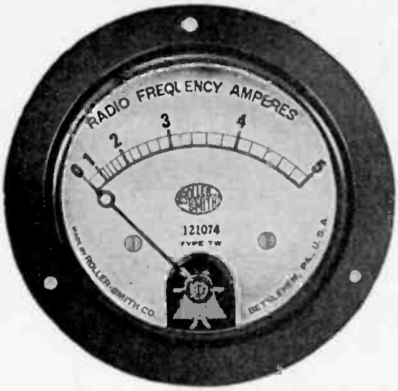

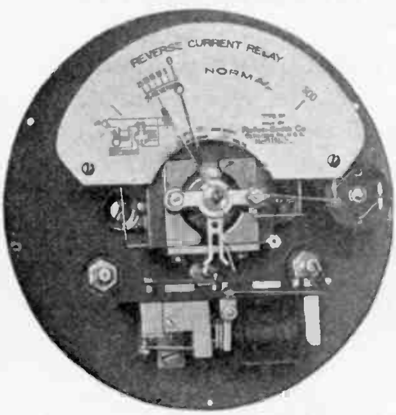

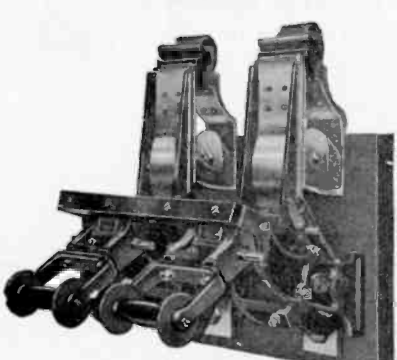

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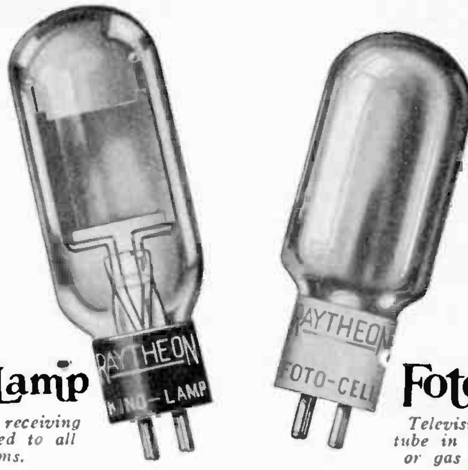

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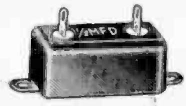

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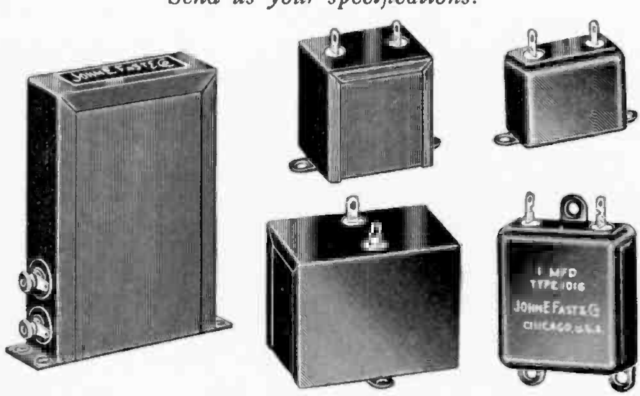

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Second: We are guaranteeing absolutely that the S-M Clough-system transformers you buy at $6.00 (list) cannot be surpassed by any of the conventional type not utilizing the Clough invention with its practical elimination of hysteretic distortion—at *any price whatsoever.*

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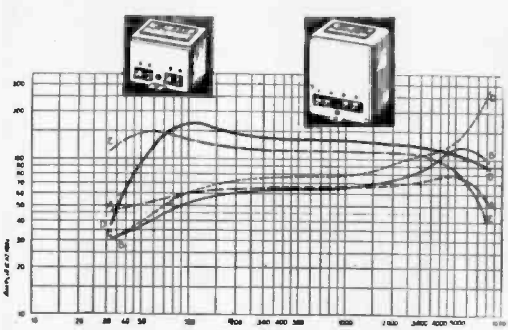

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Negative Grid Bias	16½	27	40½	Volts
Plate Current	10	16	20	Milliamperes
Plate Resistance (A.C.)	2500	2200	2000	Ohms
Mutual Conductance	1200	1360	1500	Micromhos
Voltage Amplification Factor	3.0	3.0	3.0	
Max. Undistorted Output	130	330	700	Milliwatts

R. F. & A. F. AMPLIFIER RADIOTRON UX-226

Filament (A. C.) 1.5 Volts—1.05 Amperes

Plate Voltage	90	135	135	180	Volts
Negative Grid Bias	6	12	9	13½	Volts
Plate Current	3.7	3	6	7.5	Milliamperes
Plate Resistance (A.C.)	9400	10,000	7400	7000	Ohms
Mutual Conductance	875	820	1100	1170	Micromhos
Voltage Amplification Factor	8.2	8.2	8.2	8.2	
Max. Undistorted Output	20	60	70	120	Milliwatts

DETECTOR RADIOTRON UY-227

Heater (A. C.) 2.5 Volts—1.75 Amperes

Plate Voltage	45	90	Volts
Grid Leak	2-9	¼-1	Megohms
Plate Current	2	7	Milliamperes
Plate Resistance (A.C.)	10,000	8000	Ohms
Mutual Conductance	800	1000	Micromhos
Voltage Amplification Factor	8	8	

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A.C. Filament Voltage	5.0 Volts
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D.C. Output Current (Maximum)	125 Milliamperes
Effective D.C. Output Voltage of typical Rectifier Circuit at full output current as applied to Filter	260 Volts

HALF WAVE RECTIFIER RADIOTRON UX-281

A.C. Filament Voltage	7.5 Volts
A.C. Filament Current	1.25 Amperes
A.C. Plate Voltage (Max. per plate)	750 Volts
D.C. Output Current (Maximum)	110 Milliamperes
Effective D.C. Output Voltage of typical Rectifier Circuit at full output current as applied to Filter	620 Volts

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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 fine 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 proportions.

Abbreviations—Write a.c. and d.c., kc, μf, μμf, 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.

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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 notification of acceptance of paper for publication, reprint order form is sent to the author. Orders for reprints must be forwarded promptly as type is not held after publication.

PROCEEDINGS OF
The Institute of Radio Engineers

Volume 16 | October, 1928 | Number 10

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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.

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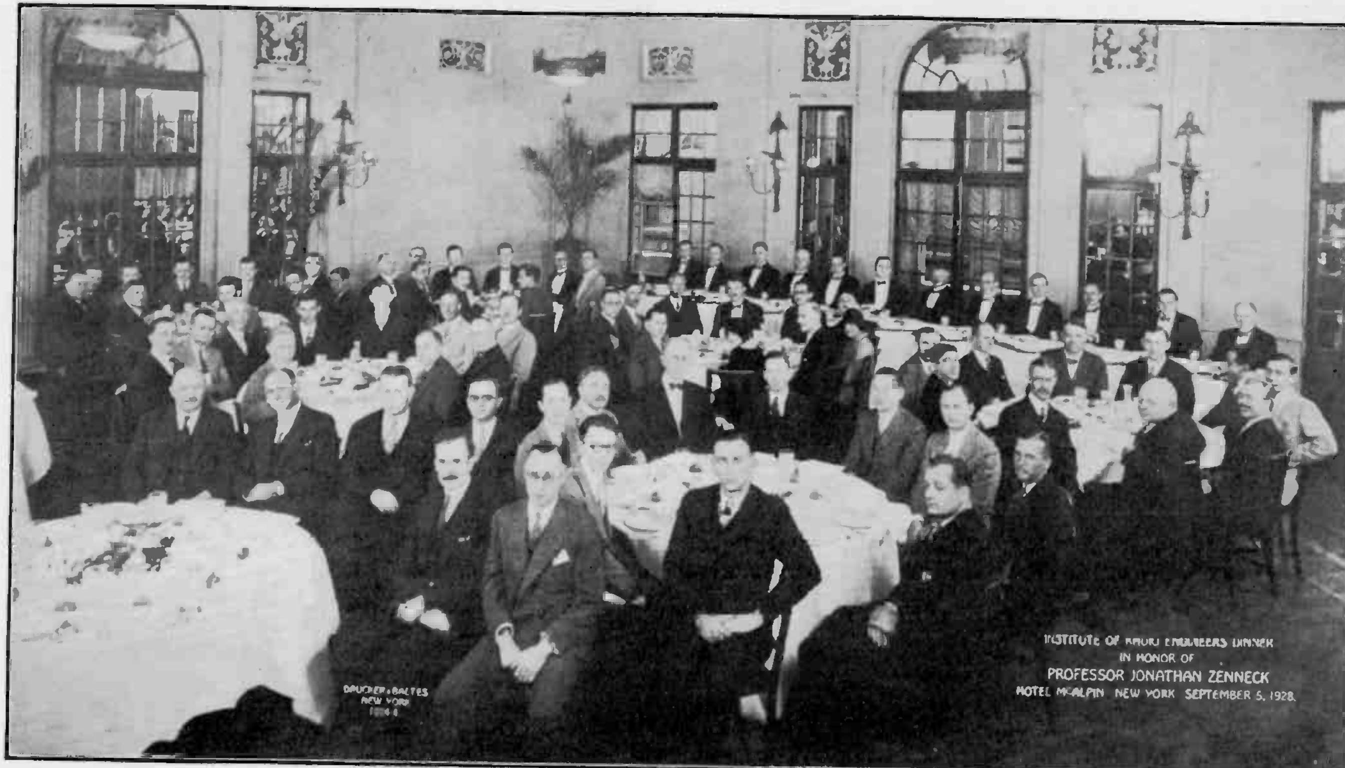

Dinner Given in Honor of Professor Jonathan Zenneck, September 5, 1928, at New York City

Dinner for Professor Zenneck

On the evening of September 5, 1928, preceding the regular meeting of the Institute in New York, a dinner was held in honor of Professor Jonathan Zenneck, recipient of the Institute's Medal of Honor for 1928, in the McAlpin Hotel.

Ninety-six members of the Institute attended the dinner, a photograph of which appears as our frontispiece for this month. Dr. Alfred N. Goldsmith made a short speech of welcome to which Professor Zenneck replied.

Seated at the speakers' table, in the right-hand background, are R. H. Marriott, Past-President; A. H. Grebe, J. V. L. Hogan, Past-President; Melville Eastham, Treasurer; L. E. Whittemore, Vice-President; Professor Zenneck, Alfred N. Goldsmith, President; Ralph Bown, Past-President; Donald McNicol, Past-President; R. A. Heising, J. H. Dellinger, Past-President; and John M. Clayton, Secretary.

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Graham, Virgil M.: Born January 22, 1902, at Rochester, N. Y. Attended University of Rochester, 1920–23; radio engineering work with Stromberg-Carlson Telephone Manufacturing Company, 1923 to date; for the past three and one-half years in charge of radio engineering laboratory; Chairman of Rochester Section of Institute, 1927; Secretary of Rochester Engineering Society; Associate member, A.I.E.E.; Associate member, Institute of Radio Engineers, 1924; Member, 1927.

Hoag, J. Barton: Born September 22, 1898, in Colorado Springs, Colo. Amateur radio experimenter since 1916. Instructor Army Radio School at Colorado College, 1918, and received A.B. degree, 1920; instructor, including course in radio, at Colorado College, 1921. Assistant in Physics at University of Chicago, 1923; Ph.D. in physics with minor in mathematics at University of Chicago, 1927; 1928 to date instructor, including radio courses. Member, American Physical Society.

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Jansky, C. M., Jr.: Born at Delton, Michigan. Graduated University of Wisconsin, master's degree in physics, 1919. Since January 1, 1920, in charge of instruction in radio engineering at the University of Minnesota and of operation of that university's broadcasting station. Member of all four National Radiotelegraph Conferences. Associate professor in radio engineering at University of Wisconsin and consulting radio engineer. 1928, member, Committee on Standardization, I.R.E.; Associate member, I.R.E., 1918; Member, 1925; Fellow, 1928.

Page, Robert M.: Born at St. Paul, Minnesota, June 2, 1903. B.S. degree in physics, Hamline University, St. Paul, Minn., 1927. Engaged in radio research and precision measurements, U. S. Naval Research Laboratory, 1927 to date. Associate member, I.R.E., 1927.

Terman, Frederick Emmons: (See PROCEEDINGS for April, 1928).

Wheeler, Harold A.: (See PROCEEDINGS for January, 1928).

INSTITUTE NOTES AND RELATED ACTIVITIES

September Meeting of the Board of Direction

At the meeting of the Board of Direction of the Institute, held at 2:00 P.M. on September 5, 1928, in the offices of the Institute, the following were present: Alfred N. Goldsmith, President; L. E. Whittemore, Vice-President; Melville Eastham, Treasurer; Ralph Bown, Junior Past-President; J. H. Dellinger, R. A. Heising, J. V. L. Hogan, R. H. Marriott, and John M. Clayton, Secretary.

The following were transferred or elected to the higher grades of membership in the Institute. Transferred to the Fellow grade: W. R. G. Baker, Harold Beverage, O. B. Blackwell, Carl R. Englund, R. V. L. Hartley, Fred H. Kroger, Richard H. Ranger, and Owen D. Young. Transferred to the Member grade: William J. Blenheim, James K. Clapp, Francis H. Engel, David Grimes, Harold T. Melhuish, Douglas Rigney, Maurice C. Rypinski, George E. Sterling, Lee Sutherlin, George S. Turner, Paul T. Weeks, and W. A. Winterbottom. Elected to the Member grade: Milton F. Bickford, William M. Browner, W. E. Downey, A. T. Haugh, W. A. Hillebrand, G. Madgwick, Francis E. Pierce, and F. V. Sloan.

One hundred and eleven Associate members and sixteen Junior members were elected.

Nominations for Officers and Managers for 1929

The Board of Direction, at its September 5th meeting, made the following nominations for 1929 officers and members of the Board of Direction:

For President: A. Hoyt Taylor, Laurens E. Whittemore.
For Vice-President: Charles P. Edwards, Alexander Meissner.
For Managers (Three-Year Term): Lawrence C. F. Horle, C. M. Mansky, Jr., William Wilson.

For President

A. Hoyt Taylor

A. Hoyt Taylor was born on January 1, 1879, in Chicago, Illinois. He was graduated with the B.S. degree from Northwestern University and became an instructor in physics and electrical engineering at Michigan State College in 1900. In 1903 he was appointed an instructor in electrical engineering at the University of Wisconsin. In 1908 he left the University to study at the University of Gottingen, Germany, from which he received the Ph. D. degree. Upon returning to the United States he was elected professor of physics and head of that department at the State University of North Dakota, where he remained until 1917. Dr. Taylor entered the Naval Reserve as a Lieutenant in March, 1917, as district communication officer at Great Lakes Naval Training Station. He was transferred to Belmar, N. J. as transatlantic communication officer in the fall of 1917 and in 1918 was promoted to Lieutenant Commander with headquarters at Hampton Roads. Early in 1919 he was ordered to Washington, D. C. and placed in charge of the aircraft radio laboratory. During this period he was promoted to Commander, remaining in active duty until July of 1922. When the Naval Research Laboratory at Anacostia, D. C. was organized, Dr. Taylor was made Superintendent of its Radio Division, in which capacity he has served to date. He was elected to Associate membership in the Institute in 1916, and was transferred to the Fellow grade in 1920. In 1927 he was awarded the Morris Liebmann Memorial Prize by the Institute.

Laurens E. Whittemore

Laurens E. Whittemore was born in Topeka, Kansas, August 20, 1892. He was educated at Washburn College, Topeka, Kansas (A.B. degree in 1914) and the University of Kansas from which he received the M.A. degree in 1915. Mr. Whittemore was an instructor in the Department of Physics at the University of Kansas from 1915 to 1917. He left the University to join the Radio Laboratory Staff of the U. S. Bureau of Standards where he remained until 1923. From 1923 to 1924 he was Secretary of the Interdepartment Radio Advisory Committee of the U. S. Government. He served as a member or as secretary of the four National Radio Conferences held by the U. S. Department of Commerce in 1921–1924, and was secretary of the American Delegation to the International Radio Conference held in Washington in 1927. Since 1925 he has been an engineer in the Department of Development and Research of the American Telephone and Telegraph Company in New York City. Mr. Whittemore became an Associate member of the Institute in 1916. He was appointed to the Board of Direction of the Institute in 1926, and served as chairman of the Committee on Standardization of the Institute from 1926 to 1928, inclusive. He is now a Fellow in the Institute and has been Vice-President of the Institute during the year 1928. He is the author of several Bureau of Standards publications and was a joint author of the "Lefax Radio Handbook."

For Vice-President

Charles P. Edwards

Charles P. Edwards was born on December 11, 1887. He attended the Arnold Technical School at Chester, England, and the Marconi Engineers' Training School at Chelmsford, England. In 1903 he was appointed technical assistant to the English Marconi Company in which capacity he served until 1906, when he became radio engineer for the Canadian Marconi Company. In 1909 he was appointed general superintendent of radio-telegraphs for the Marine Department of the Canadian Government. In 1911 that branch of the Canadian Government was transferred to the newly created Department of Naval Service. He was appointed officer of the "Order of the British Empire" for war services in 1918 and holds the rank of Lieutenant Commander, R.N.C.V.R. Commander Edwards was a Canadian delegate to the International Radiotelegraph Convention in London in 1912, and a delegate for Great Britain to the International Communication Conference in Washington in 1920. From 1921 to 1922 he was Chairman of the Ottawa Branch of the Engineering Institute of Canada of which he is an Associate member. He was elected to the Member grade in the Institute in 1913 and was transferred to the Fellow grade in 1915.

Alexander Meissner

Alexander Meissner was born in Vienna, Austria, on September 14, 1883. He was educated at the Vienna Technical School from which he received the degree of Doctor of Technical Science in 1909. In 1922 he received the degree of Honorary Doctor of Engineering from the Technical High School of Munich. In 1925 Dr. Meissner was awarded the Heinrich Hertz gold medal for his inventions in radio and its allied arts. Since 1907 he has been with the Telefunken Gesellschaft, and is at the present date head of the research laboratory of the Telefunken organization. He is an honorary professor at the Berlin Technical High School. Dr. Meissner has patented a great number of radio circuits and appliances and is credited with the invention of the Telefunken compass, musical quenched spark systems, impulse excitation spark gaps, three-electrode tube oscillators, etc. Dr. Meissner has contributed a number of papers to the Proceedings of the Institute of Radio Engineers as well as other technical journals. He was appointed to membership on the Institute's Committee on Standardization in 1928. In 1914 he was elected to Associate membership in the Institute and in 1915 he was transferred to the Fellow grade.

For Managers Three-Year Term

Arthur Batcheller

Arthur Batcheller was born at Wellesley, Mass. in 1888. He studied electrical engineering for three years at the Y. M. C. A. Polytechnic School at Boston, Mass., and was instructor for four years in radio and electricity at the evening session of the Boston School of Telegraphy. Mr. Batcheller was assistant to the electrical engineer in charge of installation and maintenance of railroad electric signal system for the Boston, Revere Beach and Lynn Railroad for four years. From 1915 to 1916 he was employed as chief electrician for the Eastern Steamship Corporation, Boston, Mass., and from 1917 to 1919 U. S. Radio Inspector in charge of New England District. In 1919 he was associate partner and founder of the Massachusetts Radio Telegraph School, engaged in training students in electricity and radio. In 1920, Mr. Batcheller accepted an appointment as radio inspector in charge of the 2nd Radio District, with headquarters in New York, and has served in that capacity to date. In 1925, he received the appointment of Lieutenant Commander, CV (S), U. S. N. R. Mr. Batcheller is a member of the Committee on Conference to study safety of life at sea, to be held in London in 1929. He was elected to Associate membership in the Institute in 1914, and transferred to Member grade in 1920.

Lawrence C. F. Horle

Lawrence C. F. Horle was born in Newark, N. J. on May 27, 1892. He was educated in the primary, grammar, and high schools of Newark, N. J. and at Stevens Institute of Technology of Hoboken, N. J., from which he received the M.E. degree in 1914. From 1914 to 1916 he was a member of the faculty of the Department of Physics at Stevens Institute, during which period a large part of his time was spent in investigations of vacuum-tube characteristics and development of vacuum-tube circuits. From 1916 to 1917 Mr. Horle was designing engineer of the Public Service Corporation of Newark. During the war (from 1917 to 1920) he was Expert Radio Aid, Navy Department, in charge of the radio development laboratory at the Washington Navy Yard. He resigned from the service to become chief engineer of the DeForest Radio Company in which capacity he served until 1921. From 1921 to 1923 he practiced consulting engineering. From 1923 to date he has been associated with the Federal Telephone Manufacturing Company, since 1927 as vice-president in charge of engineering. Mr. Horle has been Chairman of the Buffalo-Niagara Section of the Institute since its inception in 1927. He was elected to Associate membership in the Institute in 1914, was transferred to the Member grade in

1923, and the Fellow grade in 1925. For several years he was a member of the Institute's Committee on Standardization. He is a member of the Engineering Committee of the Radio Manufacturers' Association.

C. M. Jansky, Jr.

C. M. Jansky, Jr., was born at Delton, Michigan. In 1917 he was graduated from the University of Wisconsin and in 1919 received the Master's degree in Physics from the same institution. Since January 1, 1920, he has been in charge of instruction in radio engineering at the University of Minnesota and of the operation of the University's broadcasting station. He was a member of the four National Radiotelegraph Conferences. He is associate professor in radio engineering at the University of Minnesota and is practicing consulting radio engineering. Professor Jansky is on the Board of Direction of the American Radio Relay League. He has contributed several papers to the Proceedings of the Institute of Radio Engineers. In 1928 he was appointed to membership on the Institute's Committee on Standardization. He was elected an Associate member of the Institute in 1918, was transferred to the Member grade in 1925, and the Fellow grade in 1928.

William Wilson

William Wilson was born at Preston, England, on March 29, 1887. He graduated from the University of Manchester (England) in 1907 with the B.Sc. degree, in 1908 received the M.Sc., and in 1913 the D.Sc. degrees from the same institution. From 1907 to 1912 he was occupied in research work on electronic physics in the Universities of Manchester, Cambridge, and Giessen (Germany). From 1912 to 1914 Dr. Wilson was lecturer in physics at the University of Toronto. Since 1914 he has been in the Research Department of the Western Electric Company and the Bell Telephone Laboratories. During 1917-1918 he was in charge of Western Electric Company manufacture of transmitting tubes for the U. S. Government. Since 1918 he has been in charge of research, development, and manufacture of vacuum tubes, and since 1925 has also been in charge of radio research and of the development and design of the transatlantic radiotelephone equipment. He is assistant director of research of the Bell Telephone Laboratories. Dr. Wilson has served on the Institute's Committee on Meetings and Papers in 1927 and 1928. He is a member of the Executive Committee of the American Section of the U.R.S.I. and is the A.I.E.E.'s representative on the Sectional Committee on Radio of the American Engineering Standards Committee. He was elected a Member of the Institute in 1926 and was transferred to the Fellow grade in 1928.

Forthcoming Papers

The following is a list of papers on hand for publication in the Proceedings. These papers will probably be published in early forthcoming issues:

Austin Bailey, S. W. Dean, and W. T. Wintringham, "The Receiving System for Long-Wave Transatlantic Radio Telephony."

V. J. Bashenoff, Supplementary Note to "Abbreviated Method for Calculating the Inductance of Irregular Plane Polygons of Round Wire."

Robert C. Colwell, "Fading Curves Along a Meridian."

A. F. Van Dyck and E. T. Dickey, "Quantitative Methods Used in Tests of Broadcast Receiving Sets."

K. B. Eller, "On the Variation of Generated Frequency of a Triode Oscillator Due to Changes in Filament Current, Grid Voltage, Plate Voltage, or External Resistance."

A. F. Van Dyck and F. H. Engel, "Vacuum-Tube Production Tests."

J. R. Harrison, "Piezo-Electric Oscillator Circuits with Four-Electrode Tubes."

Jozef Plebanski, "Filtering Aerials and Intervalve Circuits."

E. M. Terry, "Dependence of the Frequency of a Quartz Oscillator Upon the Electrical Constants of the Circuit."

H. M. Turner, "The Constant Impedance Method for Measuring Inductance of Choke Coils."

Jonathan Zenneck, "The Importance of Radio Telegraphy in Science."

In addition to the above, the Committee on Meetings and Papers has under consideration several additional papers.

1929 Ballots; Year Book Addresses

The ballots for 1929 officers and Board members were placed in the mails early in October. Any member who has failed to receive his ballot by this time should communicate with the Secretary of the Institute immediately requesting a duplicate.

With the ballots there were forwarded pink slips upon which members are requested to place their present business and mailing addresses. From these slips the 1929 Year Book catalog of membership will be made. It is very important that the slips be returned promptly *with the ballots.*

Increase in Institute Membership

For the past twelve months ending with August 31st there has been a net increase in membership of 656. This creditable expansion in the number of Institute members is due to the efforts of the Committee on Membership and the individual members of the Institute. Through the increase during the past two years, the Institute has been able to do many things of direct benefit to the entire membership. The number of pages in the PROCEEDINGS during the past two years has been increased by some one hundred and twenty-five per cent. The Institute will continue to expand in all of its activities only through a continuation of the efforts of all members. If you do not have an application form to pass on to a desirable non-member, drop a line to the Secretary of your Section or the Secretary of the Institute.

Institute Meetings

TOURS TO SECTIONS

The following tours on the part of speakers have been arranged through the cooperation of the organizations with which the speakers are connected, and the Institute Headquarters office:

During September Messrs. E. T. Dickey and F. H. Engel visited the Connecticut Valley, Buffalo-Niagara, Rochester, Cleveland, Chicago, and Detroit Sections, presenting papers "Quantitative Methods Used in Tests of Broadcast Receiving Sets" and "Vacuum-Tube Production Tests."

During September Dr. Irving Wolff spoke before the Philadelphia, Washington, Atlanta, and New Orleans Sections on "Loud Speaker Characteristics and Sound Measurements."

In October Dr. Austin Bailey will speak before the Pittsburgh, Washington, and Philadelphia Sections on "The Receiving System for Long-Wave Transatlantic Radio Telephony."

R. H. Ranger will visit the Buffalo-Niagara, Cleveland, and Chicago Sections during October to talk on "Recent Advances in Photoradio."

NEW YORK MEETING

On September 5, 1928, the first regular fall meeting in New York City was held in the Engineering Societies Building, 33 West 39th Street. President Alfred N. Goldsmith presided. The 1928 Institute Medal of Honor was presented to Professor Jonathan Zenneck, of Munich, Germany, following which Professor Zenneck presented a comprehensive paper, "The Importance of Radio Telegraphy in Science."

Professor Zenneck's paper will appear in a forthcoming issue of the PROCEEDINGS.

Three hundred and twenty-five members and friends attended the meeting.

BUFFALO-NIAGARA SECTION

The 1928–1929 Officers and Committee Chairmen of the Buffalo-Niagara Section have been announced as follows: Chairman, L. C. F. Horle; Vice-Chairman, Dr. L. Grant Hector; Secretary, C. J. Porter; Chairman of the Committee on Meetings and Papers, F. Austin Lidbury; Chairman of the Committee on Membership, J. Eichman, Jr. K. Henderson has been appointed to membership on the Committee on Meetings and Papers, and J. W. Million and H. Smith are serving on the Committee on Membership.

The Buffalo-Niagara Section's Board of Direction holds regular bi-monthly meetings at which the various problems which confront the Section are discussed.

LOS ANGELES SECTION

A meeting of the Los Angeles Section was held on August 27th in the Elite Cafe at 633 Flower Street, Los Angeles. D. C. Wallace, Chairman of the Section, presided. R. H. Ranger, of the Radio Corporation of America, presented a paper on "Recent Advances in Photoradio." E. H. Hansen, of the Fox Case Movietone, read a paper on "Movietone System of Talking Movies."

Seventy members and guests attended the meeting and the dinner preceding the meeting.

The next meeting of the Section will be held on September 17th at which R. B. Parrish and K. G. Ormiston will deliver a paper, "Television Transmission and Reception," which will be accompanied by television demonstration.

PHILADELPHIA SECTION

At a meeting of the Philadelphia Section, held on September 11th in the Franklin Institute, Irving Wolff, of the Radio Corporation of America, read a paper, "Sound Measurements and Loud Speaker Characteristics."

Two hundred members and guests attended the meeting which was followed by a general discussion of the paper.

The next meeting of the Section will be held in the Franklin Institute on October 10th. Dr. Austin Bailey, of the American Telephone and Telegraph Company, will deliver a paper, "The Receiving System for Long-Wave Transatlantic Radio Telephony."

Rochester Section

Officers and Committee Chairmen for the 1928–1929 season of the Rochester Section are announced as follows: Chairman, A. B. Chamberlain, Radio station WHAM; Vice-Chairman, Earl Karker, 143½ Plymouth Avenue South, Rochester; Secretary-Treasurer, A. L. Schoen, Kodak Park, Rochester; Chairman of the Section's Board of Direction, Ray H. Manson, Rochester; Chairman of the Committee on Meetings and Papers, Virgil M. Graham, Rochester.

San Francisco Section

The San Francisco Section held a meeting on September 4th in the Engineers' Club of San Francisco. Dr. Leonard F. Fuller, Chairman of the Section, presided.

A paper by R. H. Ranger, of the Radio Corporation of America, on "Recent Advances in Photoradio" was presented by Captain Ranger. Sixty-one members and guests attended the informal dinner preceding the meeting and one hundred and thirty members attended the meeting itself.

This was a joint meeting with the San Francisco Post of the American Signal Corps Association.

The next regular meeting will be held on October 24th at which Ralph M. Heintz, of Heintz and Kaufman, will read a paper, "Radio in the Antarctic."

Washington Section

On September 12th a meeting of the Washington Section was held in Picardi's Cafe, 1417 New York Avenue, N. W., Washington. F. P. Guthrie, Chairman of the Section, presided. Irving Wolff, of the Radio Corporation of America, presented a paper, "Sound Measurements and Loud Speaker Characteristics."

Following the presentation of the paper, the following participated in its discussion: J. H. Dellinger, Herbert G. Dorsey, Captain Guy Hill, F. P. Guthrie, G. D. Robinson, H. H. Lyon, Marcus Hopkins, and H. J. W. Fay.

At the dinner preceding the meeting twenty-two members were present. Thirty-five members and guests attended the meeting.

The next meeting of the Section will be held on October 11 in Picardi's Cafe. Dr. Austin Bailey, of the American Telephone and Telegraph Company, will present a paper entitled "The Receiving System for Long-Wave Transatlantic Radio Telephony."

Committee Work

Committee on Sections

At a meeting of the Committee on Sections held on August 30th in the offices of the Institute there were present Donald McNicol, Chairman; E. R. Shute, E. I. Green, Quinton Adams, and F. P. Guthrie.

Correspondence covering the activities of the Sections during the summer months was discussed. At the 1929 Convention of the Institute which is to be held in Washington, D. C., during the middle of May, it is proposed to set aside a portion of the time for a meeting of the Committee on Sections with representatives from each Section present.

Committee on Admissions

Messrs. R. A. Heising, Chairman; E. R. Shute, and H. F. Dart were present at a meeting of the Committee on Admissions held on September 5th in the offices of the Institute.

The Committee considered fifteen applications for transfer or election to the higher grades of membership.

Personal Mention

Melville Eastham, Treasurer of the Institute, returned from a three months' trip to Europe on August 20th.

Satoshi Uchida has returned to Japan, where he is located in Tokio City as engineer at broadcasting station JOAK.

S. A. Jensen, formerly of Denver, Colorado, is now in the service department of Sherman, Clay and Company of Seattle.

Since June of this year K. H. Goode has been chief chemist of the Sylvania Products Company at Emporium, Pennsylvania.

Charles E. Biele has recently been appointed assistant sales engineer of the Edison Storage Battery Company. Mr. Biele is located at Orange, N. J.

C. B. Feldman, for two years a teaching fellow at the University of Minnesota, is now in the radio research department of the Bell Telephone Laboratories, at Cliffwood, N. J.

D. K. Gifford, who has been with the Radio Corporation of America in their transoceanic telegraph department, is now at Salt Lake City, Utah, at the Department of Commerce airways station.

Carl Dreher has recently been appointed chief eningeer of R.C.A. Photophone. He remains with the National Broadcasting Company as assistant secretary of the Board of Consulting Engineers.

Dr. August Hund has been transferred from the Sound Laboratory of the Bureau of Standards to the Radio Section, in which he was formerly active for several years. He is specializing in research problems in piezo-electricity.

Bruce W. David, Secretary of the Cleveland Section, has resigned from the engineering staff of the Sterling Manufacturing Company to become connected with the Cleveland Electric Illuminating Company as assistant to the President, in charge of radio engineering.

A. M. Trogner, for a number of years in the Radio Division of the Naval Research Laboratory where he specialized in high power transmitting design and development, has left Washington to become associated with Wired Radio, Inc., of New York City.

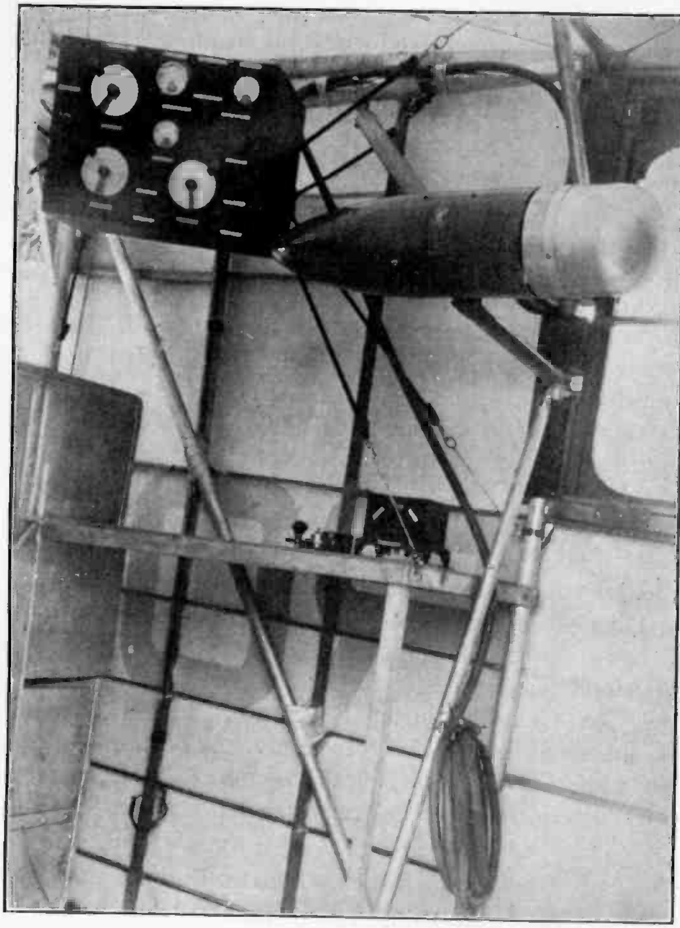
Haraden Pratt, formerly of the Radio Division of the Bureau of Standards, is now chief engineer of the Mackay Radio and Communication Company of New York City. Mr. Pratt was engaged in aircraft radio development work at the Bureau. He has contributed several papers recently to the PROCEEDINGS on "Aircraft Radio."

Alfred Crossley, for a number of years associated with the Radio Division of the Naval Research Laboratory at Bellevue, D. C., has resigned to become chief engineer in charge of research and development of the Steinite Radio Laboratories of Atchison, Kansas. Mr. Crossley, during 1928, was Secretary-Treasurer of the Washington Section of the Institute. As Secretary, pro-tem, Thomas McL. Davis, of the Naval Research Laboratory, is carrying on the Section duties performed by Mr. Crossley.

NEW YORK-ROME AIRPLANE FLIGHT

As these lines are being typed the Bellanca sesqui-plane *Roma* is poised at Old Orchard, Maine, preparatory to its attempt at a non-stop flight to Rome. The crew is composed of Commander Cesare Sabelli, pilot, Roger Q. Williams, pilot, Captain Peter Bonelli, navigator and radio operator, and Dr. Pucilli.

The radio equipment is of special design by the Radio Corporation of America. The transmitter is equipped to operate on either 600 or 45 meters. The 600-meter circuit is a Hartley oscillator inductively coupled to the antenna, and employs a UX-852 75-watt power tube which can be modulated for ICW by means of a UX-210 $7\frac{1}{2}$-watt oscillator which can be coupled to the grid of the main oscillator tube.



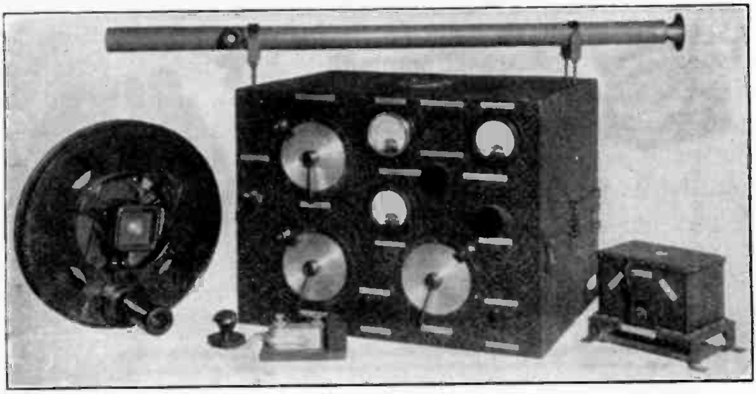
Radio Cabin of Airplane *Roma*. Retractable Wind-Driven Generator Swung In.

For 45-meter transmission the circuit is modified by means of one switch to become a crystal-controlled 75-watt amplifier operating from a UX-210 crystal-controlled oscillator.

The transmitter has been installed directly behind the 500-gallon gasoline tank. To avoid vibration the transmitter and each of its accessory units are enclosed in heavy aluminum cabinets which are suspended from the fusilage by means of heavy rubber cords.

Power for the transmitter is obtained from a 500-watt generator driven by a Deslauries air fan. The generator is mounted on a retractable frame so that it may be swung into the cabin to avoid extra wind resistance to the airplane when the apparatus is not in use.

The antenna wire is of copper-clad steel, normally rolled in on an antenna reel. Two or more ten-ounce fish weights can be attached to the end of the three-hundred and fifty-foot antenna wire which is run through the fair lead shown in the photograph, on top of the transmitter cabinet.



Transmitter, Fair Lead, Antenna Reel, Flame-Proof Send-Receive Switch and Flame-Proof Transmitting Key of the *Roma.*

The receiver uses five dry-cell tubes, the circuit being a tuned radio-frequency stage preceded by an untuned coupling tube, and followed by an autodyne detector and two stages of audio-frequency amplification. The wavelength range of the receiver is from 550 to 880 meters, no provision being made to receive short waves.

Very elaborate arrangements have been made to provide for reception of signals from the plane while in flight. Several stations on the eastern coast of the United States as well as stations in England, Portugal, the Azores, and Italy will continually guard one or both of the wavelengths used in the plane.

The call letters of the plane are WRCA.

The Byrd Antarctic Expedition

When the small bark *City of New York* put out from New York City on August 26th bound for New Zealand, the first unit of the Byrd Antarctic Expedition set forth for an absence of certainly one and one-half, and possibly three years. The *City of New York* was christened *Samson* many years ago. She has been plying the sealing trade off the shores of Spitzbergen for over forty years. On her voyage south through the Canal to New Zealand thirty-seven of the seventy men who will take part in Commander Byrd's antarctic adventure were present.

On September 15th the second unit of the expedition sailed from New York, when the trim ship *Eleanor Boling* (née *Chelsea*) set sail with additional men and additional equipment. Early in October the 10,000 giant *C. A. Larsen*, a veteran Ross Sea whaling steamer, leaves Hampton Roads, Virginia, with four airplanes and additional food and equipment, and at about the same time the fourth and last ship, the *Sir James Clark Ross*, another Ross Sea whaling steamer of some 10,000 tons, leaves from the West Coast with the remainder of the supplies and men.

The four ships will meet at the Ross ice barrier near the Bay of Whales (see insert map) where the *City of New York* and the *Eleanor Boling* will tie up alongside the barrier to remain as the base camp. The supply ships, *Larsen* and *Ross*, will unload and depart.

During the year following there are some four million square miles of territory, upon which no person has yet set eye, to be explored by "land" parties and airplanes.

This antarctic expedition is probably the best-equipped expedition which ever set forth; certainly the best to go to the south pole regions.

The radio equipment includes some thirty-three transmitters and receivers, with reserve supplies to keep them in operation for four or five years, if necessary.

Call letters for the various major radio units of the expedition have been assigned by the Department of Commerce as follows:

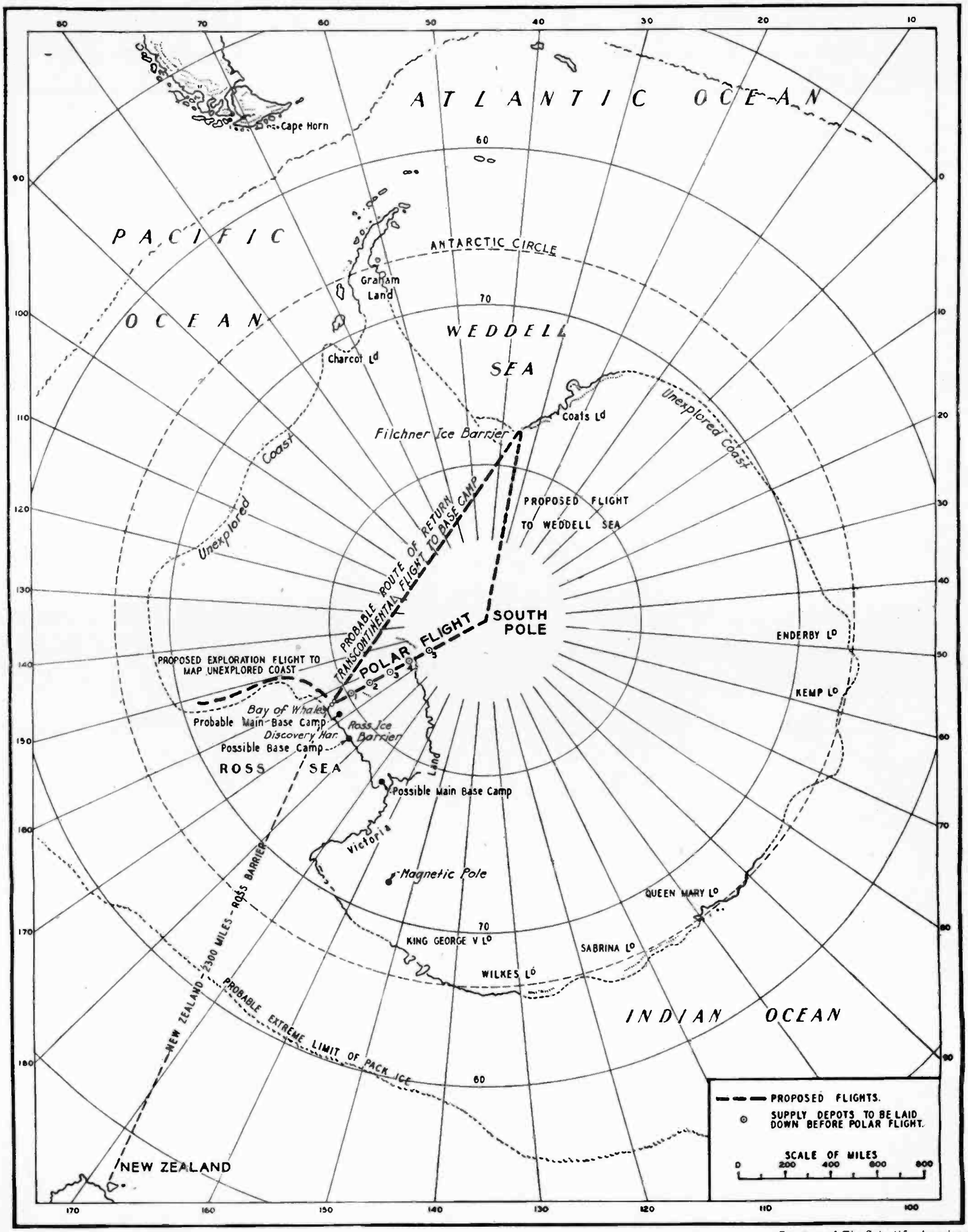
KFK—general call for any or all units of the expedition.

WFAT—the *Eleanor Boling*.

WFBT—the *City of New York*.

WFA—main base on the ice barrier (probably near Bay of Whales).

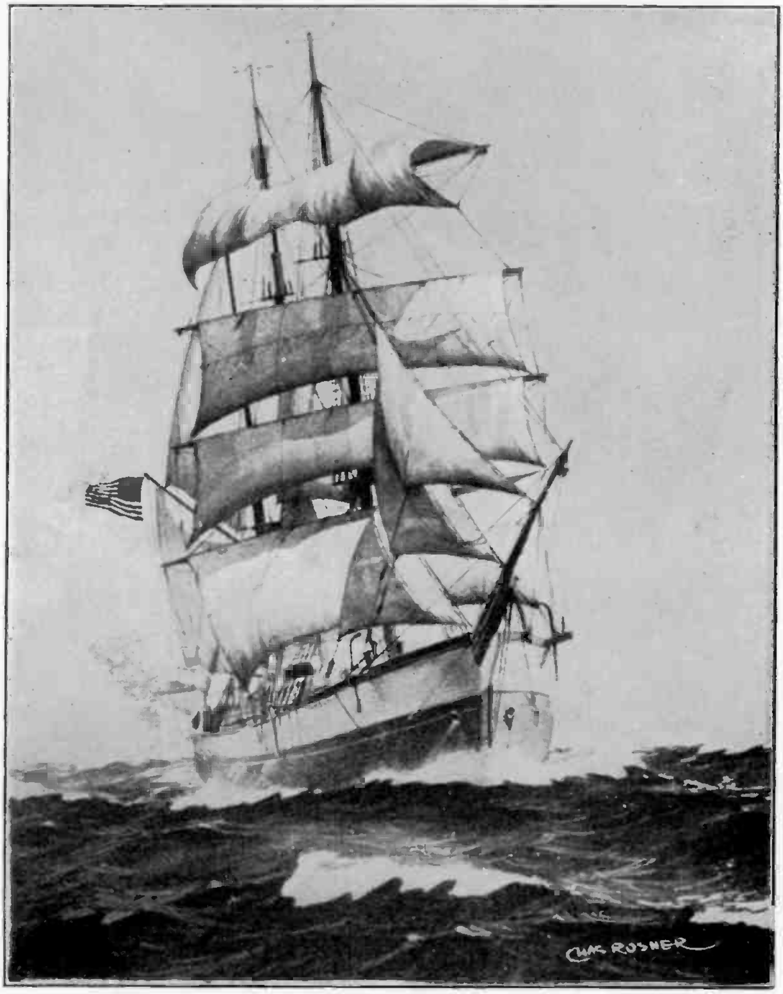
WFB—the Ford tri-motored *Floyd Bennett* airplane.



Courtesy of The Scientific American

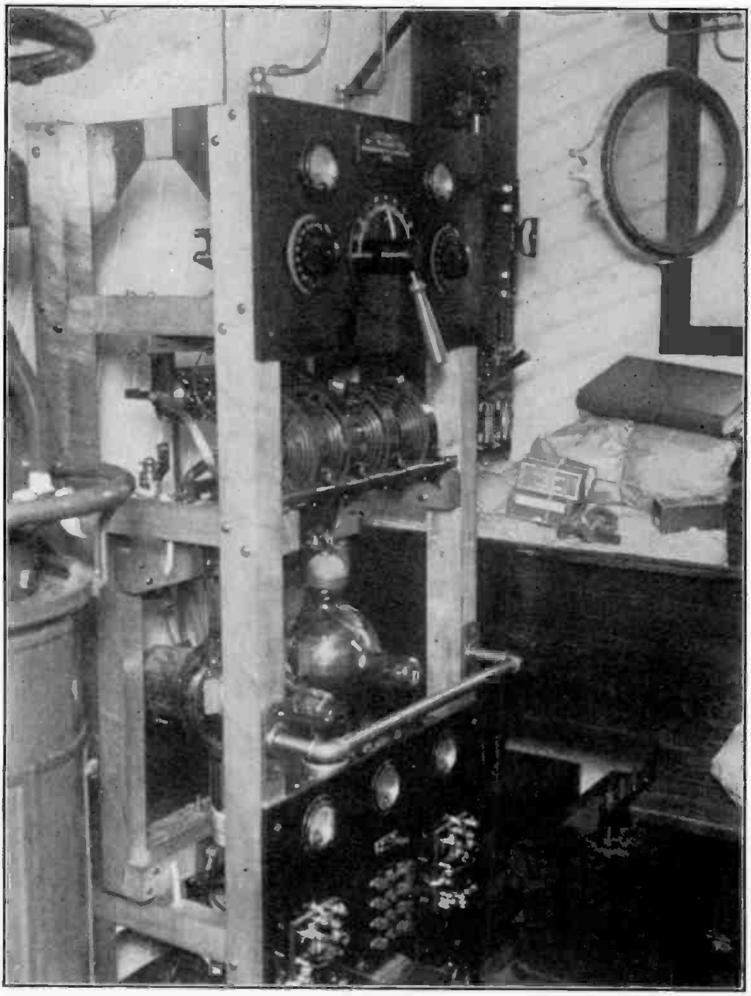
The Antarctic Regions Showing Main Bases and Routes of Exploratory Marches and Flights of Byrd Expedition.

WFC—the Fairchild *Stars and Stripes* airplane.
WFE and WFE—advance bases on land parties.
WFF—the Fokker *Virginia* airplane.
An additional plane will use either call letters WFD or WFE.



The *City of New York*, the First Byrd Ship to Sail.

The intermediate calling frequency for all units will be 500 kc and the high frequencies used for calling will be 5,600, 11,200 and 16,800 kc. The intermediate working frequencies will be 375 and 425.5 kc and the high-frequency communication frequencies will be 3,290 kc, 4,405 kc, 5,650 kc, 6,580 kc, 8,810 kc, 11,300 kc, 13,187 kc, 16,717 kc, and 21,805 kc.

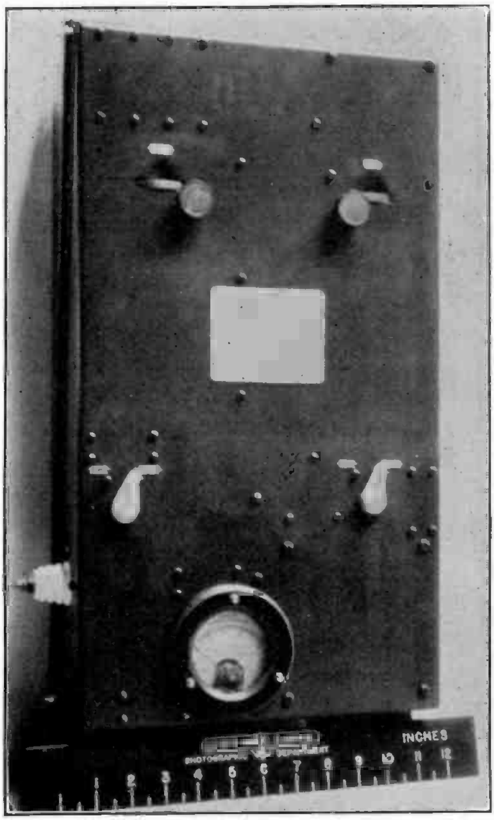


High-Frequency 1,500-Watt Transmitter on the *Eleanor Boling.*

It is expected that *all* high-frequency communications will be confined to the following frequencies, after the ice barrier has been reached: 3,290 kc, 4,405 kc, 6,580 kc, and 8,810 kc.

Both expedition ships carry 375 kc radio compass equipment. The compass receiver of one of the ships will be set up on the ice ten or fifteen miles from the main base camp and will be used in conjunction with the compass receiver of the other ship to fix the position of all advance parties and planes by taking simultaneous bearings from the movable transmitters.

The radio personnel includes Lieutenant M. P. Hanson, of the Naval Research Laboratory, who is chief radio engineer for



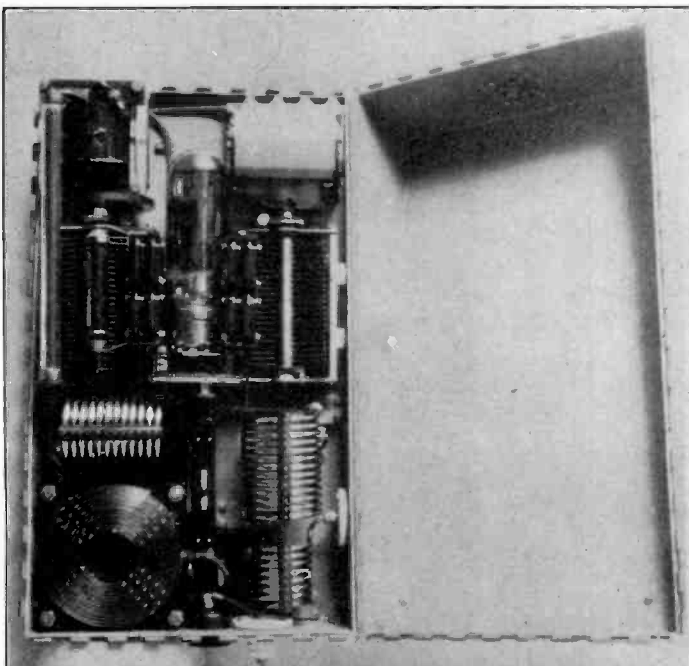
Front View of Intermediate High Frequency Airplane Transmitter.

the expedition; Ensign Lloyd Berkner, of the Bureau of Standards; Lloyd Grenlie, who accompanied the Byrd Arctic expedition; and Carl Petersen.

Both expedition ships (WFAT and WFBT) carry two transmitters, one for intermediate and one for high-frequency work. The intermediate-frequency set on the *Eleanor Boling* is an R.C.A. P-8 spark transmitter converted to a 500-watt ICW set (type

ET-3628). This transmitter will be used for short-range communication en route to the ice pack and for radio compass work with advance base parties and airplanes.

The high-frequency transmitter on this ship (shown in the illustration) was designed under the supervision of Hanson and Mason and was built by the expedition's radio personnel. It employs two 750-watt oscillator tubes in a special series-feed circuit. Plate supply of 500 cycles is obtained from a 5-kw



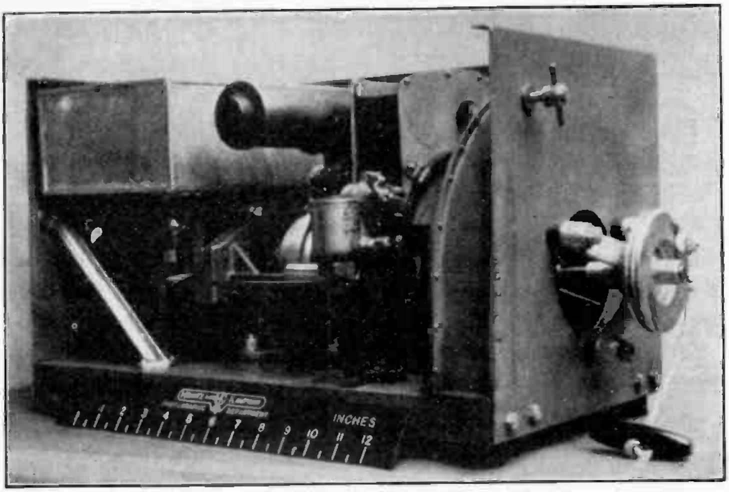
Interior of Airplane Transmitter.

steam-driven generator. A 2-kw auxiliary gasoline-driven unit is available for emergency work.

The intermediate-frequency transmitter on the *City of New York* is a fog signal type 500-watt ICW set which was obtained from the Bureau of Lighthouses. It is a General Electric type RT-I-F transmitter with a tuning range of from 300 to 500 kc. The high-frequency transmitter employs the conventional tuned-grid tuned-plate circuit, using two UX-204-A 250-watt tubes with 500-cycle plate supply. The latter set was constructed by the expedition personnel.

For intermediate-frequency reception (1,000 to 300 kc) standard Navy type R.F. receivers using four stages of transformer-coupled radio-frequency amplification, an autodyne detector and two stages of tuned audio-frequency amplification. are provided for both ships and for the base camp. High-frequency reception on the ships and at the base camp will be provided by the G.E.-R.C.A. high-frequency receiver using tuned r.f. amplification with the UX-222 tubes.

Each of the four planes is provided with 50-watt combined intermediate and high-frequency transmitters built by Heintz and Kaufman. Emergency battery-operated transmitters for



Motor-Generator Unit, Driven by Single-Cylinder Two-Cycle Gasoline Engine, for Advance Parties.

planes and for advance parties were provided by the Burgess Battery Company. The main plane transmitters obtained plate and filament potentials from small generators driven by the plane's motor of the constant current type. The tri-motored Ford plane is equipped with a spare generator geared to a second engine. The receiving equipment for all planes uses the super-regenerative circuit. The receivers were constructed under the supervision of Hanson at the National Electric Supply Company.

A main base camp transmitter, similar to the installation on the *Eleanor Boling*, and constructed by the ships radiomen at the Staten Island shops of the Bureau of Lighthouses, will be set up near the Ross Sea.

For reception on all planes a doublet from the tip of each wing extending to the tail, with feeder wires through the fusilage, will be used. For transmission in the planes a trailing wire will be dropped from the tip of each wing.

The expedition is carrying a great deal of laboratory equipment for making fading observations, oscillograms of echo signals and much other scientific data. The fading recorder is a Westinghouse superheterodyne which was calibrated by the Bureau of Standards, and a Westinghouse oscillograph is to be used for recording echo signals.

While the main function of the radio equipment will be the provision of reliable contact with the world, it is expected that much scientific radio information will be collected and collated.

Radio Commission Engineers

The permanent engineering staff of the Federal Radio Commission has been announced as follows: J. H. Dellinger, Chief Engineer; Commander T. A. M. Craven, Captain Guy Hill, F. Y. Gates, G. O. Sutton, G. C. Ross, and G. C. Blackwell.

These engineers are permanently associated with the commission and will advise it on all technical radio matters.

Standard Frequency Transmissions by the Bureau of Standards

The Bureau of Standards announces a new schedule of radio signals of standard frequencies, for use by the public in calibrating frequency standards and transmitting and receiving apparatus. This schedule includes many of the border frequencies between services as set forth in the allocation of the International Radio Convention of Washington which goes 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 about 500 to 1,000 miles from the transmitting station.

The transmissions are by continuous-wave radiotelegraphy. The signals have a slight modulation of high pitch which aids in their identification. 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 SIGNAL TRANSMISSIONS OF STANDARD FREQUENCY SCHEDULE OF FREQUENCIES IN KILOCYCLES

Eastern Standard Time	Oct. 22[1]	Nov. 20	Dec. 20	Jan. 21	Feb. 20	Mar. 20
10:00–10:08 P.M.	550	1500	4000	125	550	1500
10:12–10:20	600	1700	4200	150	600	1700
10:24–10:32	650	2250	4400	200	650	2250
10:36–10:44	800	2750	4700	250	800	2750
10:48–10:56	1000	2850	5000	300	1000	2850
11:00–11:08	1200	3200	5500	375	1200	3200
11:12–11:20	1400	3500	5700	450	1400	3500
11:24–11:32	1500	4000	6000	550	1500	4000

[1] This schedule replaces the one previously announced for this date.

CIVIL SERVICE EXAMINATIONS FOR PHYSICIST

The United States Civil Service Commission announces open competitive examinations for positions of Associate Physicist and Assistant Physicist (salaries of $3,200 and $2,600 per year, respectively) in the following branches: heat, electricity, mechanics, optics, radio, physical metallurgy, thermodynamics and aerodynamics, or any specialized work in the field of physics not included in the foregoing.

Vacancies in the Bureau of Standards and Bureau of Mines, Department of Commerce, and under the National Advisory Committee for Aeronautics, and in positions requiring similar qualifications in other branches of the service will be filled from these examinations.

Competitors will not be required to report at any place for examination but will be rated on education and experience (70 per cent) and writings (publications, reports, or thesis to be filed with application) for 30 per cent.

Form 2600 together with further particulars contained in form No. 220 may be obtained from the U. S. Civil Service Commission, Washington, D. C.

U. R. S. I. Meeting in Brussels

The following American delegates to the 1928 General Assembly of the International Union of Scientific Radiotelegraphy, are now in Brussels, Belgium: L. W. Austin, L. M. Hull, A. G. Jensen, T. Parkinson, Maj. Gen. C. McK. Saltzman, Norman Snyder, and G. Breit.

The meetings of the General Assembly will be devoted to routine business of the organization and to the presentation of a number of scientific radio papers.

In this connection, it is announced that the volume containing the papers presented before the General Assembly of 1927, held in Washington, D. C., is now available. A table of contents of Part 1 appears as follows:

Greenleaf W. Pickard.—The relation between radio reception sunspot position and area, p. 51.

Haraden Pratt.—Apparent night variation with crossed coil radio beacons, p. 55.

George Rodwin and Theodore A. Smith.—A radio frequency oscillator for receiver investigations, p. 58.

Balth Van der Pol.—The effect of retroaction on the received signal strength, p. 63.

Robert H. Worrall and Raymond B. Owens.—The navy's primary frequency standard, p. 67.

Eitaro Yokayama and Tomozo Nakai.—The directional observations on atmospherics in Japan, p. 74.

The complete volume can be obtained for 100 French francs from the Secretariat General, U. R. S. I., 54 avenue des Arts, Brussels, Belgium.

OBITUARY

With deep regret the Institute announces the death of

Hubert Milo Freeman

Mr. Freeman was connected for a number of years with the Research Department of the Westinghouse Electric and Manufacturing Company where he conducted much original tube development work. Early in 1926 he transferred to the Radio Engineering Department of the Westinghouse Lamp Company where he continued to be closely associated with the development and engineering of receiving and transmitting tubes.

He has been an Associate member of the Institute of Radio Engineers since 1919 and has served on the Institute's committees for a number of years.

Mr. Freeman passed away at his home in Bloomfield, New Jersey, in March of this year.

Volume 16, Number 10 *October, 1928*

ELECTRICAL PROSPECTING*

By

J. J. Jakosky

(Consulting Engineer, The Radiore Company, Los Angeles, California; Research Engineer, University of Utah, Salt Lake City, Utah.)

Summary—*By means of electrical geophysical methods it is possible to obtain a great deal of valuable information regarding the extent, depth and general type of mineralization present on a property. It is not a question, however, of how much information may be obtained from a geophysical survey, but only a question of conducting the survey and examination to such a stage that gives the most optimum return on the expenditure, considering the entire development program. The experience of the writer to date is that ordinarily the most information for the least expenditure can be obtained by locating the plan view of the conductors (the mineralized zones) and determining their approximate depth and width. Such work can be done at the rate of about 8 to 25 acres per day (with the usual four men field crew) depending upon topographic conditions and amount and type of mineralization present. The information derived from such work may now be studied in connection with the geology and known ore occurrence of the district and the exploration program more efficiently carried out. In some cases, however, more complete studies were required lasting over a period of months. In addition consideration must be given the training and personnel of the company for whom the work is being conducted. A majority of the operating companies have excellent engineering and geological staffs who have a thorough knowledge of the property and are therefore capable of interpreting the results of the survey and applying it to their specific development or structural problems. In such cases the geophysicists may act only as general consultants in the interpretation of their data. At other surveys, however, it is necessary to conduct a geological examination of the property and to take an active part in planning of the exploration and development program. In every case, however, the greatest benefits are derived by proper cooperation between the geophysicists, the mining engineer, and the geologists for the interpretation of all available data. The work of one supplements and is complimentary to that of the other.*

Introduction

ENGINEERS well realize that mining is one of America's key industries, for it supplies a major portion of the raw materials used in manufacturing. Therefore, a reliable and fast means of determining whether or not an area is mineralized and warrants expenditures for exploration work should in due time have its proportionate effect in producing greater profits to the industry and resultant lowered prices to the consumer. Various types of geophysical methods have been proposed as a

* Original Manuscript Received by the Institute, July 23, 1928. Presented before Los Angeles Section, May 21, 1928.

means for accomplishing this purpose. Magnetic, gravitational, seismic, and electrical methods have been developed for various sub-surface investigations. These methods are thoroughly scientific and based on well-known physical phenomena; they bear no relation to the old-time diving-rods or "doodle-bugs." The electrical methods are by far the most important for mining purposes judged from present application and the comparative simplicity with which the results may be interpreted. Alternating current and high-frequency phenomena play an important part in the application of the electrical methods. Such work is of interest to members of the Institute, and is opening up new fields of applications for the radio and electrical engineer.

There are several types of electrical methods some of which utilize natural earth currents, others direct or alternating applied earth currents, and still others electromagnetic induction. Of these the last has at present the widest application. Inductive methods of geophysical prospecting are capable of great versatility. They will function practically as well in swampy country as in the dry desert regions. Snow and ice are no bar to efficient work, and the character of the surface soil is unimportant, since, unlike other electrical methods, no contact with the ground or ore-body is employed. Territory covered with overburden such as lava, or float, or where no outcrops occur, can be as readily surveyed as other kinds of territory, a fact which offers immense possibilities in disclosing the location of hitherto unknown mineralized areas.

The Occurrence of Ores

The term *ore* generally denotes those *minerals* mined from the earth from which *metals* are derived. Metals seldom occur in the pure state but are usually combined with other elements or compounds, and as such are called minerals. Silver occurs combined with sulphur, and is often associated with arsenic. Copper is found combined with oxygen as an oxide, or with sulphur as a sulphide, and also as a carbonate. Lead occurs as a sulphide, as a carbonate, and as a sulphate. Iron is usually the most abundant in the earth's crust and occurs as oxides, carbonates, and sulphides. Many metals occur together and combined ores may be mined for several metals.

Ores occur in a great variety of ways or manners. The types of deposits most amenable to electrical prospecting, however, are those in which the ores fill fissures or seams in the rock and thereby form veins or ore-shoots. The mineral content of the rocks is usually deposited there by ground-water flowing through these fissures. This deposition may have been caused by cooling of the water, or by a chemical reaction between the water and the rocks, which decreased the ability of the water to hold the mineral substances in solution, causing their deposition. Such deposits may take almost any conceivable shape and may form in films, sheets, or crusts deposited upon the walls of the fissure. As a rule, the ore occurs in combination with other substances, called *gangues*, such as quartz, calcite, barite, dolomite, siderite, etc., which are very poor electrical conductors.

Field of Application for the Electrical Methods

All electrical geophysical methods depend for their operation upon the effects produced by the flow of an electric current. By studying these effects it is possible to predict the general axis of current flow. The greater flow of current is in the path of greatest effective conductivity.

Electrical methods can be advantageously employed when the electrical conductivities of the different strata or components of the earth's surface differ considerably. As applied to the location of mineralized areas or zones, the greater the difference in electrical conductivity between the mineralized area and the surrounding envelope (the earth), the more pronounced or definite is the effect upon the recording or detecting instruments. Generally speaking, it is necessary that the difference in conductivity be of the order of 1 to 100 or more. Ratios of 1 to 100 are quite common; and good mineralized areas (such as massive sulphide indications) often have ratios from 1 to 1,000 to 1 to 10,000 compared with the surrounding earth.

Ores which are amenable to electrical prospecting are, generally speaking, those which may be classed as electrical conductors, though, as will be shown later, the question of conductivity is a relative one. Such ores include pyrites, graphite, chalcopyrite, arsenopyrite, some anthracite coals, a few carboniferous shales, galena, pyrolusite, magnetite, and the metals.

Many ores occur in nature in such chemical form that they are electrically non-conductive. These include the majority of the oxides, carbonates, and silicates; and two common sulphides, stibnite and sphalerite. Such ores generally are not amenable to electrical prospecting unless associated with other ores which may be conductive.

In many districts the geologist or mining engineer knows from previous investigations that certain ores often occur associated with other ores. In this way, an indirect method is available for locating the pay ore, owing to the presence of a conducting ore having no special commercial value. Unless the geology and manner of ore occurrence of a district are well-known, it is difficult to obtain an authoritative idea of the commercial values of the mineralized area. Generally speaking, electrical prospecting methods are of value only in locating mineralized areas. These usually contain ores of more than one mineral. To illustrate this point, consider a mineralized area consisting largely of zinc sulphide, a non-conductor, combined with a very small amount of iron pyrite or iron sulphide, a conductor. Owing to the presence of the pyrite, the mineralized area is amenable to electrical methods of prospecting. Unless quite close to the surface, the zinc sulphide would have no effect on the electrical readings, regardless of its mass or length. The electrical effect of such a body would depend upon the amount of pyrite present; the commercial value of the area would depend upon the zinc sulphide.

Electromagnetic Generation of an emf

The inductive method is so named because the current flowing in the conductor is obtained by electromagnetic induction, instead of by the use of ground electrodes through which a current is passed as in the applied potential systems, or by direct contact with the ore-body. As is well-known an alternating current flowing in a coil will create an electromagnetic field around the coil. This field will have the same frequency as the current, and will radiate or travel outward from the coil in closed magnetic or flux circuits. These flux circuits (in air or a homogeneous medium) will be perpendicular to the plane of the coil and will extend or travel outward with uniform velocity in every direction. Maximum field exists in the plane of the coil. Such a coil used for transmitting will exhibit similar figure-eight characteristics to those exhibited by the conventional direction-finding coils.

Theory of Electromagnetic Induction

Whenever an alternating magnetic field cuts a conductor an emf is generated. The magnitude of this generated emf is among other things a function of the strength of the magnetic field and the rate of change of the field, that is, its frequency. The higher the frequency, the greater the induced emf.

The current induced in the conductor will, of course, have the same frequency as the original current flowing in the energizing loop. Regardless of the alternating current employed—whether a so-called low frequency from 50 to 3,000 cycles per second, or the higher frequencies up to many thousands of cycles per second—practically the same fundamental phenomenon takes place.

These relationships may be expressed by the formula of electromagnetic induction:

$$E = 2\pi f M I$$

Wherein E is the induced emf.

f = the frequency of the magnetic field (or the frequency of the current flowing in the energizing circuit)

M = the mutual inductance between the primary or energizing circuit and the secondary circuit, and

I = the current flowing in the primary circuit.

Mutual Inductance

The mutual inductance between two electrical circuits is a constant determining the ease with which energy from the first circuit can be transferred to the second when the two are coupled by the magnetic lines of force due to the current in the first circuit. The greater the mutual inductance or coupling, the greater will be the energy transferred between the circuits. Ordinary transformer action is the most familiar example of this phenomenon. As seen from the expression given above the larger the value of M the greater is the value of the induced electromotive force.

The range in values of M for the average energizing coil and an ore-body (assuming no absorption of the field between the energizing coil and the conducting body) may be shown by considering the case of a rectangular coil and a wire of small diameter and infinite length. The coil and the wire lay in the same plane with one side of the coil parallel to the wire. If h is the length of the coil parallel with the wire, d the width of the coil, and A the distance from the wire to the near side of the coil, a direct calculation gives us for the mutual inductance M the expression:

$$M = 2h \log_e \left(1 + \frac{d}{A}\right)$$

In case of a square coil $h = d$, and $M = 2d \log_e \left(1 + \frac{d}{A}\right)$.

The magnitude of these values may best be illustrated by a practical example. Consider a vertical energizing coil 10 ft. square placed directly above the conductor so they both lie in the same plane and assuming no absorption of the magnetic field. The relationships between M and the distance between the coil and the wire is shown by Fig. 1. The mutual inductance decreases with an increase in distance between the coil and the wire.

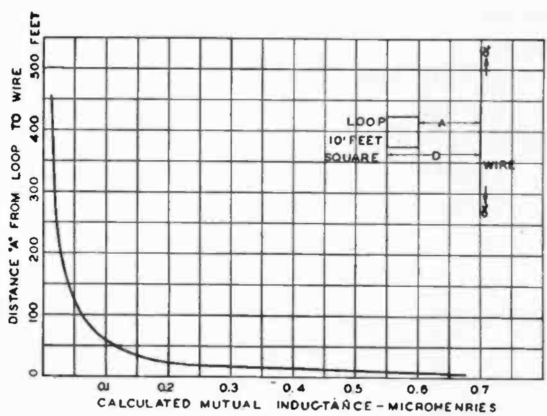


Fig. 1

When the medium between the coil and the wire is of such a character as to decrease by absorption (which is the dissipation of energy by eddy currents) the strength of the magnetic field, the value of M decreases in proportion to this decrease in field strength since absorption is equivalent to decreasing the coupling between circuits. The absorption in dry or desert countries may be practically neglected when operating at frequencies of 50,000 cycles per second or less to depths of 400 to 500 feet. In regions where the sub-strata are wet the absorption is quite appreciable, as will be shown in a later paragraph.

Magnitude of Induced Voltage

The magnitude of the voltage induced in a conductor by current flowing in the coil may be calculated from the preceding data. The current flowing in the 10 ft. square energizing coil is assumed to be 5 amperes and, as before, with the coil and conductor lying in the same plane and one side of the coil parallel with the conductor. These values, for various frequencies and mutual inductance between the coil and the conductor are shown in Fig. 2. It will be noted further that the induced emf decreases rapidly with a decrease in M; that is, an increase in the distance between the energizing coil and the conductor. In geophysical applications this means that the induced emf becomes less with an increase in depth of the conductive ore-body. This is one of the factors which limits the depth at which a conductor may be located.

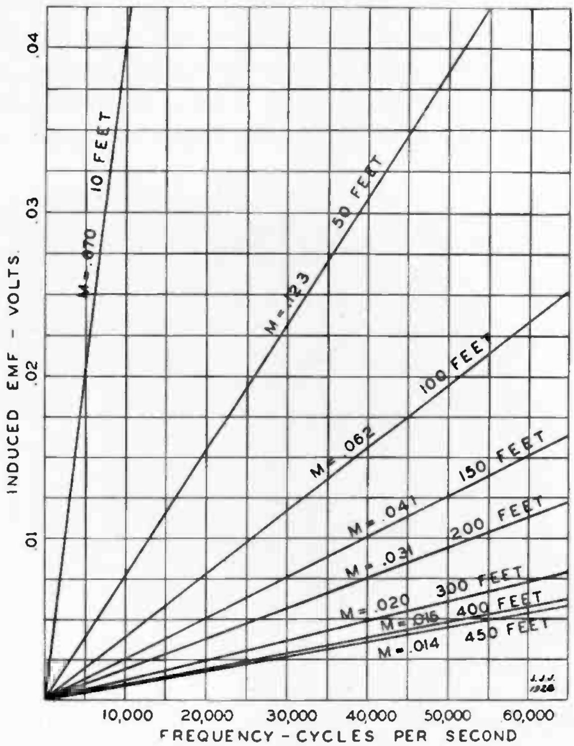


Fig. 2

Factors Affecting Current Flow

Inasmuch as electrical geophysical apparatus employing the direction-finding coil systen for the location of the underground conductive masses operates on *current flow* instead of potential difference or induced emf, it may be well to consider briefly the electrical characteristics of mineralized areas.

Mineralized zones usually possess properties quite different from ordinary solid conductors such as wires, etc. Under the practical conditions usually encountered in geophysical work, the capacitive reactance may be of very high value and in all cases where measurements or calculations have been made by the writer, the inductive component is comparatively small and completely masked by the capacitive component. This is especially pronounced in all broken, faulted, and disseminated ores, as well as in so-called massive ores containing fractures which are filled with non-conducting or very high resistance depositions such as quartz, calcite, altered feldspar or clay, and some of the oxides. These fractures may vary in size from very minute veinlets to fractures, fault zones or even igneous dikes.

The magnitude of the capacity existing between portions of a fractured ore may be seen from the following typical tests. A

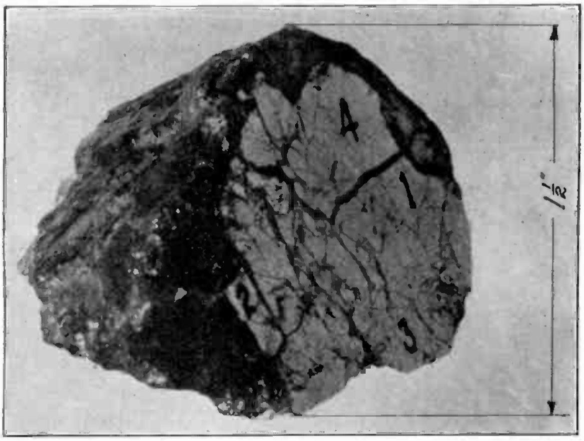


Fig. 3

view of the specimen is shown in Fig. 3. This particular sample[1] is a surface outcropping on the Duprat Mines property in Kamiskotia, Canada. Samples were cut from the specimen and analyzed chemically and also submitted to a microscopic examination. The assay results, given in Table I, show that the marcasite is impure, in that it contains silicate material, lime, and alumina. The following information and the data in the table is from work being conducted at the department of Metallurgical Research, University of Utah, by R. E. Head, and R. N. Anderson, of the Radiore Company.

[1] Submitted by E. H. Gilford, General Manager of the Radiore Company of Canada, Ltd.

"The microscopic examination shows that this impurity is contained in veins which fill the badly fractured marcasite. The fractures run in all directions and vary in size from very minute veinlets to 1/16 in. in width. The content of these veins is probably quartz, calcite, and altered feldspar or clay. There is also some altered marcasite in the form of iron oxide or limonite. Small specks of marcasite are also present in the veins. The marcasite is free from other sulphides and shows but little alteration, the iron oxide being only a film next to the impurities contained in the veins. Both the small and large samples were nearly enclosed in a covering of this impure material, the quartz predominating."

The capacities existing between different mineral parts of the specimen (see Fig. 3) were measured at 25 kc by means of the usual capacity substitution method.

Capacity between	Micro-microfarads
1 and 2	11 $\mu\mu$ f
1 " 3	7 "
1 " 4	7 "
2 " 3	3 "
2 " 4	7 "
3 " 4	8 "

In any circuit predominately capacitive, the impedance to current flow will decrease with an increase in frequency, with a resultant increase in current flow as may be seen by the following familiar mathematical relationship:

$$I = \frac{E}{Z} = \frac{E}{\sqrt{R^2 + X^2}}$$

$$= \frac{E}{\sqrt{R^2 + \left(\frac{1}{2\pi f C}\right)^2}}$$

where I = current flow
E = induced voltage
Z = impedance
R = resistance
X = reactance
F = frequency
C = capacity

It can thus be seen that as the frequency is increased, or as the capacity is increased, there is a decrease in the impedance and a resultant increase in the current flowing. This decrease in impedance at the higher frequencies more than offsets the slight increase in effective resistance due to redistribution of current caused by skin-effect. These relationships can be shown by actual measurements made on small specimens of the marcasite.

Four test specimens 1/8 in. x 1/8 in. x 1 in. were cut from samples (No. 56 and 57 from the work of Head and Anderson) and studies made of each of these specimens.

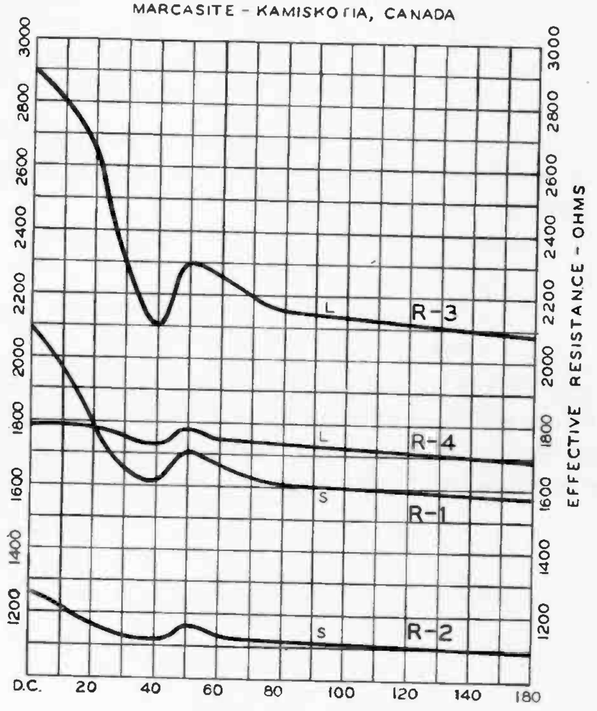


Fig. 4

Specimen No. R-1 shows a number of non-conducting veins, none of which cut entirely through it. In testing a current of 30 m-a. was initially used. This was reduced to 20 m-a. because of arcing that took place inside the specimen. The variation of impedance with frequency is shown by Curve R1 in Fig. 4.

Specimen R-2 contains less veins and consequently shows less impedance, Curve R2.

Specimen R-3 initially contained a thick transverse layer of insulating material near one end, and proved to be practically a non-conductor at the lower and intermediate frequencies. This end was cut off and constant arcing still took place within the specimen, making it difficult to obtain a balance. The results for this specimen are accurate only to about 100 ohms; Curve R3. The greater the number of fractures, the greater is the change of impedance with the change in frequency.

Specimen R4 was also practically a non-conductor due to a thick transverse insulating vein. Removing this, the sample became a fairly good conductor, Curve R4.

TABLE I

CHEMICAL ANALYSIS OF FRACTURED MARCASITE

Material	Sample No. 56 Small	Sample No. 57 Large
Iron, Fe, per cent	38.7	43.1
Lime, Ca O, per cent	0.76	0.76
Sulphur, S, per cent	42.5	44.1
Silica Dioxide, SiO_2, per cent	11.2	5.4
Aluminum Oxide, Al_2O_3, per cent	12.7	13.4
Insoluble, per cent	12.6	6.0

In observing these curves it will be noted that all of the samples of this particular marcasite had a characteristic "hump" at approximately 50 kc, and that the average impedance decreased with an increase in frequency. This decrease in impedance as the frequency is increased shows that the specimens possessed properties making them predominately capacitive.

These tests were made on a special balanced differential transformer-type alternating-current bridge designed by the author and will be described in a later paper. The results obtained on minerals and ores from various parts of the world will be given in a publication of the results of a cooperative study now being conducted by the Department of Metallurgical Research of the University of Utah and the Radiore Company.

IMPEDANCE OF DISSEMINATED ORES

Disseminated ores also exhibit quite different properties toward direct and alternating current. A disseminated ore may be considered as composed of small electrically conducting particles distributed in a matrix. As a rule this matrix is calcite, quartz, and the like, and has a low electrical conductivity; that is, a high resistance. If two conducting particles or masses are separated from one another, an electrostatic capacity exists between these two particles. This capacity is dependent upon the following factors: the geometric configuration and arrangement of the particles, and the dielectric constant or specific inductive capacity of the separating medium (in the case of a disseminated ore it would be the matrix material). A disseminated ore may therefore from an electrical point of view be considered as a resistance shunted by a number of very small capacities connected in series-multiple. Some disseminated ores have been found to have practically an infinite resistance or impedance to direct current or low-frequency alternating current, but were quite good conductors to higher frequencies of 20 kc (20,000 cycles per second) or more. Disseminated ores occurring in dry or desert regions are particularly noticeable in this respect. This is due mainly to the absence of moisture in the matrix allowing it to be practically a perfect insulator.

Impedance of Faulted Zones

The action of the average broken or faulted ore-bodies when subjected to alternating magnetic fields of different frequencies is very noticeable. The impedance of such an ore-body decreases very appreciably with an increase in frequency. Such a system of conductors and effective capacities may be represented by an equivalent series parallel circuit of pure resistance and capacities, the impedance of which could be represented by:

$$Z = \frac{R}{\sqrt{1+R^2 4\pi^2 f^2 C^2}}$$

which at the higher frequencies approaches:

$$\frac{1}{2\pi f C}$$

Thus an increase in frequency causes a decrease in the effective impedance with a resultant greater current flow. In many cases such ore-bodies cannot be sufficiently energized with low frequency, but are easily energized with the higher frequencies. This may be illustrated by considering the specimen shown in Fig. 3. The estimated effective area between particles 1 and 4 is 10 centimeters. The capacity between these particles is 7 $\mu\mu$f. Assume that this same geometrical configuration is increased in size so the effective area between 1 and 4 is 25 square feet (which would be a relatively small cross-section for an ore-body). The capacity would then become 16,240 $\mu\mu$f. Calculation will show that the impedance of such a system will be 196 ohms at 50,000 cycles per second; 9800 ohms at 1000 cycles per second; and if the body were dry and the matrix non-conducting, the direct-current resistance approaches infinity.

If such a body were in a wet region its direct-current resistance would be considerably less than infinity but might not differ sufficiently from the surrounding country rock to make its detection and a study of its electrical characteristics easy.

Field Surrounding a Simple Conductor in a Homogeneous Medium

An alternating current flowing in a conductor sets up an alternating electromagnetic field having the same frequency as the current. In the case of a simple conductor, such as a small-diameter wire of great length suspended alone in the air, the field will surround the wire and travel outward from it in the form of concentric circles or envelopes. The electrical geophysical methods employing direction-finding coils depend for their operation on this alternating magnetic field surrounding the conductor. The induced current flowing in the ore-body sets up a field by means of which the ore-body itself may be located.

Detection of Current Flow in a Conductor

The most satisfactory form of alternating-current detecting equipment, which allows almost direct field calculation of the location of the conductor, is that employing the direction-finding coil. By the use of such a coil the difficulties often encountered in conveniently obtaining good ground connections in the methods where equipotential curves, etc., are plotted, are overcome, especially when the ground surface is covered with heavy brush or moss, snow, and ice. Such a coil, with its associated apparatus, is easily portable and allows quick field manipulation. The complete apparatus consists of the direction-finding coil and an amplifier (for the audio-frequency range); or a detecting and amplifier set, the output of which is usually connected to a pair of head-phones. This equipment is somewhat similiar to the conventional radio direction-finding apparatus, with the special exception that it is designed for use mainly in a vertical plane (for location of conductive areas under the surface of the earth) rather than in a horizontal plane as employed in ordinary direction finding for location of stations on the surface of the earth.

"Sharpness" of Maxima and Minima

In practical direction-finding the accuracy with which a bearing can be taken depends to a large extent upon the sensitivity of the receiving apparatus to small changes in the direction of the plane of the coil. The well-known figure-eight diagram for direction-finding coils is very steep around the minimum position which means that the device will be far more sensitive as regards precision if adjusted for the zero signal instead of for the maximum signal. To this greater sensitivity of the directional properties of the coil is added the greater sensitivity of the average human ear in determining the existence or non-existence of a signal, rather than the maximum intensity of such a signal. If the readings are being made in a hard wind, or where disturbing noises are present, the operator will have difficulty in determining his minimum positions. In actual geophysical work, the minimum angles may be read accurately under average conditions to one-half degree for in-phase conditions. The question of phase relationship will be treated in a later paragraph.

For this reason the minimum point or direction is read in practice, but the direction usually recorded is that for maximum signal strength, which in a simple case would be 90 deg. from the position of minimum. The direction-finding equipment will be described later. Antenna effect and shifts in phase relationship between the field from the energizing coil (called the primary field) and the field from the conductor (called the secondary field), together with distortions of wave fronts caused by the difference in the velocity of propagation through various media must all be compensated for or corrections made to avoid errors.

Practical Relationships Between the Energizing and the Direction-Finding Coil

From what has previously been said, it can be seen that when the direction-finding coil is so placed that its axis of rotation is in the same plane and passes through the center of the energizing loop, minimum or zero signal will be obtained when the direction-finding coil is at right angles to the plane of the energizing coil. These relationships are fundamental and hold true in the elementary case, regardless of the position of the plane of the two coils. This is illustrated in Fig. 5. It is to be noticed that the axis of rotation for the direction-finding coil is horizontal *only* when the direction-finding coil is at the same elevation as the energizing coil. Initial setting up of the Radiore inductive equipment therefore consists of two steps: (1) proper alignment of the energizing coil so that its plane is always vertical and passes through the axis of rotation of the receiving coil, and (2) alignment of the direction-finding coil. The apparatus is so designed to allow this to be done accurately and quickly.

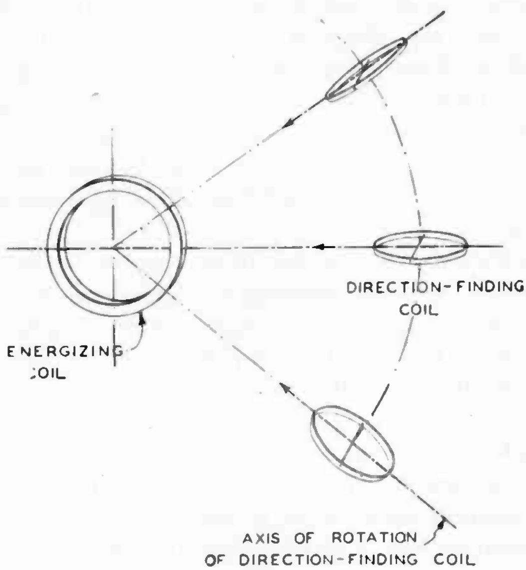


Fig. 5

When the equipment has been set up as described, the operator of the direction-finding coil knows that the position of the coil for minimum signal will normally be horizontal. Should he obtain any angle or dip other than zero (measuring from the vertical) and a strike not pointing toward the energizing coil he knows that some disturbing influence is present. This disturbing influence may be another field caused by induced current flowing in an underground conductive mass, or a distortion of the initial field from the energizing coil so it is not being propagated as would be the case were it located in a uniform homogeneous medium. These effects will be discussed later.

Operating Conditions

When the energizing coil is placed so its field "cuts" a conductor, an emf is induced and a current flows in that conductor. As previously mentioned, this induced current sets up a field (the secondary field) of its own. A direction-finding coil placed in the vicinity of the conductor will "pick up" both of these fields.

If two electromagnetic fields of the same frequency and phase cut the direction-finding coil, the position of the coil for maximum or minimum signal strength will be determined by a single resultant of the two fields. If, for instance, one field is horizontal and the other wave is tilted so that it makes an angle of 60 degrees with the horizontal, then the direction-finding coil, under proper conditions, "points" somewhere between these two vectors the exact direction depending upon the relative strengths of the two fields. If the fields were of equal strength the resultant vector would lie equidistant between the two fields.

The elementary conditions prevailing in actual operation can best be illustrated by referring to Fig. 6. Here is pictured the plan view of a conductor of considerable length and small diameter placed so as to be in the field of the energizing coil. The direction-finding coil now has two fields linking it. At position *C* (note lower right-hand part of the figure) the component fields would exert the following effect; the energizing coil, being vertical, will tend to cause the direction-finding coil to give the loudest signal when it, too, is vertical as represented by the vertical vector. The field surrounding the conductor will tend to produce the loudest signal in the direction-finding coil at the angle shown by the vector pointing toward the conductor. The resultant effects of the primary and secondary fields are added vectorially, and the coil actually gives the loudest signal when in the position shown by the resultant vector. Moving the direction-finding coil to the position *F*, which is directly above the conductor, results in a vertical angle being obtained. At this point both the primary and the secondary fields will induce the loudest signal in the coil when it is vertical. As the coil is moved beyond the vertical position the direction of the dip angle changes, as shown by the vectors *G*, *H*, etc. Thus it can be seen that as a traverse is taken across a conductor through which an induced current is flowing, a series of dips will be obtained on the direction-finding system. For purposes of illustration, we will assume that a series of readings are being taken on a circular traverse across the surface of the ground above the conductor, as shown in the plan view. Beyond point *A*, the secondary field vectors due to the distance from the conductor are quite weak and not sufficiently strong to give a noticeable deflection to the angle of the direction-finding coil. The resultant direction for all practical purposes is vertical, or a zero dip. As the direction-finding coil is moved along the traverse toward the conductor the dip angle

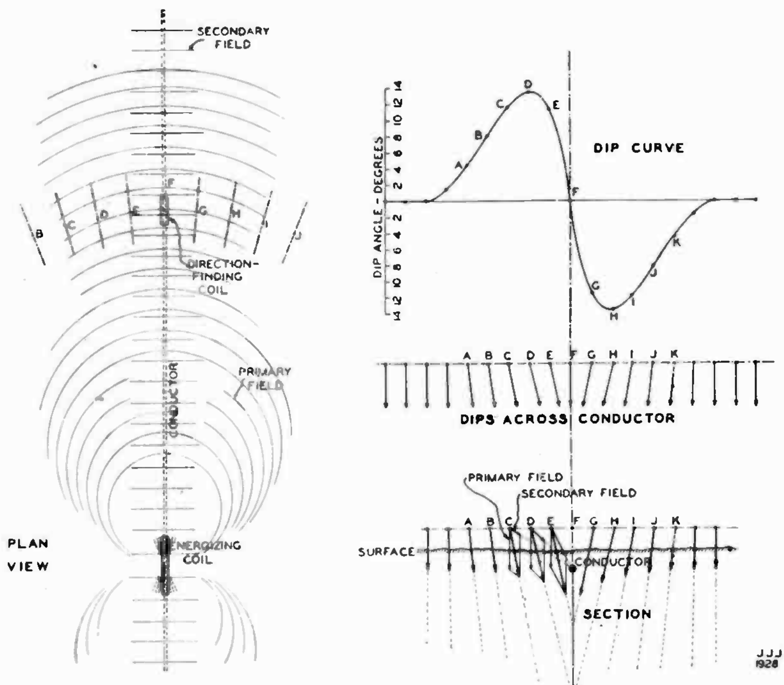


Fig. 6

becomes increasingly larger until a maximum dip is reached, after which it decreases until a zero dip angle is obtained when vertically over the conductor. As the readings are continued beyond a point over the conductor the same condition results, except that the dips are in the opposite direction. This is illustrated by the arrows in the diagram entitled "Dips Across Conductor." The Dip Curve shown plots the angles to scale.

In this illustration a circular traverse is shown, in order that the primary field may be constant and the change in resultant angle will be due only to variation in intensity of the secondary field and its change in angle. In practice, however, the traverses are taken along straight lines perpendicular to the conductor. The relative distance between energizing and direction-finding coils allows this to be done without any error within practical limits.

Effects of Phase Shift Between Primary and Secondary Fields

The effects of phase relationship between primary and secondary fields should be considered. If the primary and secondary

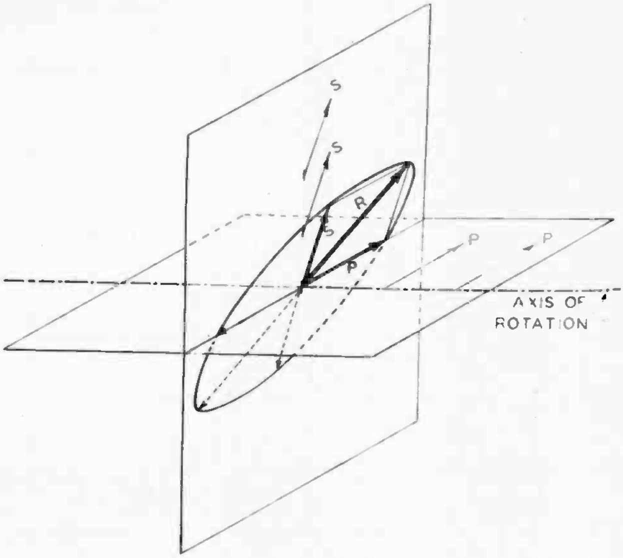


Fig. 7

fields both arrive at the receiver so that they reach their maximum or minimum values simultaneously, they are said to be in-phase. Under such conditions a definite resultant can be obtained for any given ratio of primary to secondary fields and sharp definite minimum readings will be obtained with the direction-finding loop. This can be illustrated by means of Fig. 7. The primary field is represented in magnitude and direction by the vectors P along the horizontal plane. The secondary field is likewise represented by vectors S, making, in this illustration, an angle of say 45 degrees with the horizontal plane. If the two fields are exactly in-phase their resultant will be the line R, and if a direction-finding coil is revolved about any axis of rotation lying in the horizontal plane and perpendicular to the vertical plane no signal would be heard in the head phones when the coil is perpendicular to line *R*.

A shift in the phase relation between primary and secondary fields is due largely to the following factors: average depth of the conductive body as compared to the distance between energizing and receiving equipment; distortion of wave front and difference in velocity of propagation between air (through which the primary field travels in reaching the receiver) and the earth (through which the energizing and the secondary field travels); transformer action whereby the current is induced in the conducting body; distribution of current in the conductor and the complex electromagnetic and electrostatic conditions existing in the vicinity of the energizing coil. When working at the higher frequencies, the phase relationship between the primary and secondary fields becomes of increasing importance. At higher frequencies the phase shift may be of sufficient magnitude to introduce a serious error in the indicated direction unless compensated for. Errors of 10 degrees or more due to phase relations may be encountered in field work[2].

Usually, however, the two fields are not in-phase and then their resultant will no longer be constant in direction and magnitude but will be of the type known as a radius-vector, the locus of which will be an ellipse lying somewhere within another ellipse passing through the extremities of the *P*, *S*, and *R* vectors. This resultant is a continually rotating vector and completes one revolution for each cycle of the alternating current. Under such a condition we find that an absolute zero signal can be obtained only when the direction-finding coil is parallel to this plane. In practice, the axis of rotation of the direction-finding coil is somewhat as shown in the figure and a zero signal cannot be obtained. Such an "out-of-phase" condition is readily recognized in practice by the operator. Out-of-phase conditions may be corrected for by numerous methods—including shifting the energizer frequency until the proper relationship is obtained at a point where readings are being made. Because of the comparatively long wavelengths used by the Radiore Company this method is by far preferable, and the energizing apparatus is so

[2] "Fundamental Factors Underlying Electrical Methods of Geophysical Prospecting," J. J. Jakosky. *Engineering and Mining Journal*, Feb. 11 and 18, 1928.

designed that proper phase relationships may be obtained merely by moving a multi-point switch.

Due to the operating characteristics of the average direction-finding equipment it is not necessary for the primary and secondary fields to be exactly in phase. It is necessary, however, that they be close enough in phase for their resultant radius-vector to be an ellipse having a major axis somewhat greater than the minor axis. The greater the difference between these two axes the sharper the reading, although an experienced operator will have no difficulty in obtaining readings of an accuracy sufficient for field operations when the ratio of major to minor axis is three or more. This ratio varies within wide limits, depending upon the strengths of the primary and secondary fields, depth of the ore-body, etc. This means that frequency of the energizer need not be shifted every time the two fields are not *exactly* in phase, but only when their resultant radius-vector does not have sufficient ellipticity for sharp readings.

If the primary field alone is present, a zero signal will be obtained when the direction-finding coil is parallel to the primary vector. Due to the fact that an infinite number of planes may be passed through a single line, inspection will show that when the primary field alone is present, the axis of rotation of the direction-finding coil may be placed in such a position as to give zero signal regardless of the position of the coil. This is one method of definitely determining the presence of a secondary field, and usually can be employed at the lower frequencies when the secondary field is too weak to allow readable dip angles being obtained.

Relationships Between Depth and Length of Ore-Body

When working over a conductor of considerable length and uniform depth the ratio of primary to secondary field varies with the distance between the direction-finding and the energizing apparatus. This is due mainly to the less attenuation of the induced current when travelling over the conductor, as compared to the attenuation of the primary field. Since a certain minimum relationship exists between field strengths of the primary and secondary fields and their relative propagation angles, at which a readable dip angle may be obtained, it can be seen that the deeper a conductive ore body exists, the longer must be its effective length for optimum operating conditions. Increasing the power of the energizing system in order to impart more energy to the current induced in the conductor will not materially change conditions inasmuch as the primary field is usually increased in proportion. The greater the power used for energizing the less sensitive may be the direction-finding apparatus. The trend in design of Radiore equipment is towards lower-powered energizing apparatus and more sensitive direction-finding apparatus. This results in greater overall portability of the equipment.

The depth at which an ore body may be detected and its characteristics determined by geophysical methods depends largely upon its shape and mass. A conductive body in the shape of a sphere is one of the most difficult types to work with by inductive methods. Such a body, however, would be most optimum when using the torsion balance or other gravitational methods. A long sheet or vein conductor having the same mass as the sphere would be almost ideal for the inductive process, while its detection might not be possible with the gravitational methods, especially if it existed at any depth.

Length of Ore-Bodies

The *electrical* length of a conductive ore-body varies with the type of mineralization and the frequency of the energizing current. If the body is a massive mineralized area containing no faulted zones or fractures filled with an electrically non-conducting material, the body will be electrically conductive to high- or low-frequency current and direct current. If, however, the body is fractured, broken, or faulted and replacements or depositions of calcite, lime, quartz, etc., have taken place in such a manner as to insulate various portions of the body, it will behave quite different electrically with currents of different frequencies. When using high frequencies the induced current will readily pass through these breaks due to the electrostatic capacity existing between the various parts of the body, as has been discussed in an early part of this paper. Low-frequency currents will suffer much greater impedance and considerable difficulty will be obtained in energizing such a broken body. It will thus be seen that the effective length of an ore body may vary with the frequency. The change in energizing frequency from low (1000 cycles) to high (50,000 cycles or more) will furnish considerable information as to the structure of the body and has been successfully applied in any number of cases.

It must not be assumed, however, that breaks or faults are not detected by using the high-frequency equipment. Such breaks are clearly indicated by reversal and shape of the index curve due to the change in ratio of primary and secondary fields, and the shift in phase relationship at the break or faulted zone. The phase relationship existing between various parts of a broken conducting body depend upon their relative length, the mutual inductance between those component bodies and the energizing system, the effective resistance of the separating medium and the operating frequency. At best, it is a complicated

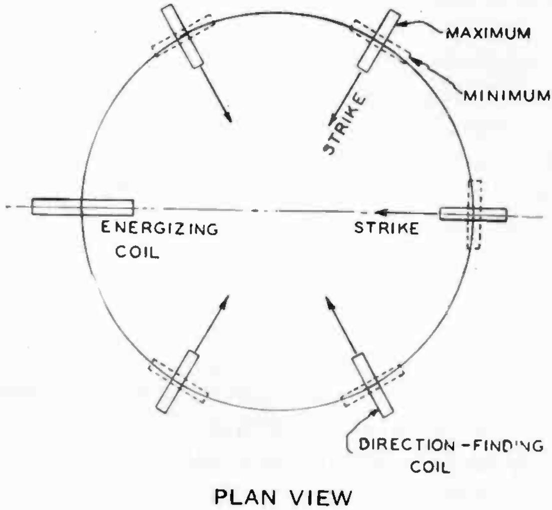


Fig. 8

relationship. Detailed studies have been made of numerous faulted or broken zones and absolute check obtained between the electrical readings and the geologic conditions.

Under such conditions the high-frequency equipment possesses another advantage in that one set-up of the energizer will usually be sufficient to read the entire body, while when using the low-frequency source of power it is usually necessary to move the energizing apparatus past each broken or faulted zone. This is of especial disadvantage when the conducting bodies are of short length as compared to depth, as difficulty is usually met with in detecting the presence of a secondary field in the region of the energizing coil where a strong primary field exists.

Strike Readings

The azimuth angle or direction of the direction-finding coil when in vertical plane, is called the "strike," and represents the resultant direction of the fields cutting the direction-finding coil with reference to a horizontal plane or plan projection. The relationships between the relative position of energizing coil and the direction-finding coil may be seen by referring to Fig. 8. It will be noticed that the strike of the direction-finding coil is

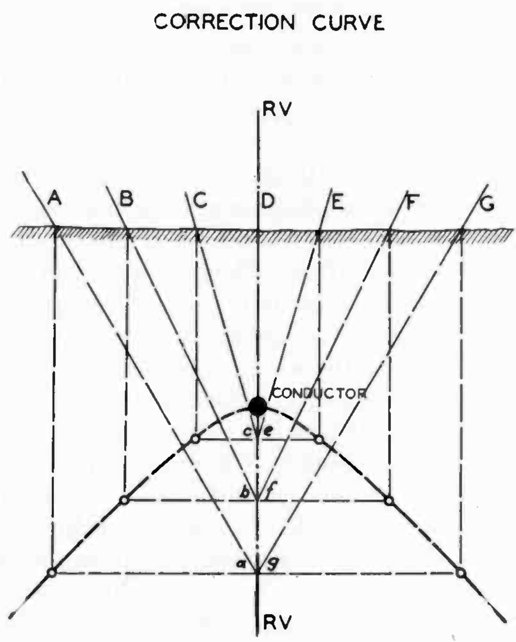


Fig. 9

toward the energizing coil *only* when it lies in the plane of the energizing coil. When the direction-finding coil is not in the plane of the energizing coil, the directions for strike are as indicated. This is one of the reasons why the energizer in Radiore practice is always "pointed" toward the direction-finding apparatus. When in this position, the receiving operator knows that any strike other than toward the energizing equipment is caused by some distorting influence which may be due to distortion of the primary field wave-front, as will be described in more detail later, or a secondary field created by an induced current flowing in a conductor underground.

When the energizer is placed in the vicinity of a conductive zone, the secondary field induced in such a zone will have a certain direction with reference to the primary field and cause a distortion in the apparent strike from where it would be normally, were that field not present. Strike and dip angles are two of the important electrical phenomena to be noted in a reconnaissance survey for the indication and resultant location of a conductive mass or zone.

Determining Depth of Conductor by Curve

A previous paper[2] described an empirical method of plotting to obtain the depth of a conductor. Briefly this consists essentially of the procedure illustrated in Fig. 9. Through each observation point on a given traverse lines are drawn making an angle with the vertical equal to the dip angle. Through the points of intersection of these lines with the vertical *RV* at which zero dips were obtained at the surface, lines are drawn parallel to the surface. Then perpendiculars are dropped from each observation point to its corresponding horizontal line. A smooth curve drawn through the intersections of these horizontals and verticals is the so-called correction curve. The apex of this curve is the position of the conductor.

Plotting the correction curve as described virtually amounts to assuming that the secondary field vector is horizontal and that the primary vector is vertical and that a definite relationship exists between the magnitude of these two vectors. In this position the secondary vector is between the upward angle produced by distortion of wave front (to be described later) and the downward angle caused by drawing a smooth curve which neglects the "tip" that normally belongs on the complete curve of the general type: $y = Ke^x + K'e^x$. The relative magnitudes of the primary and secondary field vectors is taken into account in actual practice by proper distance of operation between the energizing and direction-finding apparatus. This distance is dependent upon the energizing power used, approximate depth of ore-body, conductivity of overburden, and type of mineralization. This type of curve need not be considered as empirical, however, in location of the plan view of the conductor. The reversal or change in direction of the dips at a point immediately over the electrical axis of the conductor is indicated by the point of inflection of the curve, and is usually further checked by plotting the dip curves, etc. The curves are therefore an ex-

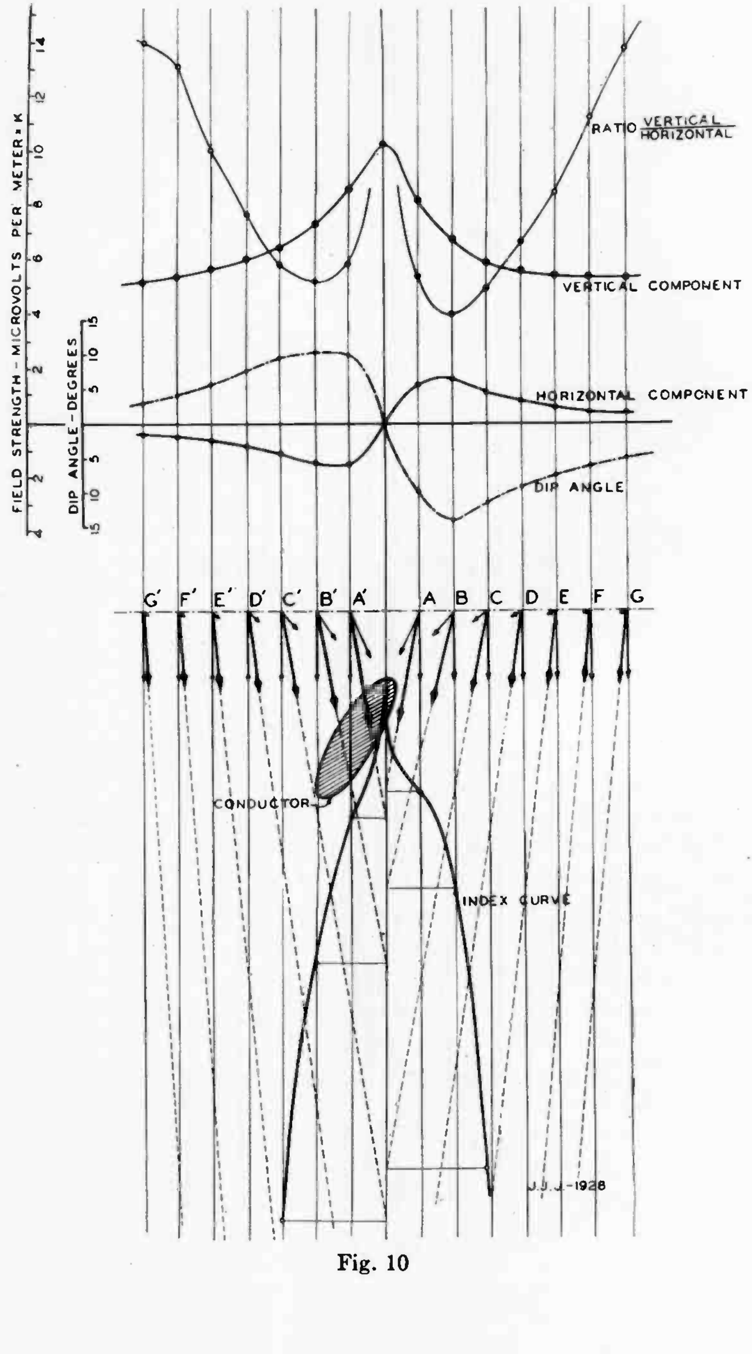
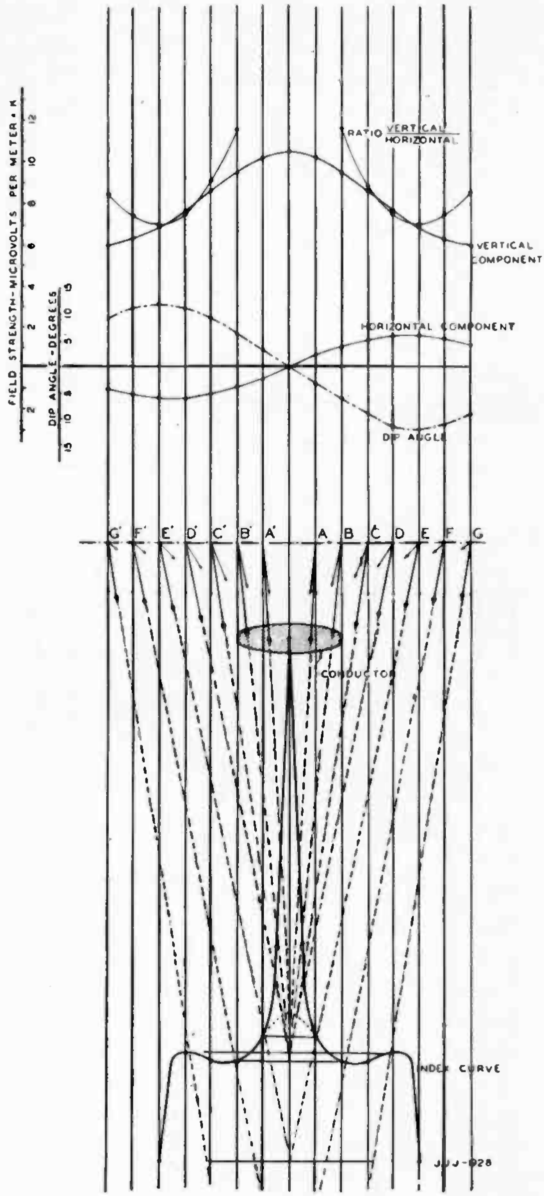

FIELD STRENGTH - MICROVOLTS PER METER = K
14
12
10
8
6
4
2
2
4
DIP ANGLE - DEGREES
15
10
5
5
10
15
RATIO VERTICAL / HORIZONTAL
VERTICAL COMPONENT
HORIZONTAL COMPONENT
DIP ANGLE
G' F' E' D' C' B' A' A B C D E F G
CONDUCTOR
INDEX CURVE
J.J.J.-1928

Fig. 10



RATIO VERTICAL / HORIZONTAL
VERTICAL COMPONENT
HORIZONTAL COMPONENT
DIP ANGLE
FIELD STRENGTH-MICROVOLTS PER METER • K
DIP ANGLE-DEGREES
G' F' E' D' C' B' A' A B C D E F G
CONDUCTOR
INDEX CURVE

Fig. 11

cellent graphic method for determining the plan view of the conductor, and allow the field operator to determine something of the nature of his conductor by the general shape of the curve, as well as to check any errors in field readings. By ascertaining the depth of the electrical axis of the conductor at different traverses, it is possible to draw a profile view of the entire conductor.

Study of Electrical Readings

Various methods may be used in studying the data obtained from an electrical survey. Graphical methods are more rapid and by their use considerable information can be gained of the nature and geometrical configuration of the conductive body. Curves characteristic of certain types of ore bodies have been analyzed mathematically and completely verified by field measurements and subsequent mining operations. The applications of such curves will be illustrated in a general way for three cases of using an elliptically-shaped conductive body, assuming even current distribution, no adjacent conductors, or wave distortion.

In Fig. 10 is shown the conductor "on edge," and traverse readings made at stations, A, B, C, A', B', C', etc. The index curve for this type of conductor is as shown. Above this are plotted the dip angles, the vertical and horizontal component of the vectors and the ratio of vertical to horizontal components. Note the general shape and symmetry of the curves.

In Fig. 11 is shown the same elliptical ore body having its major axis horizontal and with its geometrical center at the same distance below the surface as in the preceding illustration. A decided difference can be noted in the shape of the index curve, as well as the values of the other components.

In Fig. 12 is shown the same shape conductive body making an angle of approximately 30 degrees with the vertical. The unsymmetrical curves immediately show this condition, and also indicate the general direction of the dip of the ore body. Such a conductor will present an unsymmetrical electrical arrangement when readings are made at the surface of the ground and the strike and dip curves will be unsymmetrical in appearance. By proper interpretation of dip and strike curves it is possible to determine the angle of dip of a mineralized zone. Especially is this valuable in regions where overburden exists and the structural geology of the underground structure is not definitely

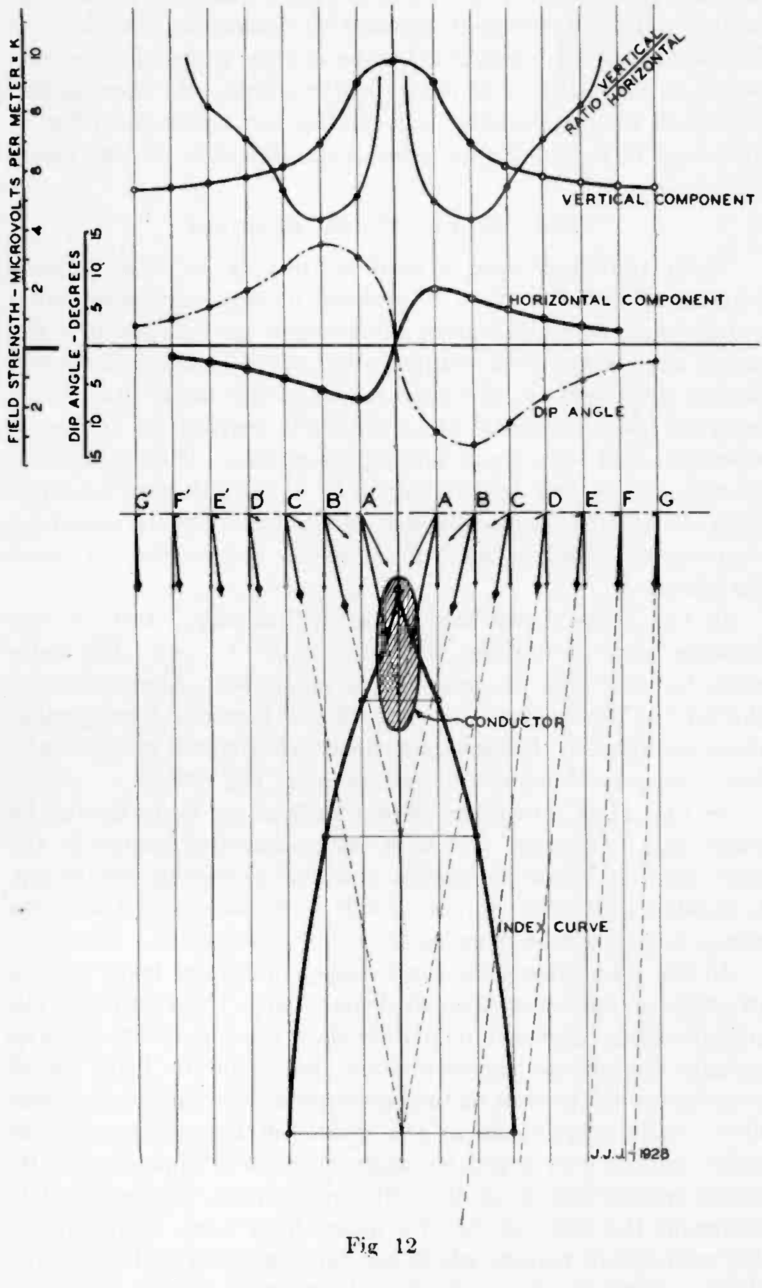

FIELD STRENGTH - MICROVOLTS PER METER ÷ K
DIP ANGLE - DEGREES
RATIO VERTICAL / HORIZONTAL
VERTICAL COMPONENT
HORIZONTAL COMPONENT
DIP ANGLE
G' F' E' D' C' B' A' A B C D E F G
CONDUCTOR
INDEX CURVE
J.J.J.-1928

Fig 12

known. In such instances it is quite impossible to plan the proper diamond drilling program without knowing the dip or at least the direction of the dip of a conductor. Inspection of the dip curve shown in the figure will indicate that the diamond drilling should be on the side of the conductor having the smallest dip angles. Actual field practice has proven that these theoretical curves check very well with the results of field practice, and that after drawing the index curves it is possible to predict the general shape and depth of the ore-body, well within reasonable mining tolerances.

Field Procedure During Detailed Survey

After the electrical conducting or mineralized areas of a property have been determined in the reconnaissance survey, a detailed survey is usually conducted to ascertain the depth of the electrical axis and the characteristics of the conducting zones. The energizing apparatus is set up over the conductor and the plane of the coil is placed in the general direction or strike of the conductor. Direction-finding coil readings are then made at various stations called *traverses* along the conducting zone or "indication," by the procedure described in connection with Figs. 6 and 9. Eight or ten readings are taken with the direction-finding coil at each traverse. The traverses are from 40 to 200 ft. apart, depending upon local conditions and the information desired. During each set-up of the direction-finding and energizing apparatus the operators must have the energizing coil vertical, the plane of the energizing coil passing through the center of the direction-finding coil, and the axis of rotation of the direction-finding coil passing through the axis of the energizing coil. Resultant strike and dip angles, distances between energizer and direction-finding coil, traverse and station numbers, topography, etc., are recorded. For certain work the power and operating frequencies are recorded in addition.

Completed Survey Map

A portion of a map of a typical electrical survey is illustrated in Fig. 13, showing data from a survey conducted in Inyo County, California. The "indication" in the plan view is tied in by the usual surveying methods to known property corners, bench marks, and other features, to allow later location of the indication should the electrical survey stakes be removed. In drawing the profile view of the conductor the depth of the conductor is obtained by plotting correction curves for traverses taken at intervals along the *indication.* By drawing a curve through the indicated depths at each of these traverses, the electrical axis of the conductor is located. The correction curves

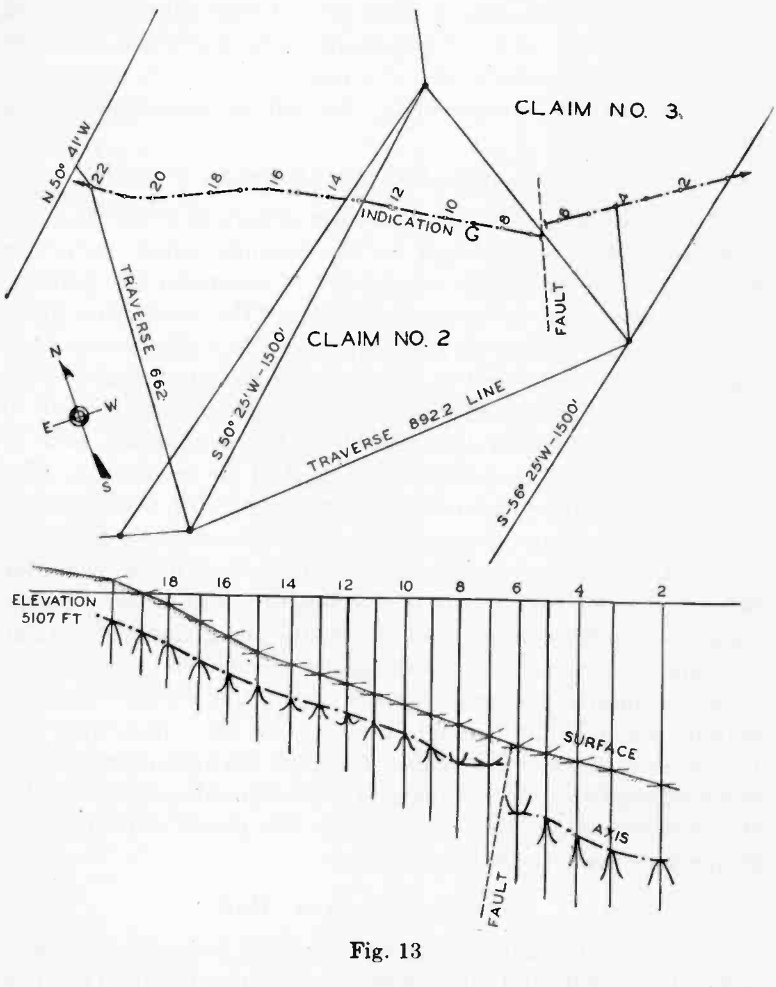


Fig. 13

for each traverse are shown in the figure. These curves as shown are drawn by imagining the traverses as being rotated 90 degrees to allow the curves to be plotted in the plane of the paper. Note the reversal of the index curves at the fault, and the displacement of the conductor.

Distortion of Secondary Field

In an ideal case the magnetic field surrounds the conductor and travels outward from it uniformly in all directions. Under such conditions the direction-finding coil can be used to locate by triangulation the position of the conductor where two or more different readings have been made. In actual practice, however, the wave front traveling outward from the conductive ore body is not a true circle, and the conductor cannot be located by the simple process previously described. The wave front is distorted because of the existence of three factors: irregular shape of the conductor, irregular current distribution in the conductor, and difference in velocity of propagation for the wave in penetrating different media.

As is well-known, the velocity of propagation of an electromagnetic wave varies with the character of the media through which the wave passes. Measurements made in various locations give values of the velocity of propagation in air to that through the earth from 1.5 to 4.5. In other words, the wave travels from 1.5 to 4.5 times as fast through the air as through the earth.

In Fig. 14 is plotted the wave front for conditions where a 4 to 1 velocity ratio exists. Assuming an ideal condition where the earth is homogeneous, with the secondary field alone present and the wave fronts as indicated, the position of the direction-finding coil for maximum signal strength will vary with the distance from the vertical position above the conductor; hence, it will be noted that the curve is not a circle after the wave emerges above the effective surface of the earth. When immediately above the ore-body the direction of maximum signal strength is downward, and toward the ore-body. A reading made at point B would give an intersection at point b. A reading at F will give an intersection at f, which is above the surface of the ground. It must be remembered, however, that the intersections obtained in practice when the conventional vertical energizing coil system is used are due to the resultant effects of the primary and secondary fields. The presence of the primary field usually causes the resultant intersections to be below the surface of the ground.

It will be noted that distortion of wave front tends to give an indicated depth less than that of the actual conductor. This factor has been considered in the working out of the empirical *correction curve* already described.

Distortion of Primary Field

The primary field from the transmitter is also subject to distortion. This distortion is, as before, due to the difference in velocity of propagation of the different media through and over which the wave travels before reaching the direction-finding coil.

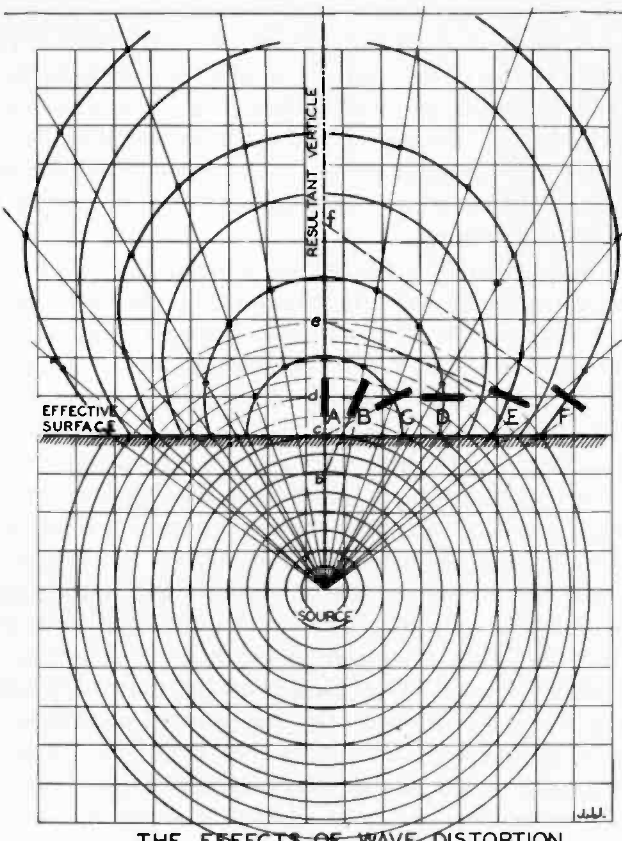


Fig. 14

The distortion of the wave front in using the small loop transmitter is much greater than usually encountered in radio work due to the low effective height of the radiating system. The distortion varies among other factors[3] with the topography and

[3] *Annalen der Physik*, Dr. F. Hack, 27, page 43; 1908.
"Principles of Wireless Telegraphy, G. W. Pierce, McGraw-Hill Book Co., page 122 to 127.
"Wireless Telegraphy," J. Zenneck, McGraw-Hill Book Co., page 246 to 262.

the height of the energizing coil above the surface of the earth. The distortion increases, however, with the frequency, but within the range of operating frequencies and the range in earth resistivities of the overburden encountered in practical geophysical applications, the increased distortion due to the employment of the higher frequencies has been found to be well within experimental error. The question of frequency will be discussed later.

Phantom Dips

Owing to the distortion of the primary field or improper alignment of energizing and receiving equipment, it often happens that a small (usually less than 20 deg.) "dip" or improper strike direction is obtained. These are called phantom dips or strikes and are readily recognized by the experienced operator. Such dips and strikes are often obtained when the energizer and direction-finding coils are located on a ridge, in a narrow valley or canyon, or at the edge of a deep cut or precipice. Usually the greater the distance between the energizer and the direction-finding coils, the greater is the wave-front distortion. This accounts for the Radiore practice of keeping a relatively short distance between energizing and direction-finding apparatus. Such a system, of course, requires many more "moves" or "set-ups" of the energizing equipment per day, but this was considered in making the energizing equipment quite portable and quick to set up.

Referring to Fig. 15 we have an illustration of distortion of a wave front due only to the fact that the energizer was placed "back" and a little to one side of a conductive hill. The heavy dot-and-dash line shows the position of the actual wave front. No secondary field is present. Note that the "strike" of the direction coil does not indicate the true direction of the energizer. The right-hand view (which looks from point C toward O) shows that the wave front is distorted vertically as well as horizontally. At that point a vertical distortion or phantom dip of 18 degrees is obtained, and a strike error of 27 degrees.

Effects of Overburden

At this point the question of relative conductivities and directional effects may be considered. In desert countries the highly resistant nature of the overburden makes the secondary field from the induced current flowing in the overburden negligible. Even in wet regions where the ratio of conductivity of ore to overburden may be only of the order of 100 to 1, the secondary field of the overburden will not mask that of the ore because of the large difference in conductivities. The currents flowing in the ore-body are so large compared to those in the overburden that the field due to the latter practically never masks that due to the former. It will readily be apparent that the field caused by the current in the ore-body will have a definite or well-defined axis while that from the currents in the

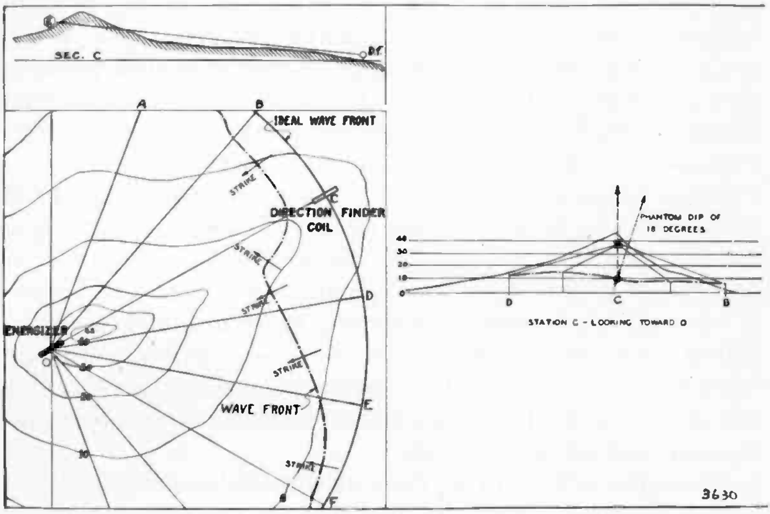


Fig. 15

overburden will not have such an axis. The result is definite indications of maxima and minima on the proper type of direction-finding apparatus for the ore-body field and no definite converging dips or "indications" for the overburden field. The field from the overburden tends of course to minimize that from the ore-body, and proper corrections must be applied for the depth calculations.

Effects of Frequency

The high-frequency geophysical methods described in this paper differ from the conventional inductive methods in that a comparatively high frequency is used, i.e., 30–50 kc. These frequencies were adopted after a series of tests to determine the best frequencies for the complex electrical and physical conditions met with in field practice. The various electrical geophysical methods depend for their success on the existence of a difference in electrical conductivity between the ore-body and the overburden. Granting that there is a difference in conductivity the problem is to cause a current to flow through the ore-body. Other things being equal a higher frequency means a higher induced emf not considering the decrease in magnetic intensity due to absorption of the magnetic field by the overburden. If the conductivity of the overburden is appreciable the question is whether the increase in the emf at a high frequency is more than compensated for by the decrease due to absorption. It must be remembered that absorption takes place at all frequencies both high and low. There is a balance between an increase in emf due to an increase in frequency as compared to a decrease in field strength with the increase in frequency.

Without going into a detailed mathematical discussion, it is possible to illustrate the effects of high frequency by means of a numerical example. Applying a theoretical absorption equation[4]:

$$H = H_0 e^{-2\sqrt{\frac{f}{\sigma}} Z}$$

where H is the magnetic intensity at any depth Z; H_O is the intensity at the surface, f is the frequency and σ is the specific resistance of the overburden. We find that there is an increase in the induced emf at the higher frequencies. For purposes of illustration consider an overburden having the comparatively low specific resistance of 10,000 ohms per centimeter[3] and for a depth of 100 feet (3048 cm). If we assume first a frequency of 10,000 cycles we find the intensity of the field at that depth is 52 per cent that at the surface. If we increase the frequency five-fold (to 50,000 cycles) we find that the intensity is 26 percent that at the surface. Thus increasing the frequency five times only doubles the absorption. If we introduce these facts into our equation $e = 2\pi MfI$ we find that e has increased 2.5 times. Now if we consider that the high frequency will also be

[4] Also see "Principles of Radio Communication," by John H. Morecroft, John Wiley and Sons, 1927, pages 146 and 844.

"Electricity and Magnetism," by J. H. Jeans, Chapter 15, pages 473-479; Cambridge University Press.

"Transient Electric Phenomena and Oscillations," by C. P. Steinmetz, Chapter 6, pages 361-374; McGraw-Hill Publishing Co.

effective in decreasing the impedance of the ore-body if it is disseminated, broken or faulted, it is seen that the induced emf in the conductor at high frequency is much greater than at a lower frequency. In dry regions the overburden is of a high resistance making absorption negligible so that high frequency is very effective in creating a strong secondary field. Skin effect, causing a redistribution of current with a resultant slight increase in the effective impedance of the conductor, is not of sufficient importance materially to affect the above calculations for average conditions.

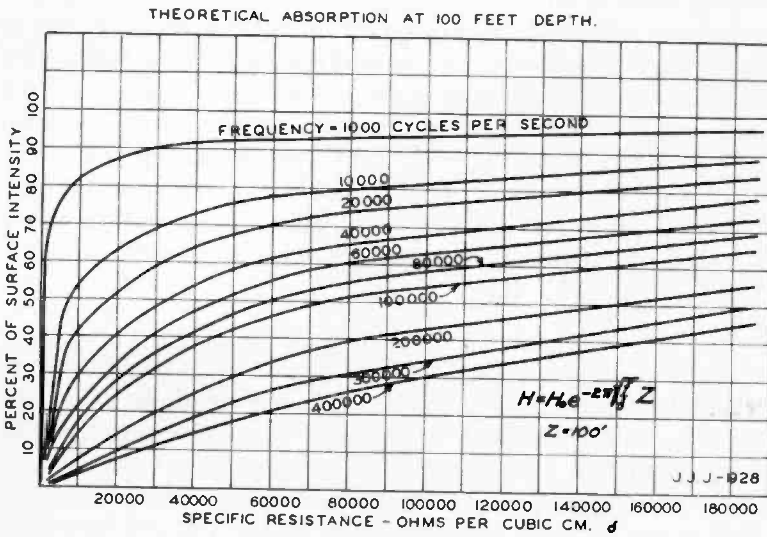


Fig. 16

The effects of the resistance of the earth on the absorption may be seen from Fig. 16. This curve shows the theoretical field strength for the ideal case after penetrating 100 feet of overburden, with reference to the field at the surface. It will be noted that the absorption is quite great when the specific resistivity is low. In ordinary geophysical work, however, the resistivity is high and the increased absorption at the higher frequencies is more than offset by the greater induced voltage.

Description of Energizing Apparatus

Two types of energizing systems are shown to illustrate the general principles. Fig. 17 shows a so-called "high-frequency" apparatus, operating at frequencies from 30 kc (30,000 cycles per second) to 50 kc. The wire or coil through which the high-frequency current flows is enclosed within the waterproof housing or "doughnut" *A*. The lower part of the loop case contains the frequency changing apparatus shown in the insert. This apparatus consists essentially of a high-frequency oscillator using two 7½-watt tri-electrode vacuum tubes *B* operating on each half of the 500-cycle supply. Proper plate and filament potentials are obtained from a transformer *C*. The entire equipment, in-

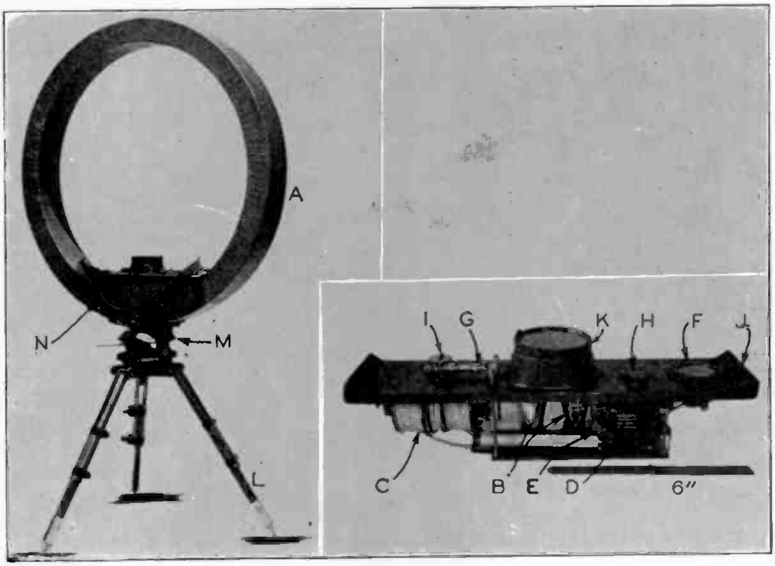


Fig. 17

cluding tube sockets, transformer, blocking and loading condensers *D*, grid resistor *E*, radio-frequency ammeter *F*, leveling bubbles *G*, frequency changing switch *H*, and marine connection plug *I*, etc., is mounted on an aluminum chassis or cover-plate *J* as shown. A glass-covered waterproof "port-hole" *K* is provided for observing operation or changing of the tubes.

The energizing apparatus is set on a tripod *L* having a graduated turntable and universal leveling attachment *M*.

In moving the apparatus from place to place a shoulder strap *N* (also see Fig. 18) is provided, and the tripod swings up alongside the coil. This allows the apparatus to be quite portable and minimizes the time required to make readings. The entire energizing apparatus weighs about 55 pounds and may be readily carried and handled by one man.

Fig. 19 shows a low-frequency coil. This coil consisting of a number of turns of rubber-insulated stranded wire is bound together into a single cable to facilitate handling. The flag shown is placed at the electrical center of the coil and is used for proper alignment of the direction-finding coils.

Fig. 18

Power supply for both the high- and low-frequency systems is obtained from a specially designed 600-cycle 150-watt hand-cranked alternator, a disassembled view of which is shown in Fig. 20. Two handles for cranking are provided, and connected to a sprocket chain and gear drive on the alternator. The alternator turns over at a speed of 4000 r.p.m. Ball bearings are provided throughout and the outfit cranks easily for the generation of the necessary power. Approximately 50 watts is required for the high-frequency apparatus and 150 watts for the low-frequency loop. Field excitation is supplied by three

No. 6 dry cells in series with an automatic switching arrangement which closes the circuit while the cranks are being turned. A flywheel is placed on each side of the rotor of the alternator, the whole rotating assembly being enclosed in an aluminum dust-proof housing. A waterproof steel case, provided with carrying straps and tump-line, encloses the entire unit. This outfit, complete with batteries, connection cords, a.c. and d.c. indicating meters, etc., weighs approximately 60 pounds.

In actual field operation the outfit of course is cranked only while a reading is being made with the direction-finding coil. About 5 seconds time is required to make a reading by an average experienced operator.

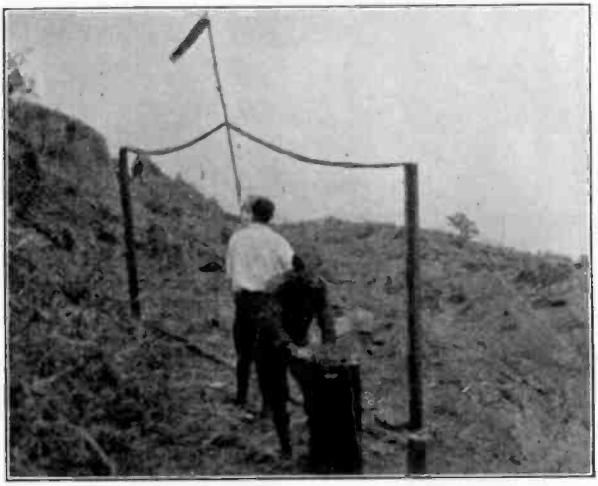


Fig. 19

Direction-Finding Apparatus

The most recent direction-finding apparatus developed is illustrated in Fig. 21 showing the high-frequency and low-frequency equipment. The mounting head *A* on which the direction-finding coils are mounted is provided with a slighting arrangement *B* (similar to gun peepsights), whereby the axis of rotation *C* of the coil may be aligned quickly with the center of the energizing coil. A graduated vertical arc *D* is attached to the pivoted plate *E* holding the direction-finding coil. The vertical angle index mark and level bubble arc are attached to the movable arm adjusted by thumb screw.

The head is rotatable on a vertical axis and azimuth angles may be read on a scale H. The entire assembly is mounted on a ball and socket plate to permit rapid set-up in rough territory.

The same mounting head and set-box are used for both low- and high-frequency work; it is only necessary to fasten the proper direction-finding coil on the rotatable plate with two thumb screws. A 600-cycle coil is shown in the center view of Fig. 21, and a 30- to 50-kc coil in the righ-hand view.

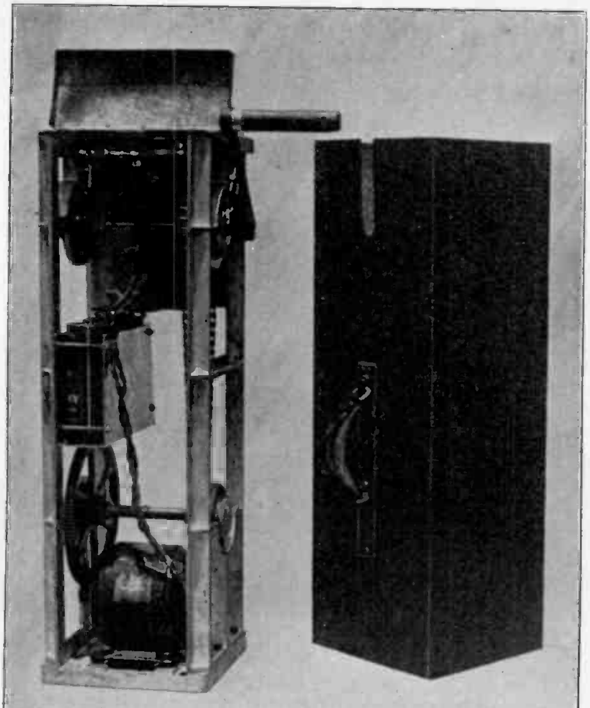


Fig. 20

The direction-finding coil is electrically connected to the vacuum-tube set box containing a detector (so arranged that it functions as an audio-frequency amplifying stage when using the low-frequency coils) and a two-stage peaked transformer-coupled audio-frequency amplifier. The entire apparatus, (including the heterodyne control dial, compensating controls, and batteries) is contained in a waterproof aluminum box $4\frac{1}{2}$ in.$\times$ $4\frac{1}{2}$ in$\times$17 in. (See Fig. 22.) A double range voltmeter is placed

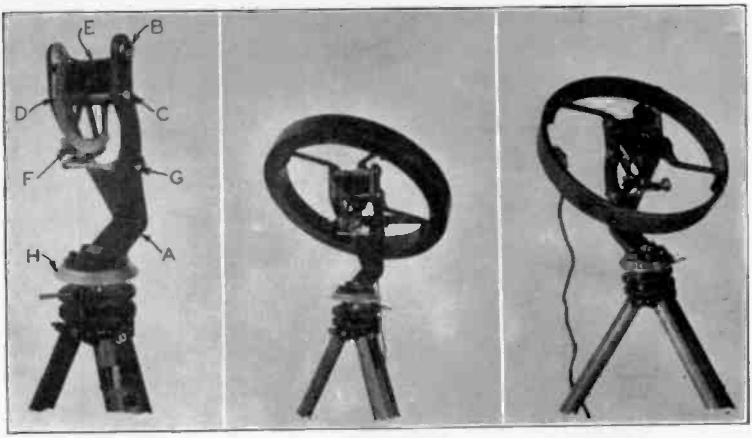


Fig. 21

underneath a waterproof "port-hole" by means of which filament and plate voltages may be read. As will be noted, the control knobs are placed on a recessed panel, for protection against mechanical injury.

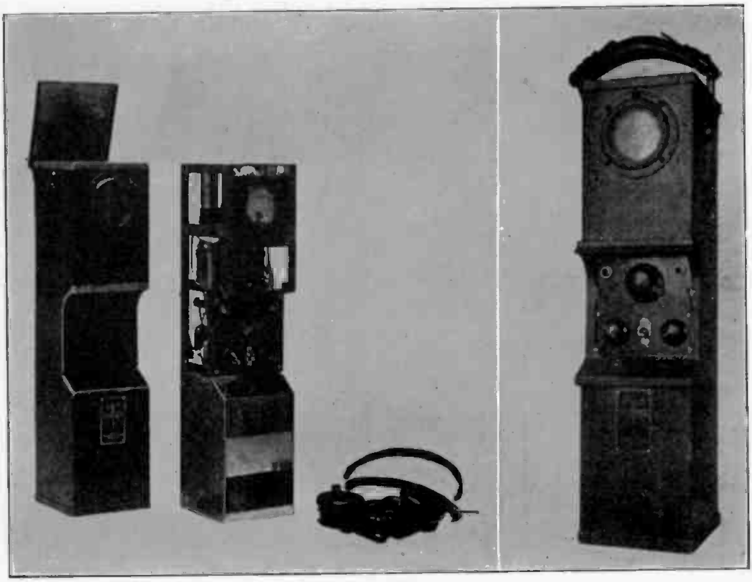


Fig. 22

The conventional type of head-phones is provided so the operator may read the point of minimum signal strength when determining direction of the resultant wave.

The design of the set is such as to minimize tube noises due to mechanical vibration of the box or wind. Tubes are of the UX-199 type, and may be changed by raising the cover of the

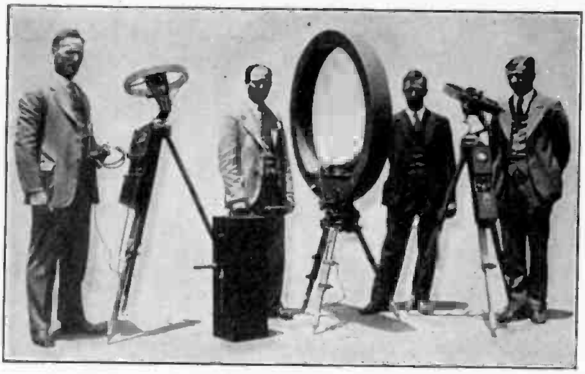


Fig. 23

box. Batteries are changed by lifting the entire chassis from the box. This also affords ready inspection and testing of the outfit. Every effort has been made to make the apparatus and all

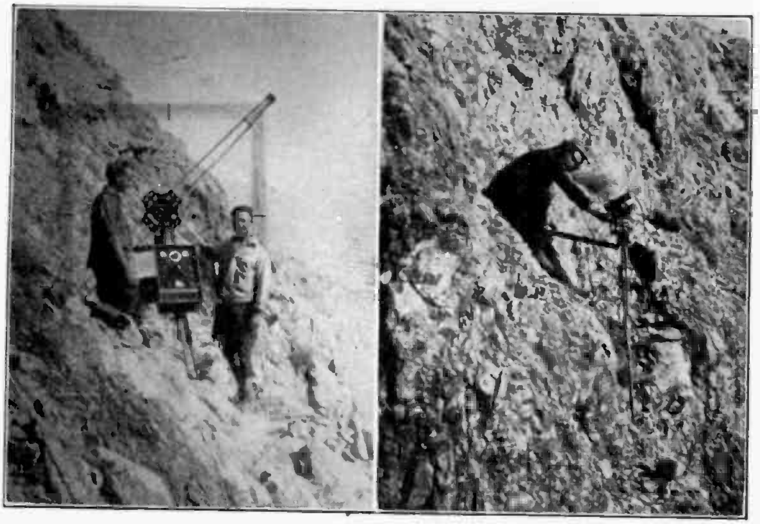


Fig. 24

associated equipment waterproof, which is especially necessary in swampy country, or when operating in the morning in areas where dews are heavy.

A view of the complete apparatus is shown in Fig. 23. Two direction-finding outfits are usually worked with each energizer. The energizer operator alternately aligns his coil while the reading is being made with first one outfit and then the other.

Field Operating Conditions

The design of the equipment is such as to allow maximum flexibility, and to be of efficient use under the various climatic conditions encountered in field practice.

Fig. 25

In Fig. 24 is shown one type of equipment in use on the Minnietta Property of the Modoc Mining District in California. This is within a few miles of Death Valley and is quite a rugged country. The other climatic extreme is encountered in the work in the province of Quebec, Canada. The field crews operate through the winter and snowshoes are used for both men and apparatus tripods. The tripod shoes consist of cast aluminum plates 6 in. × 8 in., fastened to the tripod leg about 6 in. above the tip, Fig. 25.

Operation in swampy country or lakes is not uncommon as many mineralized areas exist in such territories. Fig. 26 was taken during a recent survey over a swamp in Southern Canada.

Personnel of Crews

The field crews usually consist of four men; a mining engineer, a geologist, an electrical engineer or trained radio technician, and a field assistant. As a rule all of these men are technical graduates.

Interpretation of Field Data

One of the most important steps in geophysical prospecting is the proper interpretation of the field notes. The fundamentals of geophysical prospecting are well-known and all relation-

Fig. 26

ships for ideal conditions may be theoretically expressed by mathematical formulas. The proper interpretation of data, however, contains many empirical steps or operations and can only be done in the light of experience. At first glance it may seem inconsistent that the interpretation of data contains many empirical steps when the fundamentals are definitely known. This is due to the fact that conditions existing underground are quite complex. Take for instance only one of the many factors to be considered; the occurrence of ore. If conductive ore-bodies occurred in uniform diameter straight cylinders and in a homogeneous medium, the problems of depth, etc., would be relatively simple. Actually, however, mineralization occurs in anything but uniform shapes. A mineralized zone may be quite large in one place (ore shoot) and then diminish to a very small cross-section (stringer, pinch-out) at another place. Numerous connecting zones (fingers, shoots) branch out from the main body, each of which will conduct a certain amount of current with its resultant secondary field. Ore-bodies also occur at irregular angles or dips, and may be in thin sheets or veins. When it is recalled that *any* geophysical instrument operates on the combined *resultant* of all of these component forces, and that the nearest component has the greatest effect on the instrument, it can be readily seen how complex the correct interpretation of data may become from the one viewpoint of ore occurrence alone. To this may be added the topographic disturbances, variations in conductivity, tilting strata, and distortions to the primary and secondary fields, etc. Proper interpretation of geophysical data requires that due consideration be given the electrical, geological and tectonic, and mining data on each particular property.

Previous publications[5] have described the results obtained. Only a few types of survey data will be given in this paper to illustrate some interesting points regarding the application of the inductive process to geophysical exploration.

Exploration May Be Profitably Preceded by Geophysical Examination

Although it is well-recognized that geophysical methods alone are not a direct means of locating commercially valuable ore-bodies, such methods are of real economic value in outlining the development program of a property and securing information of value to the geologist regarding structural features and the location of the conductive mineralization. One valuable feature of the electrical methods usually is their ability to eliminate barren areas and to furnish information which the geologist and mining engineer may use to determine the most probable mineralized areas likely to contain commercially valuable

[5] "The Radiore Method," E. H. Guilford, The Canadian Mining and and Metallurgical Bulletin, May 1928, pages 644 to 670.

"Fundamental Factors Underlying Electrical Methods of Geophysical Prospecting," J. J. Jakosky, *Engineering and Mining Journal*, Feb. 11 and 18, 1928.

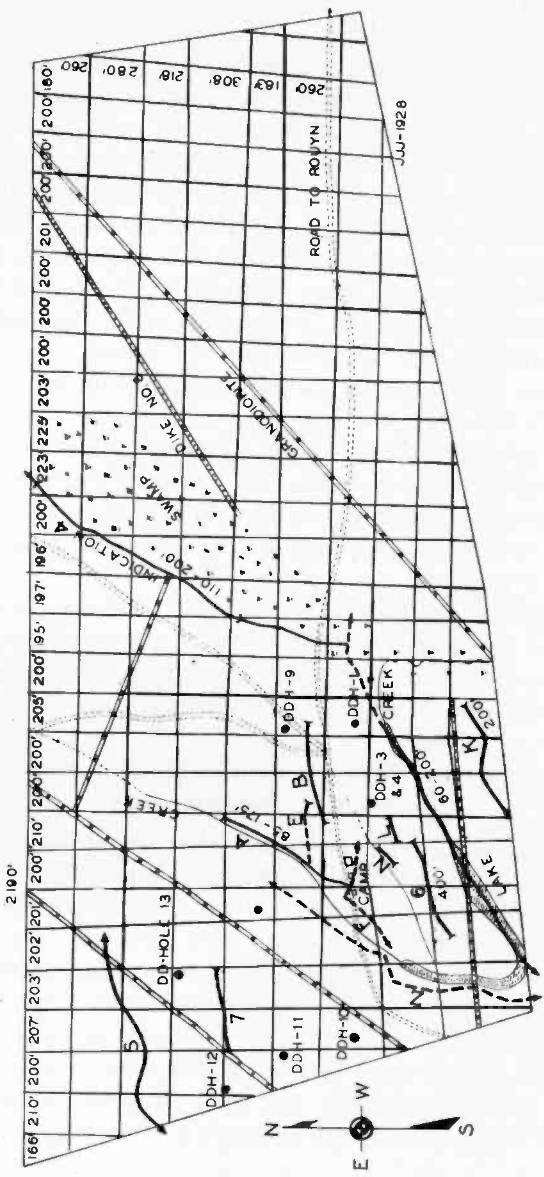

ROAD TO ROUYN
JJJ-1928
GRANODIORITE
SWAMP
INDICATION
CREEK
LAKE
CAMP
DD-HOLE 13
DDH-9
DDH-11
DDH-12
DDH-3 & 4

Fig. 27

ore deposits. This may be illustrated by the exploration conducted by a Canadian Company in the Rouyn District.[6] This company had previously explored the region by a system of diamond-drilling, as shown in Fig. 27. The drill-cores gave some promise of mineralized zones to substantiate what

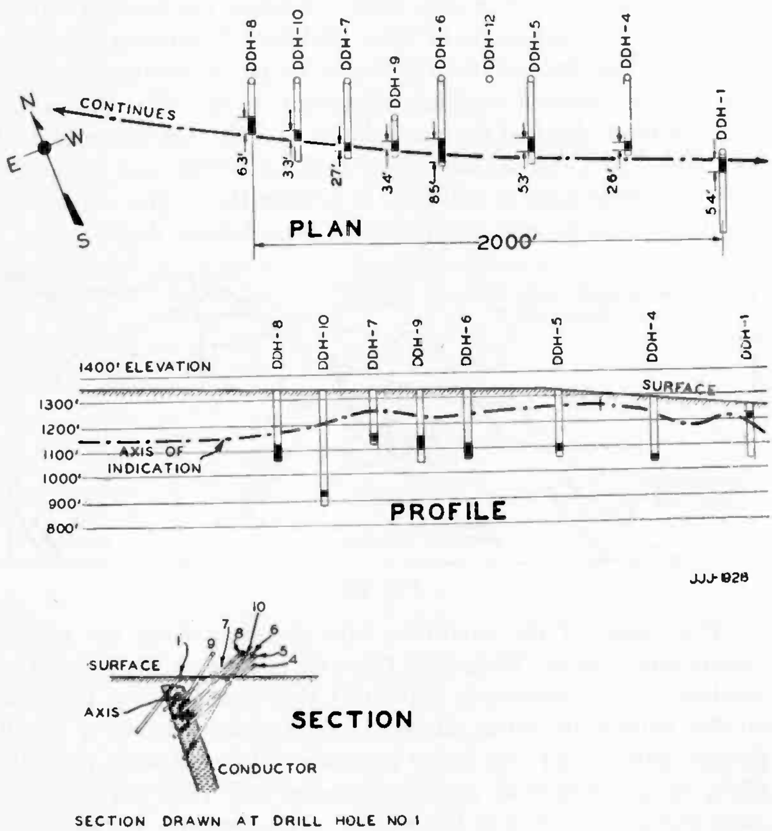


Fig. 28

little surface geology could be studied through the overburden typical of that district. This same property was later surveyed and the indications obtained, as shown on the map. It is safe to predict that had the electrical survey been conducted as one of the initial steps in the development of the property, the dia-

[6] Data from E. H. Guilford, of the Radiore Company of Canada, Limited.

mond-drilling could have been used in proving-up the indications and determining their value. Subsequent diamond-drilling on the indications has shown good mineralized zones.

Continuity of Mineralized Zones

An interesting example[6] of the continuity of a mineralized zone may be seen in Fig. 28. This *indication* was located during a survey of a property in Des Meloizes Township, Quebec, Canada. The indication was found to be of proper electrical character to warrant further exploration work. This indication has now been checked over a distance of 2000 feet between drill hole No. 1 and No. 8, and every drill hole with one exception has cut a wide zone of sulphide mineralization. The conductor is a dipping sheet vein and possesses considerable depth.

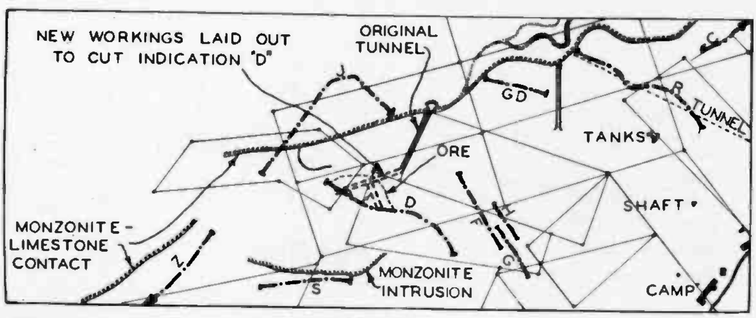


Fig. 29

The "axis" of the conductor was determined by use of the "correction" curve. Note that this axis is close to the top of the conductor. As previously explained this is due to the portions of the conductor lying close to the surface having a much greater effect than the lower portions. As a general rule the effect of a differential conductive area will vary inversely as some power greater than the square of the distance to the direction-finding coil. An end view of the conductor and the drill holes are show. The mineralized portions of the drill hole are shown by solid black.

Special Case Where Surface Geology Could Not Give Information

An illustration[7] of where surface geology failed to give any hint of a possible mineralized zone is illustrated by an indication

[7] Data supplied by H. E. Olund, Geologist, The Radiore Co. of U. S.

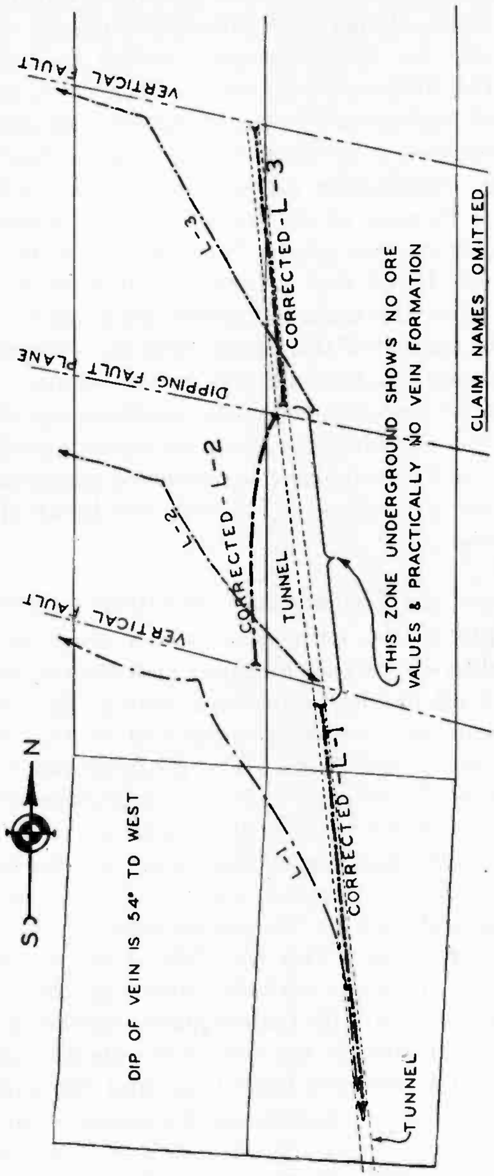

VERTICAL FAULT
L-3
CORRECTED - L-3
DIPPING FAULT PLANE
THIS ZONE UNDERGROUND SHOWS NO ORE VALUES & PRACTICALLY NO VEIN FORMATION
CLAIM NAMES OMITTED
L-2
CORRECTED - L-2
TUNNEL
VERTICAL FAULT
S
N
DIP OF VEIN IS 54° TO WEST
L-1
CORRECTED - L-1
TUNNEL

Fig. 30

located on an Inyo County, California, property, Fig. 29. This is a lead-silver district which has been mined intermittently since 1865. Experience from previous ore occurrences showed that the ore values always occurred in the limestone adjacent to the limestone-monzonite contact. A major conductor (named Indication D) was located during the electrical survey, but because of its distance from the contact as shown in the surface, considerable doubt existed as to its being of a special value. Because of its proper electrical characteristics, however, a cross-cut was driven, from the tunnel to Indication D, where it was found that a tongue of monzonite (probably an off-shoot from the main monzonite intrusion to the north) existed and the contact of this tongue with the surrounding lime had created conditions favorable for ore deposition. The high-grade oxidized ore associated with the sulphides was of excellent value, carrying approximately 21 ounces silver, and 33 per cent lead. The conducting sulphide zone consisted of galena, sphalerite, chalcopyrite and pyrite and is over one hundred and fifty feet in thickness.

Corrections for Topography and Dipping Conductor

An example of the corrections which must be made for topography when working over dipping vein conductors is shown in Fig. 30 of a preliminary map taken from a Mexican Survey. The locations of the *indications* projected to the surface are shown by the heavy dotted lines. This property has been opened up by underground workings under the indications L1 and L3. No ore was encountered in the drift through one of these faulted blocks, and the electrical survey has shown the displacement of the vein in this block. Attention may be called to the apparent existence of a conductor on the continuation of the indication parallel with each fault. This probably is due to the faulted zone containing conductive material caused by the "drag" and wet clay gauge. The dip of the faulted plane, together with the dip of the vein of 54 degrees to the west, accounts for the displacement between the electrical indications and the surface fault projections. The conductive zones in this property are from 400 to 700 feet in depth. A diamond drill hole was driven from the tunnel to intercept the indication L2 and to establish identity with L1 and L3, but after penetrating about 30 feet encountered such a badly broken zone that further drilling was impossible. A crosscut will now be driven.

ACKNOWLEDGMENTS

The writer desires to acknowledge the material assistance and cooperation received from his associates of the Radiore Company, particularly to Messrs. A. B. Menefee, H. E. Olund, E. H. Guilford, M. Brenner, H. O. Walker, and R. N. Anderson. Especial acknowledgment is also made to Dr. D. A. Lyon and Mr. H. E. Head, of the Department of Metallurgical Research of the University of Utah, for assistance and help in the cooperative studies now being conducted on the electrical properties of various ores, etc.

Volume 16, Number 10 *October, 1928*

SOME STUDIES OF RADIO BROADCAST COVERAGE IN THE MIDDLE WEST*

BY

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(Associate Professor, University of Minnesota, Minneapolis, Minnesota)

Summary—*Studies of the radio field intensities produced by broadcasting stations throughout the states of North and South Dakota and Minnesota have been made. From these studies and from information concerning the service rendered standards of service based upon field intensities have been suggested for daylight broadcasting in rural communities.*

Data concerning the distribution of radio sets throughout the three states in question have been gathered and ratios showing the percentage of families owning radio receiving sets have been calculated. The lack of correlation between this percentage and the availability of daylight broadcast service has been pointed out together with the fact that a large majority of radio listeners must rely entirely upon night-time reception from relatively distant stations. Some of the factors affecting reception from distant stations are mentioned. The apparent correlation between rapidity of fading and distance to the transmitting set is illustrated by fading curves.

QUANTITATIVE study of the electric field intensities produced by the radio broadcasting stations throughout a given territory yields valuable information, first, concerning the service areas of the stations studied and, second, the interference conditions which will be encountered in the use of receiving sets possessing given selectivity characteristics when subjected to known radio fields from two or more stations operating upon specific frequency assignments. This paper presents in part the results of certain studies made throughout Minnesota and adjacent states during the past two years with the view of determining some of the conditions affecting the service range of radio broadcasting stations located in the middle west.

The electric disturbances at a given receiving location which will cause sounds to be emitted from the loudspeaker of a radio receiving set will, for the purposes of discussion, be classified as follows, (1) a modulated signal such as would be produced by the operation of one broadcasting station, provided no other broadcasting station were in operation on a carrier frequency near enough to cause interference; (2) atmospheric disturbances; (3) interfering disturbances, produced by the operation of non-radio electrical devices and systems by man; (4) interfering disturbances produced by radio stations other than the one from which reception is desired.

* Original Manuscript Received by the Institute, July 3, 1928.

The sensitivity of the great majority of radio receiving sets in use throughout the territory under consideration is such that it is not the actual value of the electric intensity produced by a radio broadcasting station which is of importance, but the ratio of that intensity to the intensity of interfering disturbances. If the ratio of the desired signal intensity to the intensity of the

Fig. 1—Daylight Distribution of Radio Field from WCCO, 720 kc, 5000 watts.

maximum interfering disturbance is sufficiently high and the sensitivity of the receiving set is sufficiently great, then satisfactory reception can be obtained by amplifying the signal to the desired volume. If this ratio is not sufficiently high, then satisfactory reception cannot be obtained. It is, of course, true that the permissible value which this ratio can possess will depend to a certain extent upon the type of receiving set in use, type of signal collector, nature of interference, nature of program, etc., but these factors are of relatively small importance in comparison with some of the others involved.

The determination of the service area of a radio broadcasting station on the basis of the electric intensities produced throughout the territory under consideration involves, among other things, the establishment of a ratio of field intensity to static and interfering intensities which may be considered as determining the

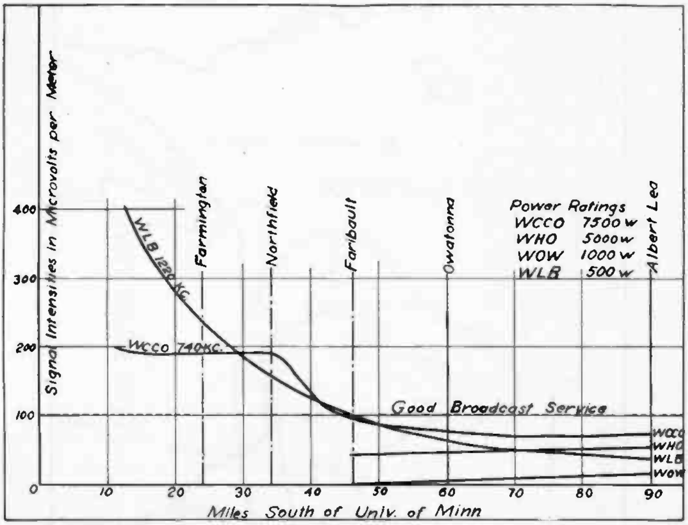

Fig. 2—Daylight Intensities Produced South of Twin Cities Along Minnesota Trunk Highway No. 1 by Radio Stations WLB (University of Minnesota), WCCO (Anoka), WHO (Des Moines), WOW (Omaha).

border line between satisfactory and unsatisfactory reception. It is also necessary to establish a standard of reliability which can be considered satisfactory. In the studies under discussion, these questions were not considered separately, but an attempt was made to set up daylight service standards by means of numerous observations utilizing a signal intensity measuring set throughout the area involved. Since fading and other peculiar transmission phenomena are of great importance in determining the night time range of stations, separate consideration must be given to night time conditions. These will be considered later.

Both summer and winter daytime observations seem to substantiate the statement that, where rural or small town areas in the State of Minnesota are receiving daylight field intensities of the order of 100 microvolts per meter, the radio listeners inhabiting those areas feel that they are receiving *good broadcast service.* Where the field intensities produced are approximately 50 microvolts per meter, listeners feel that they are receiving *fair broadcast service.*

The author realizes that standards of service based upon field intensities as low as these are far from ideal and, in fact, far lower than those which must be established for thickly

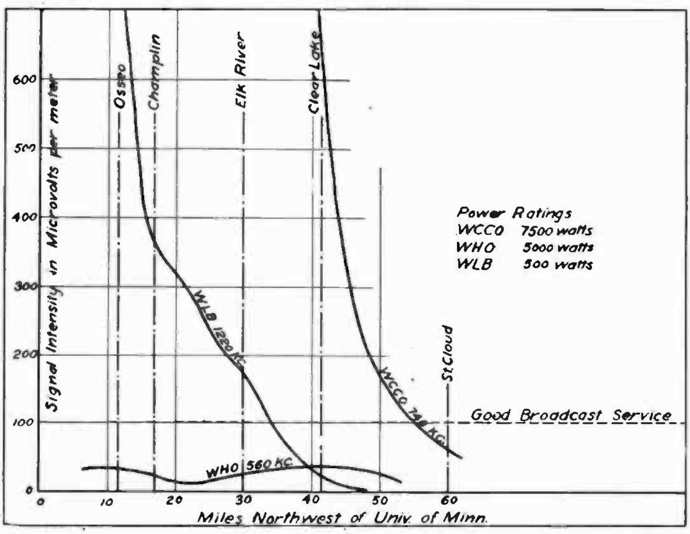

Fig. 3—Daylight Signal Intensities Produced Northwest of Twin Cities Along Minnesota Trunk Highway No. 3 by Radio Stations WLB (University of Minnesota), WCCO (Anoka), WHO (Des Moines)

populated districts where interference from non-radio devices and other factors offer more serious limitations[1,2]. However, unless we are willing to accept a standard of this order of magnitude for rural districts, we must somehow explain the almost every-day use of thousands of sets for daylight reception in localities which, on the basis of service standards higher than the one proposed, are receiving no broadcast service at all. Nevertheless, the owners of these sets are found to be reasonably well satisfied with the daylight service they are receiving when it is

[1] "Reduction of Interference in Broadcast Reception," by Alfred N. Goldsmith, Proc. I.R.E., 14, 575; October, 1926.

[2] "Radio Broadcast Coverage of City Areas" by Lloyd Espenshied, *Journal* A.I.E.E., 46, No. 1; January, 1927.

supplied by signal intensities which equal or exceed that which has been proposed as a standard for "good broadcast service."

Fig. 1 shows the location of the 100- and the 50-microvolt-per-meter lines for WCCO, a 5000-watt station, as approximately determined by numerous observations made during the summer of 1926. Figs. 2 and 3 show daylight field intensities along lines running south and northwest, respectively, produced by WCCO and WLB (a 500-watt station operated by the University of Minnesota) during the fall and winter of 1927. Faribault and Albert Lea, which lie south of the Twin Cities, and St. Cloud, which is northwest, can be located on Fig. 1. In comparing field intensities produced south with those produced northwest it must be remembered that WCCO is located 20 miles north of the Twin Cities while WLB is located in the City of Minneapolis near the boundary line which separates that city from St. Paul.

Carefully prepared estimates place the number of radio receiving sets in Minnesota, North and South Dakota, February 1 1928 at 330,895. Of this number 116,425, or 38 per cent, are actually located on farms. 208,156, or approximately 62 per cent, are either on farms or in towns of less than 2500 population. (Residents of towns of less than 2500 population are considered as rural dwellers by the United States Census Bureau.)

Fig. 4 shows the distribution of receiving sets by counties in the three states under consideration. The upper figure in each county designates the number of sets on farms or in towns of less than 2500 population (sets owned by rural dwellers). The lower figure designates the number of sets owned by urban dwellers[3]. A study of Figs. 1 and 4 will show that of the 330,895 sets in the three states, only about 90,610 or 28 per cent lie within the "good" daylight broadcast service range of WCCO as defined earlier in this paper. Of this 90,610 only 23,810 or 27 per cent lie outside the Twin City Metropolitan district. For stations of lower power than 5000 watts, located in or near the Twin Cities, the percentage of sets served outside the metropolitan district will, of course, be still smaller.

Consideration of all of the broadcasting stations in or near the three states of Minnesota, North and South Dakota will show that, of the 330,895 sets, not more than 130,000 or 40 per

[3] The data on the distribution of radio receiving sets in Minnesota, North or South Dakota contained in this paper were collected by J. O. Maland, of the *Dakota Farmer*, President of the Northwest Radio Trade Association.

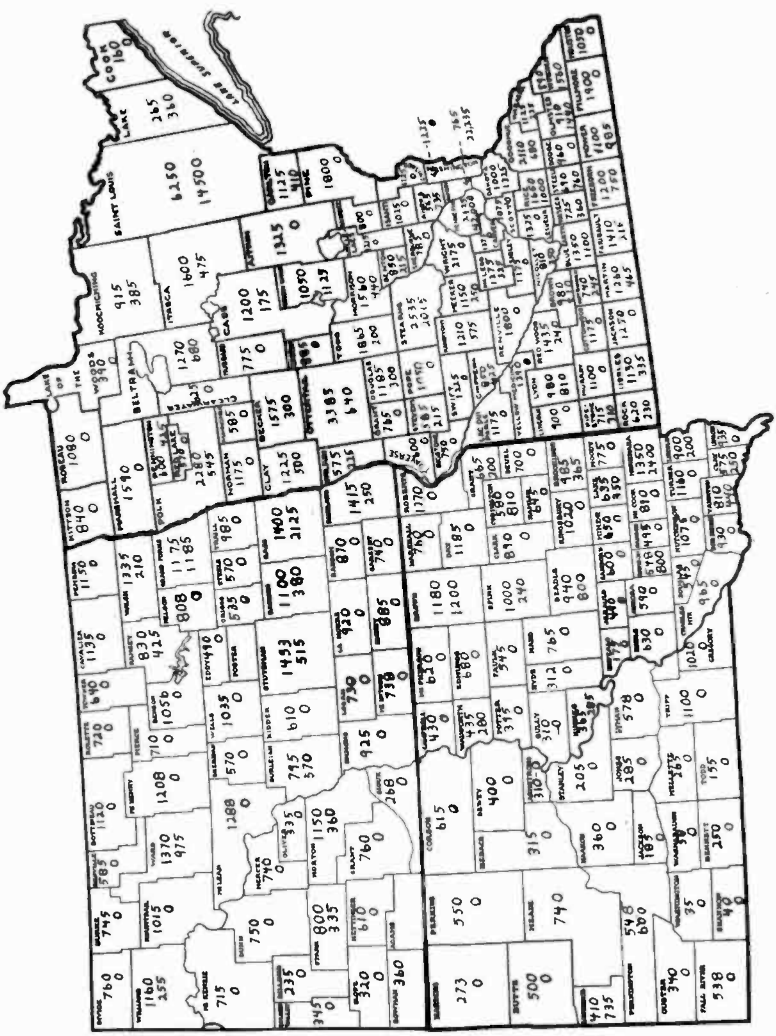

Fig. 4—Number of Radio Receiving Sets in Minnesota, North and South Dakota February 1, 1928. (Upper Figure—Sets Owned by Rural Listeners; Lower Figure—Sets Owned by Urban Listeners).

	Rural	Urban	Total
Minnesota	104,665	105,195	209,860
North Dakota	51,454	7,585	59,039
South Dakota	52,037	9,955	61,992
Total	208,156	122,735	330,891

cent lie within the "good" daylight broadcast service range of *any* station, even on the basis of as low a standard as 100 microvolts per meter. 200,000 or 60 per cent are on the basis of this low standard, getting no daylight broadcast service at all.

If the number of families and the number of receiving sets in a given community are known, then the ratio of the number of sets to the number of families, expressed in per cent, might be called the receiving set saturation factor for that community. Fig. 5 shows this saturation factor by counties for Minnesota, and North and South Dakota as obtained from Fig. 4 and from population figures for the various counties, assuming four people per family. As before, the upper figure refers to the rural population and the lower figure to the urban population.

It is evident from Fig. 5 that no apparent relationship exists between the saturation factors for the various counties and the availability of service on the basis of daylight field intensity standards. The natural question which arises is: "If the ratio of the number of receiving sets in a given community to the number of families does not depend upon the presence of adequate field intensities from broadcast stations, regardless of how low an intensity is considered as adequate, then upon what factors does it depend?" It is now quite universally accepted that radio broadcasting can fundamentally be of greater economic and social service to rural communities than to cities. From the high value of the receiving set saturation factor which exists in some of the counties, as shown by Fig. 5, which possess only a rural population, it seems, probably, that the value which this factor will possess in a given community is likely to depend more upon the need for broadcast service than upon its continuous availability.

The wide dissemination of receiving sets and the high value of the receiving set saturation factor throughout the three states, shown to exist in spite of absence of reliable daylight broadcast service, can only mean that night time reception of signals from stations at considerable distances is not only of value, but is all that the majority of listeners have available. Since large numbers of broadcast listeners in the central northwest, and similarly throughout large portions of the entire United States, have invested their money in receiving sets on the basis of distant night time reception and such reception only, schemes for the distribution of broadcasting stations which are intended to

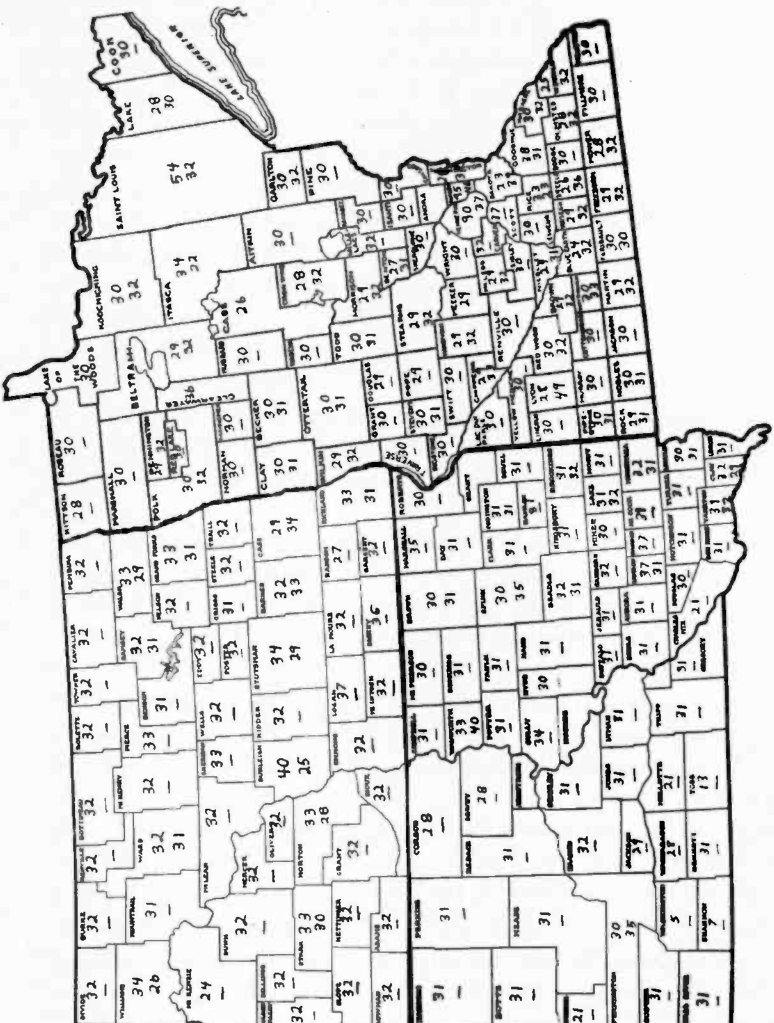

Fig. 5—Receiving Set Saturation Factors for Minnesota, North and South Dakota February 1, 1928 on the Basis of Four Individuals for Each Family. (Upper Figure Refers to Rural Population; Lower Figure Refers to Urban Listener).

deliver equitable broadcast service should give adequate consideration to receiving conditions which will exist several hundred miles from any broadcasting station.

An analysis of the conditions affecting night time reception in a region such as is under consideration is immeasurably more difficult than where high quality service range only is of interest. Absolute figures based upon field intensities alone do not tell the complete story. Atmospheric disturbances, non-radio electric disturbances, radio station interference and fading all become matters of great importance. On the other hand, the geographic separation between listener and broadcasting station becomes a factor of relatively minor importance. Often, reception from a particular station is more satisfactory at points 200 or more miles distant than at points lying between 50 and 200 miles[4]. While the scope of the investigations forming the basis for this paper was not such as to yield a great amount of information concerning these factors, important as they are and must continue to be to the broadcasting art for some time to come, they did, however, forcibly call attention to certain phenomena which are worthy of mention.

In general a station 1,000 miles away from a rural listener, free from heterodyne interference, will probably be of greater service to him than a station 200 to 500 miles away subject to such interference. Many instances are known where heterodyne interference from a 500-watt station 1,000 miles away has destroyed reception from a 5,000-watt station 20 miles away. It follows, therefore, that a broadcast structure designed to serve rural communities should, as far as possible, eliminate interference of this sort.

Since today and probably for a long time to come the rural listener must rely upon relatively low field intensities, it follows that any increase in power on the part of the stations serving him will improve his receiving conditions. If these stations are operating on clear channels, then such increase will not affect the general interference situation providing the stations involved are not located in thickly populated districts.

Of the remaining factors which limit distant reception, there is one, dependent upon the characteristics of the transmission medium, concerning which, as yet, far too little is known. Statistical data have repeatedly indicated that at night there is a zone which lies approximately between 50 and 200 miles of a broadcasting station in which reception is not as good as at points farther distant[4]. This condition has been found to exist in the territory under consideration. Sometimes the zone of poor reception extends closer than 50 miles and sometimes it extends further than 200 miles, depending upon weather conditions, frequency, and other factors. Under some conditions and with some transmitters, such programs as are received are so distorted as to be rendered useless. Increasing power at the transmitter does not seem to overcome the difficulty.

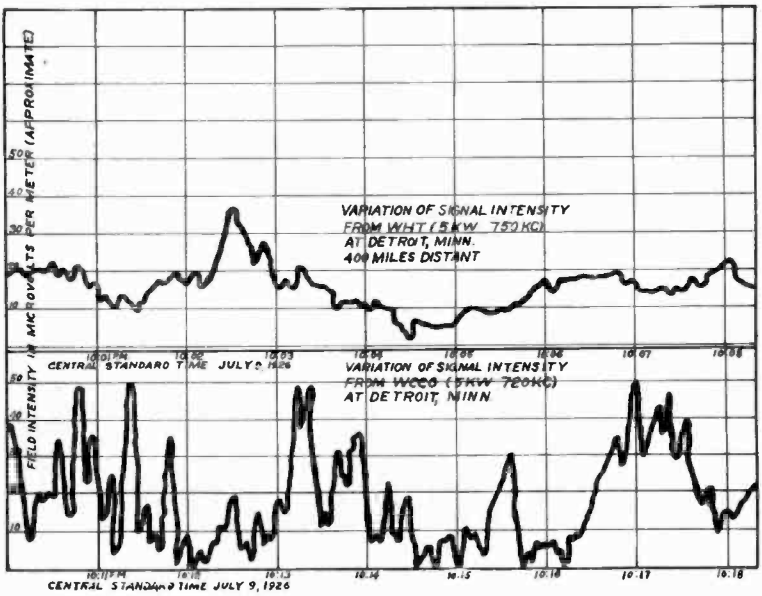

Fig. 6—Fading at 112 and 400 Miles.

Such evidence as has been collected seems to connect the condition described above with fading. As an illustration of a probable explanation, attention is called to Fig. 6 showing fading curves taken at Detroit, Minnesota in the summer of 1926. Data for the two curves were taken one after the other. The two stations involved were of the same make, type and power and were operated on frequencies separated by only 30 kilocycles. The field intensity from the station 112 miles away fluctuated

[4] "A Statistical Study of Conditions Affecting the Distance Range of Radio Telephone Broadcasting Stations" by C. M. Jansky, Jr., Technological Papers of the Bureau of Standards No. 297.

much more rapidly than the field intensity from the station 400 miles away. Although the peaks of the curve for the nearby station rise somewhat higher than those for the more distant one and the average intensities are approximately the same, the program from the nearby station was not enjoyable while that from the distant station was. The listener was seriously disturbed by the rapid fluctuations in intensity produced by the former station while the slower variations of the latter were hardly noticeable. Had the observations been made at a point 80 miles from

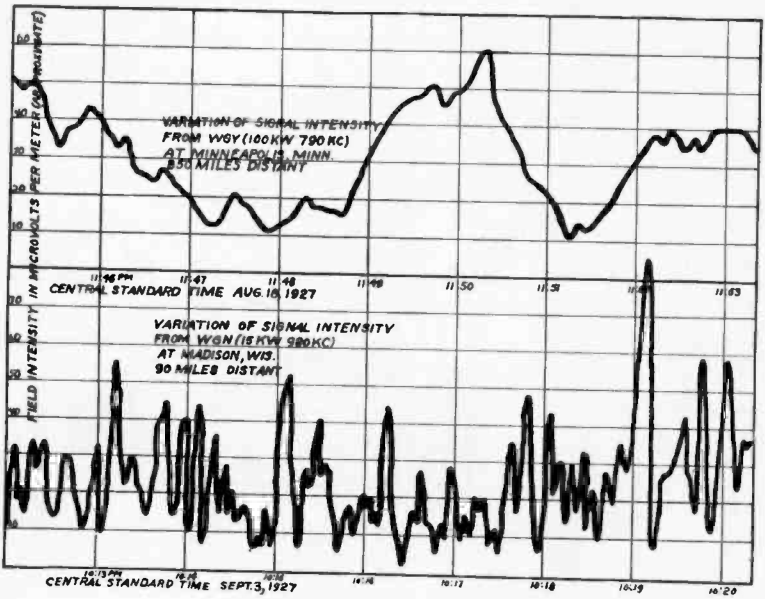

Fig. 7—Fading at 90 and 850 Miles.

the nearer station, the program from it would probably have been still less acceptable.

Fig. 7 shows curves obtained from two stations taken at different times and at different locations. Here the difference is still more marked. Numerous observations which the author has made upon stations operating throughout the broadcast spectrum lead to the conclusion that while the rapidity of fluctuation of intensity in the broadcast band at a particular time varies to some extent with the frequency in use at the broadcasting station, it varies to a much greater extent as the distance between the transmitter and receiving location is varied. The shorter the distance the shorter the average period. This, together with the effect of the rapidity of variations of intensity upon the sensitivity of the human ear to such variations, the author believes to be the main reason for the existence of the zone of poor reception.

When the more serious limitations imposed by heterodyne interference and lack of power have been removed, fading will probably be the most important remaining deterrent to the delivery of good night time broadcast service to listeners outside the high-quality service range of stations. The writer has believed for some time that the detrimental effects of fading as have been described might be largely overcome by radiating the modulated high-frequency energy from a plurality of locations which need not be so widely separated geographically as to make the scheme wholly uneconomic.

It seems, probably, that the most efficient utilization of a given broadcast channel could be obtained by operating a sufficiently large number of synchronized stations scattered throughout the entire nation, all carrying the same program. Such a system, if elaborate enough, would deliver adequate signal intensities everywhere and would also probably overcome the detrimental effects of fading. Aside from the technical difficulties to be encountered, the economic impossibility of inaugurating such a system in the immediate future should be obvious. The scheme proposed in the preceding paragraph is, however, somewhat different and certainly more workable from an economic standpoint at least.

The author wishes to express his indebtedness to Mr. R. R. Sweet, Chief Engineer of Station WCCO and to Mr. C. B. Feldman, Teaching Fellow at the University of Minnesota, who assisted in taking much of the data used in this paper, and to the management of WCCO whose interest in this subject made possible the studies of that station.

A STUDY OF SHORT-TIME MULTIPLE SIGNALS*

By
J. B. Hoag and Victor J. Andrew

Summary—*The echos or multiples of the direct signals from a transmitting station which arrive shortly after the main signal are due to direct-reflection from the Kennelly-Heaviside layer. Those arriving after considerable time (about one-seventh of a second) have travelled around the world. This paper deals with new, intermediate types of multiple signals which arrive at the receiving station from 0.01 to 0.04 second after the direct signal. Groups of these have been associated with paths to the regions of auroral activity, the magnetic and geographic north poles. A classification of these short-time multiple signals is given and resolved into the regular echos and a new wedge-shaped echo. The wedge or hangover multiples may be due to a plurality of paths resulting in successive echos of decreasing amplitude. Surprisingly large fluctuations of path difference of all short-time multiples occur in as short a time as one-quarter second.*

Introduction

THIS paper deals with radio signals which have traversed various paths between the transmitting and receiving aerials. The rays leave the transmitter in all directions both along the earth's surface and upwards. The first signals to arrive at the receiver have travelled in a straight line or along the shortest arc between the two stations. Later, "echos" or "multiples" of the direct signals come in (especially for very high frequencies) which have travelled upward and suffered reflection or refraction from regions of high electron concentration, the

Fig. 1

Kennelly-Heaviside layer, seventy-five to three hundred miles above the earth. Then there are multiple signals arriving at a considerable time later, about one-seventh of a second, which have made a complete excursion around a great circle of the earth. These latter may have travelled in the original direction of the direct signal or in the opposite sense and have been observed after three and four trips around the earth.

* Original Manuscript Received by the Institute, August 6, 1928.

Measurements were started on the first of this year with the intention of repeating Quack's[1] observations on these circumterrestrial signals and continuing their study. However, it was soon found that multiple signals often appeared after time intervals very much less than that expected for signals following great

Fig. 2

circle paths, but longer than for direct reflection from the Kennelly-Heaviside layer. In May, Taylor and Young[2] reported such short-time intervals in addition to circumterrestrial signals, and emphasized the need of further work at different geographical locations. This paper deals with such signals as observed in Ryerson Physical Laboratory at the University of Chicago during the first four months of 1928.

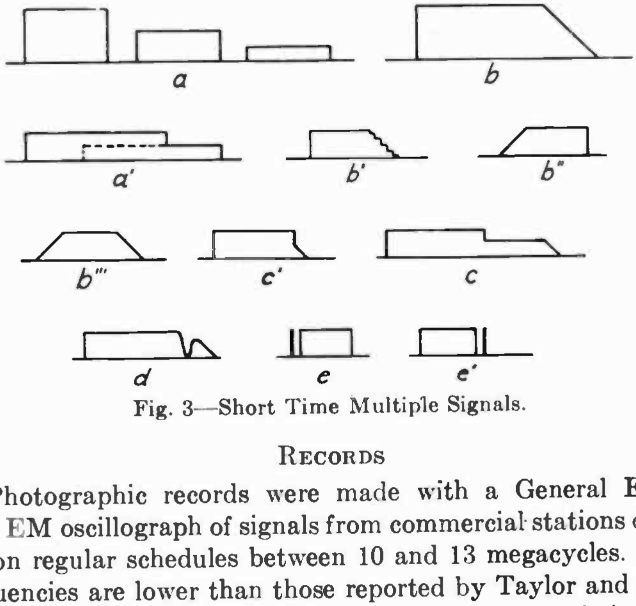

Fig. 3—Short Time Multiple Signals.

Records

Photographic records were made with a General Electric type EM oscillograph of signals from commercial stations operating on regular schedules between 10 and 13 megacycles. These frequencies are lower than those reported by Taylor and Young (14 to 20 megacycles) or Quack (around 18 megacycles). Interpretation of many of the records was difficult because of intense

[1] Proc. I.R.E., 15, 341; April 1927.
[2] Proc. I.R.E., 16, 561; May, 1928.

rapid fading of the types shown in Figs. 1 and 2. At times this fading was periodic and at other times it was extremely irregular. No attempt was made to study the phenomenon in detail.

After a large number of records were obtained it became possible to distinguish several different forms of distorted and multiple signals which appeared so consistently as to warrant classification. Idealized cases of these are shown in Fig. 3. Further study indicated that these could be reduced to two fundamental types, *a* and *b* of Fig. 3.

Fig. 4

The normal short-time multiple signals of type *a* are shown in Fig. 4, which is a series of dots from KEL, Bolinas, California, taken at 6:05 Central Standard Time, May 5th, on approximately 10.25 megacycles. It is significant that most of the dots reappear not only once, but twice, and those on the left three times. Furthermore, in the fraction of a second between successive dots a considerable variation in both time and intensity of multiple signals occurs, indicating great instability in the paths followed. The variation in time is seen from the detailed measurements of one record of KEL, given in Table I.

TABLE I

Dot Number	Interval in Seconds						
	Beginning of signal				End of signal		
1	—	—	—	—	0.0108	0.0195	0.0334
2	—	—	—	—	0.0093	0.0213	0.0320
3	—	0.0214	0.0435	—	—	0.0213	0.0433
4	—	0.0181	0.0435	—	0.0147	—	—
5	—	0.0302	0.0480	—	—	0.0193	—
6	—	—	0.0426	—	—	0.0170	0.0286
7	—	0.0276	0.0362	—	—	—	0.0331
8	—	0.0263	—	—	—	0.0232	0.0301

These may be roughly grouped into time intervals of 0.011, 0.022, 0.031, and 0.043 second. Records of the same station taken at various times give group values of 0.011, 0.012, 0.018, 0.028 0.029, 0.030 and 0.042 second. The average of these gives short-time multiple signals from this station of 0.011, 0.020, 0.029, and 0.042 second. These measurements include types *a* and *a′* since the latter is a special case of the former in which the main signal is of sufficient duration to cover the beginning of the multiple signal. Fig. 5 gives an example of this type. Similar records on AGB, Nauen, Germany give averaged time intervals of 0.005, 0.006, 0.083, and 0.016 second.

The second fundamental type, *b*, which we shall call wedge signals, was at first thought to be a case of rapid fading. However, their continued appearance at times when fading was slight made it evident that a different phenomenon was involved. In a few

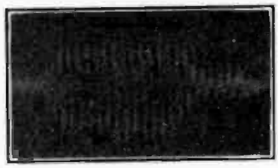

Fig. 5

cases a multiple signal consisted of one normal signal and one wedge-shaped signal. On these the entire length of the wedge-shaped signal, to the point of the wedge, appeared to be the length of the transmitted signal. The evidence was inconclusive, and it appeared more reasonable to believe the period of maximum signal strength equal to the length of the transmitted signal. If the latter is true, the signal shape may be due to a large number of multiple paths, giving a figure of type b'. This would correspond to the case mentioned by Heising[3] of transmission of a short jab of energy, and reception of a longer diffuse signal. Type *b* is shown in Fig. 6. The less frequent types b'' and b''' are illustrated by Figs. 7 and 8 respectively.

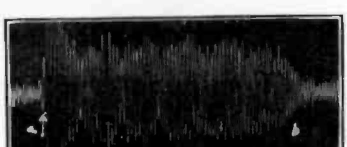

Fig. 6

Type *c* is shown in Fig. 9. It is partially masked by a short extraneous noise of a wave form which often appears. Type c' occurs very frequently, and is illustrated by Fig. 10. *c* and c' are probably both combinations of types *a* and *b*. The principal signal is normal, and second signal wedge-shaped. Another variation of type *b* is type *d*, illustrated in Fig. 8.

Several signals of type *e* or e', Fig. 11, appear in our records and in illustrations in Taylor and Young's article. Measurements

[3] Proc. I.R.E., 16, 75, January, 1928.

of accompanying multiple signals indicate that the transmitted signal extended over the extreme length of the two portions of the signal.

Measurements of the duration of the wedge or hangover of type *b* signals are given in Table II.

TABLE II

Station	Length in Seconds Min.	Max.	Average
WIK	0.003	0.045	0.017
AGB	0.011	0.060	0.027
CJ	0.017	0.020	0.019
VIY	0.006	0.014	0.010
GBH	0.008	0.027	0.016
KEL	—	—	0.020

Theory

Multiple signals must originate either in a plurality of paths of different length between the transmitting and the receiving stations, or in a plurality of signal velocities. Velocities differing as greatly as would be necessary to explain observed signals are too improbable to warrant consideration. Attempts to explain the origin of multiple signals must be based on the existence of several paths over which the signal arrives, travelling at approximately the velocity of light. To account for the measurements discussed in this paper the lengths of the paths must vary over wide limits in a fraction of a second. It is, of course, not inconceivable that different phenomena are involved in indirect paths of different lengths. Since there is no other evidence of reflecting or refracting surfaces at great distances above or below the earth's surface attention must be directed to the possible paths approximately parallel to the earth's surface.

Fig. 7

Taylor and Young have suggested two possibilities, reflection from regions of high electron concentration near the earth's magnetic pole and scattered reflection from rough country beyond the receiving station. The first of these checks well with the 0.020 time intervals from KEL, but we are still confronted with the 0.011, 0.029, and 0.042 values. The Aurora Borealis is known to be most prominent above North America in latitude 60 deg. north and in the north Atlantic, falling off to the north and to the south. Its height ranges from 50 to 100 miles above the earth's surface for the lower strata of light and 75 to 200 miles for the upper. Further, brilliant Auroras accompanying

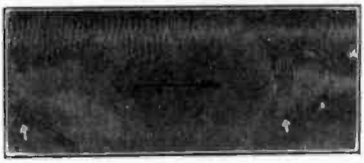

Fig. 8

magnetic storms and the Auroral rays follow the lines of the earth's magnetic field. Rough calculations on the time intervals, 0.011 from KEL and 0.005-0.006 from AGB for indirect paths to 60 deg. north check as well as could be expected. It is highly

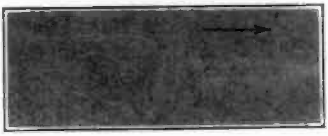

Fig. 9

desirable that experiments on the direction of the incoming direct and multiple signals be performed and an attempt be made to obtain a correlation with the Aurora or magnetic storms.

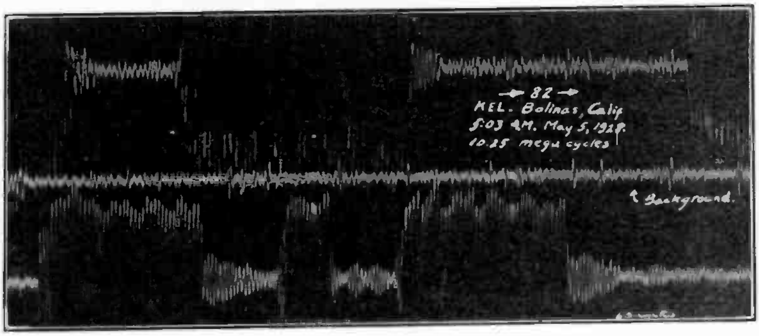

Fig. 10

The 0.042 values indicate a path as far north as the geographic pole. It is suggested that, since the arctic regions are in comparative darkness for many months of the year, the Kennelly-Heaviside layer is considerably elevated over these regions, like an inverted bowl, and that the rays are reflected around its inner surface. These signals would be expected to be rarer during the arctic summer months.

The Kennelly-Heaviside layer, normally parallel to the earth's surface, has a vertical component along the twilight zone. For signals travelling at a certain elevation and encountering this at a certain angle, it would serve as a source of horizontal reflection or refraction. Such deflection, if large, might produce indirect paths. Friis[4] has reported a large and rapidly changing error in high-frequency direction finding when the twilight zone lies between the transmitting and the receiving stations.

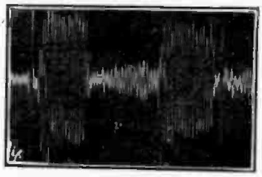

Fig. 11

In considering the wedge type signals, and especially the type *b'*, it is proposed that these consist of the main signal followed by a large number of multiple signals close together and of decreasing amplitude. This would require a band of indirect paths or echelon reflection. Since the time duration of these hangover signals is different, even in one-quarter of a second, the step-like reflector must be moving rapidly. Measurements on KEL check roughly for reflections from 60 deg. to 80 deg. north latitude. Here we are again reminded of the intense Auroral or magnetic action. If such a correlation be established these multiple signals will serve to study the nature of Aurora as well as the propagation of radio signals.

It is hoped that additional information may be obtained, especially from stations farther north, including the direction of reception and angle of polarization of the received signals.

[4] Proc. I.R.E., **16**, 658; May, 1928.

Volume 16, Number 10 *October, 1928*

A NEW METHOD FOR DETERMINING THE EFFICIENCY OF VACUUM-TUBE CIRCUITS*

BY

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Summary—*A new method for determining efficiency of vacuum-tube circuits at both high and low frequencies has been described. This method consists of the application of a surface pyrometer which indicates the temperature of the glass walls of a vacuum tube. Readings are made of the temperature of the tube walls when the circuit is oscillating together with notation of d.c. plate watts input and then oscillation of the tube system is stopped and the plate input watts changed until identical pyrometer reading is obtained. The difference in wattage between the two measurements represents the radio-frequency output power.*

The simplicity of the method and the short time required for the measurement recommends it for serious consideration where air-cooled tubes are employed.

VARIOUS methods for determining the efficiency of vacuum-tube amplifying and oscillating circuits have been used to date with some success, especially in the low-frequency band. The advent of high-frequency communication systems in the band between 3000 and 20,000 kc and studies of vacuum-tube circuit efficiencies in this band have shown that certain methods for determining tube circuit efficiencies are not reliable. It is the object of this paper to describe a new method which has been found to be reliable for any frequency range when applied to circuits which employ the air-cooled vacuum tube.

Our experience with the commonly-known resistance variation and the optical pyrometer methods in the high-frequency band has proven them to be unsatisfactory. In the resistance variation method, where we determine the tank circuit resistance and, knowing the current flow, estimate the watts dissipated, we are very dubious of our resistance standards. These standards are most likely accurate at low frequencies but are not so in the high-frequency band. This condition can be attributed to the presence of appreciable inductance and distributed capacity in these standards which, if not compensated for, will introduce large errors. The general use of low resistance tank cir-

* Original Manuscript Received by the Institute, August 15, 1928.

cuits with the appreciable resistance of tuning condenser and thermoammeters do not permit checking of measurements to less than ten per cent. The precautions to be observed when using this method at high frequencies and also the time required for such a measurement do not recommend it for quick and accurate work.

The optical pyrometer method is another means for obtaining tube circuit efficiency, but is not preferred for precision work with air-cooled tubes. In this method the optical pyrometer is employed to observe the temperature of the plate of the vacuum tube. A run is made with the tube in the non-oscillating state and the temperature of the plate is noted for different plate watt dissipations. The circuit is then placed in

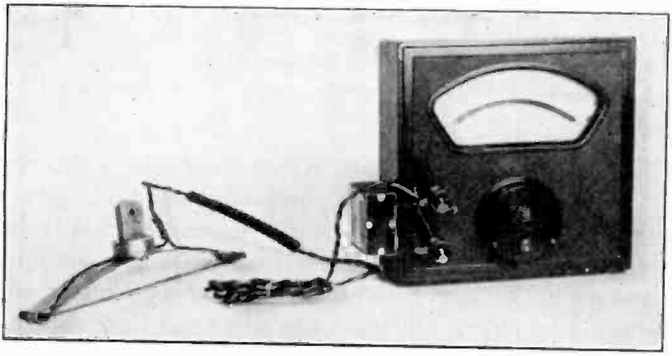

Fig. 1

the oscillating state and the temperature of the plate is again obtained by use of the optical pyrometer. The plate watts input is noted for the oscillating condition, and from this is subtracted the watts dissipation represented by the pyrometer reading. The remaining number represents the watts which have been converted into radio-frequency power.

This method is easier to apply than the resistance variation method but has its limitations. These limitations are variation of temperature over the surface of the plate for the direct-current dissipation measurement and a change in color for the same dissipation when the tube circuit is in the oscillating state. It is a common occurrence to observe a definite part of the plate that is of a cherry red color while other areas are of a dull red or black color when the tube is dissipating a certain wattage during the direct-current test, but as soon as the tube circuit starts oscillating and the plate is dissipating the same number of watts the color pattern spreads out and no longer shows the definite color portion. This spreading out is more pronounced as the frequency generated by the circuit is increased, particularly when operating in the high-frequency range. This change in color for the two conditions introduces a considerable error at high frequencies and therefore eliminates the system from consideration for precision measurements.

Another serious difficulty with this method, especially when the tube circuit efficiency is high, is the lack of sufficient color on the plate to permit an accurate pyrometer reading. From the foregoing statements it can readily be seen that only at excess

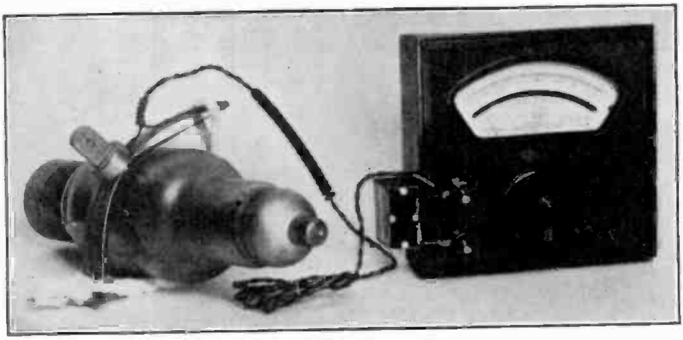

Fig. 2

power ratings or inefficient tube circuit conditions is it possible to use this method.

Having determined the limitations and difficulties encountered in these two methods it became imperative that a more simple and reliable method be developed for measurement of the efficiency of air-cooled tube circuits. An opportunity for the solution of this problem was presented in the use of a Cambridge surface pyrometer. This pyrometer was designed primarily to measure the temperature of rolls and other cylindrical or flat surfaces which are employed in the manufacture of paper, rubber, and textile materials.

The type employed in our work is shown in Fig. 1. In this figure a flat strip thermocouple is illustrated with flexible leads connecting it to a millivoltmeter. The thermocouple strip is stretched between the ends of a heavier metal strip and insulated from it by hard rubber end pieces. A paper condenser of 1 μf capacitance is shunted across the millivoltmeter for the purpose of bypassing any radio-frequency currents that may be picked up by the thermocouple and leads.

Figs. 2, 3, and 4 show the pyrometer and the method of connecting it to the 250-watt, 50-watt, and 75-watt (shield-grid) tubes. This type of pyrometer measures the temperature of the glass walls of the tube and in part indicates an average or integrated value of temperature, while the optical pyrometer measures the temperature of the particular part of the plate upon which it is focused. The heat delivered to the thermocouple from the plate of the tube has to pass through the evacuated space between the plate and the tube wall and then through

Fig. 3

the glass wall and enroute it is averaged out and represents, indirectly, the heating effect of the entire plate.

For precision measurements it is advisable to explore the entire surface of the tube and find a place where there is minimum temperature difference between readings taken with the tube circuit in the oscillating and non-oscillating state. There will be a difference in temperature for these two conditions on certain parts of the tube surface, but there are a number of places on the tube surface where there is no perceptible temperature difference and at one of these places the pyrometer is secured.

The same method of determining the output of the tube circuit is employed with the surface pyrometer as was employed with the optical pyrometer; namely, to obtain a run showing temperature difference for different direct-current plate dissipations and then with the circuit in the oscillating condition note the input watts to the plate and subtract from this the dissipation wattage represented by the pyrometer reading with the remaining number of watts equal to the radio-frequency output.

The simplicity of the method and the ability to repeat the experiments and obtain results that check to less than 10 per cent recommends this new method for consideration.

There are a number of applications of this method for important measurements, among which are the following:

Antenna resistance
Tank circuit resistance
Condenser resistance

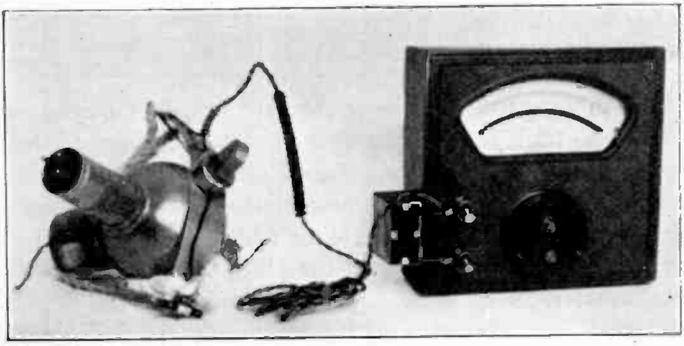

Fig. 4

Choke coil losses
Inductance coil resistance
Output power in antenna or tank circuit
Efficiency of amplifier tube circuits when singling, doubling, or tripling frequency
Efficiency of oscillator systems

An example of the various uses to which this system can be applied may be noted from the measurements which are described in the following paragraphs.

Crystal-Controlled Oscillators

An investigation was made to determine the efficiency of the Navy standard crystal-oscillating circuit[1] and also the push-pull, crystal-oscillating circuit. The Navy standard circuit employs a single 50-watt tube with reduced plate voltage and a parallel feed plate circuit. The push-pull circuit employs

[1] A. Crossley, Proc. I.R.E., 15, 9; January, 1927.

two 50-watt tubes operating at same plate voltage as the single tube circuit with the push-pull principle, wherein the crystal is connected between the two grids and the plates are connected to the opposite ends of the tank circuit.

There was some doubt as to the efficiency of the push-pull crystal-oscillating circuit, particularly the question of whether or not the output was equal to twice that obtainable with the single-tube circuit. Table I shows definitely that the output obtained with the push-pull circuit is double that of the single-tube circuit.

TABLE I

Circuit	Input (Watts)	Pyrometer Reading	Dissi-pation (Watts)	Output (Watts)	Efficiency
Single tube oscillator	62.	447 deg. F	41.	21	34 per cent
Push-pull tube No. 1	73.5	452	50.5	23	31 per cent
Push-pull tube No. 2	73.	448	52.	21	29 per cent

In this measurement the pyrometer was first placed on one tube of the push-pull circuit and data was obtained, then the pyrometer was shifted to the second tube and the experiment was repeated. In this way it was possible to check the operation of each tube, thus obtaining the data which is shown in Table I. Repeated checks were made on the efficiency of the two circuits in the band between 2000 and 4000 kc, and it was possible to repeat such measurements with a maximum error of 5 per cent.

Vacuum-Tube Amplifiers

Measurements were made on the efficiency of the CG-1860 250-watt and the Westinghouse AT-671 250-watt (shield-grid) tube when operated as an amplifier in the 4000- to 4500-kc band. Figs. 5 and 6 show graphically the efficiency and output obtainable with these two types of tubes.

In these measurements it was desired to determine whether the shield-grid tube was as efficient as the three-electrode tube and in addition what was the relation between excitation and negative C grid voltages for maximum output and efficiency. These tubes obtained their excitation voltage from a push-pull, crystal-controlled master oscillator. The three-electrode tube amplifier stage was balanced by resort to the Hazeltine method of neutralization in order that a fair comparison could be made with the shield-grid amplifier.

In computing the efficiency of the shield-grid amplifier, the dissipation in the shielding grid was considered. The variation of negative *C* voltage produced a variation in shielding grid dissipation from 2 to 32 watts which values were considered when computing efficiencies.

Referring to Figs. 5 and 6, the solid lines represent tube-circuit output while the dotted lines indicate efficiency. A study of these figures show, first, that the three-electrode tube is a more efficient amplifier than the shield-grid tube and secondly greater efficiency and output is obtainable with greater excitation voltage. The ratio of excitation peak voltage to negative *C* voltage for maximum efficiency is approximately two to one.

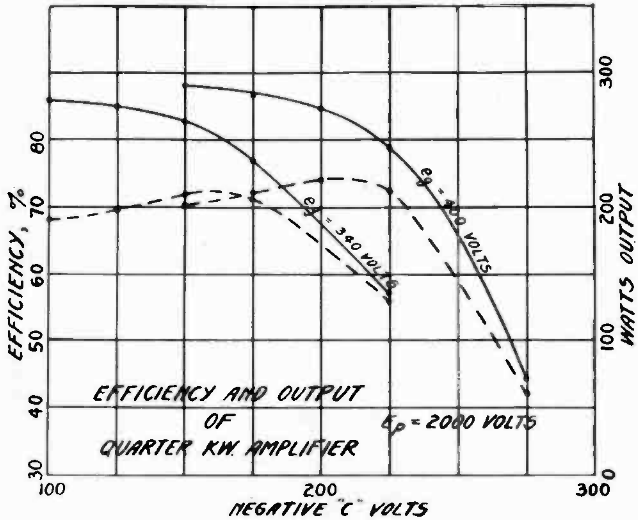

Fig. 5

In this experiment a vacuum-tube voltmeter was employed to determine the excitation voltage to the grid of the amplifier tube. Due to this method of measurement only peak voltages can be obtained and consequently all values of excitation voltage quoted in this paper are peak values.

Antenna Resistance

The measurement of the resistance of antennas operating in the band between 4000 and 20,000 kc presents a problem which cannot be successfully solved by the resistance variation method. This is due to the fact that such antennas cannot be duplicated very readily by dummy circuits which employ lumped inductance and capacity. These high-frequency antennas are not loaded as are the low-frequency antennas, but have a considerable amount of radiation resistance which is many times the resistance represented by the d.c. and dielectric losses.

Generally, these antennas are of such length that they are a whole wavelength or a fraction of a wavelength long. Best practice at present time calls for antennas which are one-quarter, one-half, or three-quarter wavelength long according to type of radiating system employed.

The pyrometer method is well-adapted to the measurement of power which is delivered to the antenna system, and if proper precautions are made to note the current at the current node of the antenna, it is possible to measure the antenna resistance.

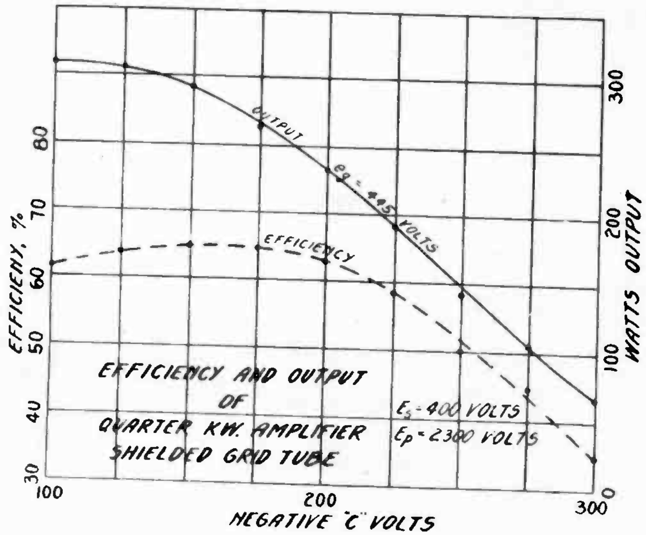

Fig. 6

To obtain this data with the pyrometer, we first compute the output of the tube system in the same manner which was described in the preceding chapters having the antenna connected to the tube system. In this measurement the current in the tank and antenna are recorded, after which the antenna is disconnected.

The next step is to retune the tank circuit to resonance and reduce the power until the current value obtained in the tank circuit is the same as when the antenna was connected. Now measure the output of the tube and subtract this value from that which was obtained with the antenna connected. The remaining power represents the antenna output. The antenna resistance is computed by dividing the antenna power by the square of the antenna current.

TABLE II

Total Output (watts)	Tank Circuit (watts)	Antenna (watts)	Antenna Resistance
283	47	236	49.7 ohms
159	32	127	49.7 "
302	66	236	49.7 "
362	47	315	56.1 "
311	41	270	52.4 "
254	66	188	45.5 "
333	46	287	55.8 "
	Average Antenna Resistance		51.3 ohms

Table II indicates the accuracy of the new method and cites measurements made over a period of ten days on a quarter-wave vertical antenna which was operating on 8000 kc.

Volume 16, Number 10 *October, 1928*

SOME PRINCIPLES OF GRID-LEAK GRID-CONDENSER DETECTION*

By
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Summary—*The action taking place in the grid-leak, grid-condenser method of detection is reduced to an equivalent circuit consisting of the grid-leak condenser impedance in series with the dynamic grid resistance. The effect of applying a signal voltage to the detector, as far as the rectified grid current is concerned, can be represented by the introduction in the equivalent circuit of a fictitious voltage that is determined by the signal, and by a single tube constant called the voltage constant. The voltage drop produced by this fictitious voltage across the grid-leak condenser impedance is the change of grid potential resulting from the detector action. A bridge method of measuring all detector constants is described. The effects of grid leak and condenser sizes are discussed, and the factors involved in the selection of conditions for best detection with telephone and telegraph signals are considered.*

Introduction

AT THE present time there is no way of treating the phenomenon of detection of radio signals by the grid-leak grid-condenser method that is satisfactory for engineering purposes. The theory of detectors has been developed in a more or less complete form by various investigators,[1,2] but there has been no simple way of visualizing the quantitative relations existing in the detection process, and of measuring the detector coefficients. As a result the computation of detector performance is practically never undertaken.

PROCESS OF GRID-LEAK GRID-CONDENSER DETECTION

In grid-leak grid-condenser detection, the circuit for which is shown in Fig. 1, the applied signal voltage is rectified by the non-linearity of the grid-filament circuit, producing a rectified

* Original Manuscript Received by the Institute, July 31, 1928.

[1] "A Theoretical and Experimental Investigation of Detection of Small Signals," by E. L. Chaffee and G. H. Browning, PROC. I.R.E., 15, 113; February, 1927.

"On Optimum Heterodyne Reception," by E. V. Appleton and Mary Taylor, PROC. I.R.E., 12, 277; June, 1924.

"The Rectification of Small Radio-Frequency Potential Differences by Means of Triode Valves," by F. M. Colebrook, *Experimental Wireless*, 2, 865; 1925.

[2] Since this manuscript was first drafted there has appeared an article by Stuart Ballantine, "Detection by Grid Rectification with the High-Vacuum Triode," PROC. I.R.E., 16, 593; May, 1928.

grid current that must necessarily flow through the grid-leak grid-condenser impedance and produce a voltage drop. This voltage drop then affects the plate current of the tube by ordinary amplifier action.

The amplitude of the rectified grid current depends upon the amplitude of the signal voltage. When the signal voltage is a modulated alternating-current voltage, the rectified grid current varies in amplitude at the frequency of modulation. Thus, when the radio-frequency signal voltage is modulated at a frequency of 1000 cycles, the rectified grid current pulsates in amplitude at 1000 cycles, and accordingly contains a direct-current part with superimposed alternating-current components having a fundamental frequency of 1000 cycles.

The problem of grid-leak condenser detection is centered around the determination of the change of detector grid potential

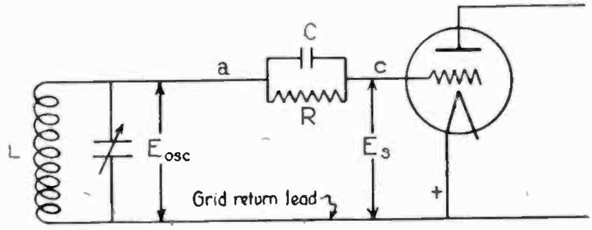

Fig. 1—Circuit for Grid-Leak Grid-Condenser Detector.

produced in the detecting or rectifying process. The effect which a known change of grid potential produces in the plate circuit is an amplification problem and can be determined from the theory and equations of the vacuum-tube amplifier. The sensitiveness of the detector, that is, the change of grid potential produced by a given signal voltage, depends upon the curvature of the grid-voltage grid-current characteristic at the operating grid potential, and upon the impedance offered to the rectified grid current by the grid-leak condenser combination.

In radio-telephone and telegraph reception it is the audio-frequency components of the rectified grid current that convey the intelligence, and the grid-condenser grid-leak combination should accordingly offer a high impedance to audio-frequency currents. The impedance of the grid-leak condenser combination depends upon frequency, however, and becomes less as the frequency is increased. The detector is accordingly less sensitive for high modulation frequencies. The result is distortion in which the high notes are discriminated against.

Equivalent Circuit of the Grid-leak, Grid-condenser Detector

The change of grid potential which a given signal will produce can be analyzed with the aid of the equivalent circuit of the grid-leak condenser detector shown in Fig. 2. This equivalent circuit is based on the following law of detectors:

The rectified grid current produced by application of a small signal voltage (such as 0.05 volts effective or less) to the grid of a detector tube is exactly the same current that would be produced by a series of suitable generators acting between the grid and filamen

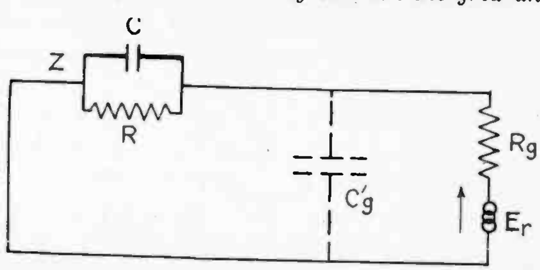

Fig. 2—Equivalent Circuit of Grid-Leak Grid-Condenser Detector.

in series with the grid-filament resistance of the tube. There is one such generator for each frequency component of the rectified current. The proper amplitude and phase of each generator depends only upon the operating grid potential, and the nature of the signal, and is given in Table I. The current produced by these fictitious generators if actually present in the grid circuit is the rectified current that the applied signal voltage produces. A proof of this proposition is given by Carson.[3]

The generators that can be assumed acting between the filament and grid in series with the dynamic grid resistance to produce the rectified grid current have no actual existence. It is merely that the effect of applying a signal voltage to the grid is the same as though these fictitious generators actually were present, and as though they and not the signal voltage were the

[3] The writer discovered this proposition in the latter part of 1926, and then found that it had been derived by three previous investigators, namely, Chaffee and Colebrook in the references cited, and John R. Carson, "The Equivalent Circuit of the Vacuum-Tube Modulator," Proc. I.R.E., 9, 243; June, 1921. Carson seems to be the first, although his application of the idea was to plate-circuit modulation.

forces really producing the rectified grid current. The voltage developed by this series of fictitious generators that represents the rectifying effect of the grid upon a signal voltage can conveniently be called the *rectified grid voltage,* and will be represented by the symbol E_r.

The rectified grid voltage E_r has a number of components, one for each component of the rectified grid current. Table I gives the frequency, amplitude, and phase of the different components that are present with various types of signal voltages. The rectified grid voltage E_r always contains a direct-current component, and when the signal voltage consists of several voltages of different frequencies (as a modulated wave which has a carrier wave and two side bands) the rectified voltage has in addition to the direct-current component a component of every possible difference frequency that can exist with the signal frequencies present.

The results of Table I are special cases of a general formula. To obtain the rectified grid voltage in the general case one writes down the signal voltage e_s as a function of time, squares this function, and divides by v. The low-frequency terms of the result are the components of the rectified grid voltage.

The rectified grid potential E_r is determined only by the signal voltage, and a tube constant v that will be discussed in the next section.

The size of grid condenser and grid leak has no effect on the amplitude of the rectified voltage E_r except insofar as the grid-leak resistance affects the operating grid potential. The current that the rectified voltage produces in the grid circuit, the rectified grid current, therefore depends upon the impedance of the grid-leak condenser combination, and consequently upon the size of grid condenser and grid leak. Each component of the rectified grid voltage acts by itself in producing its component of rectified grid current, independently of the presence or absence of other components of rectified grid voltage and current.

TABLE I

Formulas for Rectified Grid Voltage

1. Unmodulated radio signal voltage of crest value E_s, having equation $e_s = E_s \sin \omega t$.

   Components of rectified grid voltage:

   Direct-current component $= +E_s^2/2v$

2. Two superimposed alternating-current voltages of amplitudes E_1 and E_2, and frequencies f_1 and f_2, respectively, having equation $e_s = E_1 \sin 2\pi f_1 t + E_2 \sin(2\pi f_2 t + \phi)$
   Components of rectified grid voltage:
   Direct-current component $= +(E_1^2 + E_2^2)/2v$
   Component of frequency $f_1 - f_2 =$
   $+(E_1 E_2/v)\cos[2\pi(f_1 - f_2)t - \phi]$
3. Modulated wave with carrier crest amplitude E_m and degree of modulation k, having equation $e_s = E_m(1 + k \sin qt)\sin \omega t$
   Components of rectified grid voltage:
   Direct-current component $= +(E_m^2 + k^2 E_m^2/2)/2v$
   Modulation frequency component $= +(E_m^2 k/v) \sin qt$
   Double modulation frequency component $=$
   $-(k^2 E_m^2/4v) \cos 2qt$

Notation and formulas:

$R_g = dE_g/dI_g =$ dynamic grid resistance
$v = 2R_g/(dR_g/dE_g) =$ detector voltage constant
$E_r' =$ a component of rectified grid voltage.
$Z' =$ vector impedance of grid-leak condenser combination to component of rectified grid voltage E_r'

The change of grid potential produced by component E_r' $\Big\}\; E = E_r' \dfrac{Z'}{R_g + Z'}$

Note that all amplitudes given in this table are crest values.

The capacity C_g' shown in dotted lines in the equivalent detector circuit of Fig. 2 is the effective grid-filament input capacity of the tube at the frequency of the rectified voltage component being investigated. This capacity depends upon the plate-circuit impedance of the tube, and in general its value changes with frequency. As C_g' is in parallel with the grid condenser C it has the effect of making the grid condenser correspondingly larger. Strictly speaking, the effective grid-filament capacity C_g' should be shown shunted by the grid-filament input resistance, but for practical purposes the simpler arrangement illustrated in the figure is perfectly satisfactory.

The change of grid potential that is produced by the application of the signal voltage to the grid can be readily determined with the aid of the equivalent detector circuit of Fig. 2 and the formulas of Table I. This change of grid potential is simply the voltage developed across the grid-leak condenser impedance by the rectified grid voltage E_r acting in the equivalent circuit.

While the rectified voltage usually has a number of components, ordinarily only one of them is of practical importance. Thus in detecting a modulated signal voltage, the chief interest is in the component of the grid-potential variation that takes place at the modulation frequency. The change of grid potential for any such frequency component can be obtained as follows: Let E_r' be the component of rectified voltage of the desired frequency, as obtained from Table I, and let Z' be the impedance offered to this frequency by the grid-leak condenser combination. Then calling ΔE_g the change of grid voltage at the modulation frequency, reference to Fig. 2 gives:

$$\Delta E_g = E_r' \frac{Z'}{Z' + R_g}$$

The change of grid potential will be largest when the grid-leak condenser impedance Z' is great, but in no case can it exceed the rectified grid voltage E_r'.

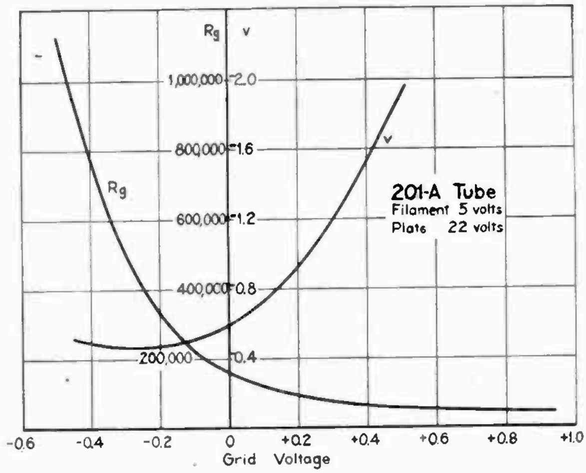

Fig. 3—Dynamic Grid Resistance and Voltage Constant As A Function of Grid Voltage.

The effect upon the plate circuit of the change of grid potential of the tube that takes place during detection can be determined by ordinary amplifier theory. In brief, a change of grid potential of ΔE_g is equivalent to inserting a voltage $-\mu\Delta E_g$ between the plate and filament of the tube in series with the dynamic plate resistance.

All equations essential to the computation of detector performance are given in Table I. Appendix I gives a complete set of computations for an actual numerical case.

Detection Constants

To set up the equivalent circuit of the vacuum-tube detector shown in Fig. 2 a knowledge of the dynamic grid resistance R_g is required. This is the resistance offered by the grid circuit of the detector tube to an increase of current caused by a slight increase in grid voltage. It is completely analogous to the dynamic plate resistance R_p, and depends upon the tube construction, and on plate, grid, and filament voltages.

The grid resistance of a typical vacuum tube is given in Fig. 3. The resistance, which is very low for positive values of grid potential, rises rapidly to high values when the grid is made negative by only a few tenths of a volt.

The quantity v that appears in Table I is the factor that takes into account the influence of tube characteristics upon the magnitude of rectified voltage produced when a signal is applied to the grid of the detector. This constant v has the dimension of a voltage, so can be appropriately called the *detector voltage constant*. The numerical value of the voltage constant v depends upon the operating grid potential, the plate voltage, and tube construction. Fig. 3 gives the effect of operating grid potential upon the voltage constant v for a typical tube. The rectified grid voltage is inversely proportional to v, so that an operating grid potential giving a small numerical value of v is desirable.

The detector voltage constant is determined by the grid resistance at the operating grid potential, and upon the rate at which the grid resistance changes with change of grid voltage. The exact relationship is given by the formula

$$\text{Detector voltage constant} = v = \frac{2R_g}{\dfrac{dR_g}{dE_g}}$$

Proof of this equation is given by Carson.[3]

A knowledge of the two detector constants, grid resistance R_g and voltage constant v, is all that is needed to compute the detector performance (i.e., to compute the change of grid voltage caused by the application of the signal voltage to the detector). Both of these constants can be measured by an alternating-current bridge suitable for measuring high resistances, such as shown in Fig. 4, in which the X arm of the bridge is supplied by the grid-filament resistance R_g.

The capacity C_1 balances out the grid-filament tube capacity and also stray capacities to ground of the 1000-cycle source. The input voltage to the bridge is controlled by resistance R_5

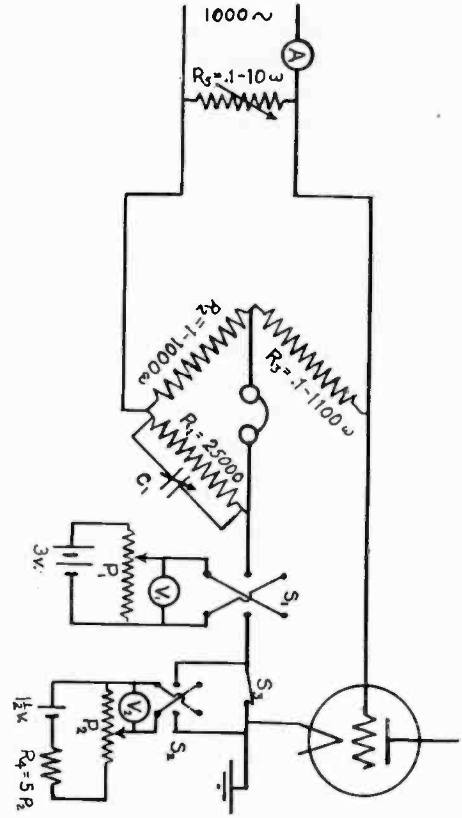

Fig. 4—Bridge Circuit for Measuring Detection Constants R_g and v.

and current read by thermocouple milliammeter A. The grid potential is controlled by variable voltages supplied from potentiometers P_1 and P_2 and read by voltmeters V_1 and V_2. Potentiometer P_2 supplies small but accurately known increments to the grid potential furnished by P_1, and can be cut out by switch S_3 when these increments are not needed.

Numerical values that have been found satisfactory for this equipment are given in Fig. 4.

To measure grid resistance with this equipment, potentiometer P_2 is cut out of the circuit by S_3, and the desired grid voltage is obtained by adjusting P_1 and the reversing switch S, The bridge is then balanced, which gives the grid resistance as

$$R_g = \frac{R_3}{R_2} R_1$$

The setting of the condenser C_1 does not enter into this result, although the condenser is necessary to obtain a null point.

The value of voltage constant v at this grid potential is obtained by measuring the grid resistance when the grid potential is higher and then lower than the potential at which v is desired, by a small amount ΔE. This increment of voltage can be obtained by connecting P_2 in series with P_1 by opening S_3. The increment ΔE is read by V_2 and can be made either positive or negative by the switch S_2.

Call E_0 the voltage read by V_1 (the potential at which R_g and v are desired), and let R_g' be the grid resistance at a grid potential of $(E_0+\Delta E)$, and R_g'' is the grid resistance at a grid potential $(E_0-\Delta E)$, then the grid resistance has been changed an amount $R_g'-R_g''$ by changing the grid voltage $2\Delta E$ volts. Accordingly

$$\text{Detector voltage constant} = V = \frac{2R_g}{\dfrac{(R_g'-R_g'')}{2\Delta E}}$$

The voltage constant is usually negative.

In measuring v and R_g, the input to the bridge should be kept low, preferably not over 0.10 volts effective. The voltage ΔE should also be small. Values of 0.05 volts have been found satisfactory. The sensitivity of the bridge can be increased by using an amplifier to detect balance.

This method of measuring R_g and v is quite accurate. The dynamic grid resistance can be measured to a number of significant figures that gives the difference $R_g'-R_g''$ with fair accuracy, and the increment of voltage ΔE is read directly on the millivoltmeter V_2.

The Grid Leak and Grid Condenser

The primary function of the grid leak is to fix the operating grid potential, which is the potential of the grid return lead minus the voltage drop produced in the grid leak by the grid current, at a value most suitable for detection. The higher the grid resistance the more negative will be the actual grid potential.

The proper size grid condenser is a compromise between two conflicting requirements. It should be large to by-pass the radio-frequency signal voltage to the detector grid with a minimum of voltage drop, and it should be small in order to offer a high impedance to the rectified grid voltage.

The loss of signal voltage due to a finite grid condenser of capacity C is easily analyzed. Referring to Fig. 1, let E_{osc} be the signal voltage applied to the grid circuit, with E_s the part of this voltage that actually reaches the grid. Then[4]

$$E_s = E_{osc} \frac{C}{C+C_g}$$

where C_g is the effective grid-filament capacity of the tube to the radio-frequency signal, and is generally less than the corresponding value at audio frequencies.

It is important that the loss of signal voltage in the grid condenser be kept small as the rectified grid voltage is proportional to the square of the voltage applied to the grid. Using a large grid condenser to accomplish this gives a low grid-leak condenser impedance, however, and hence a poor utilization of the rectified grid voltage present. The best compromise seems to be a grid condenser about ten times the effective grid-filament capacity at radio frequencies. This leads to grid condensers of 150 to 250 $\mu\mu$f.

Detection of Radio-telephone and Telegraph Signals

In the reception of telephone signals the rectified grid current contains the frequencies present in speech and music, and high-quality reception can be obtained only if all frequencies up to about 5000 cycles are about equally well reproduced.

[4] This formula neglects the effect of the grid-filament resistance that in reality shunts the capacity C_g. When the grid condenser is large compared with C_g, as is always the case, this approximate formula is sufficiently exact for ordinary work, even at low radio frequencies where the error is greatest. The exact formula is

$$E_s = E_{osc} \frac{Z_g}{Z_g + 1/jwC}$$

where

$$Z_g = \frac{1}{1/R_g + jwC_g}$$

The most satisfactory way of obtaining equally good detection for all audio frequencies is to select an operating grid potential that makes the grid resistance R_g lower than the grid-leak condenser impedance at all audio frequencies to be preserved. Under this condition the change of grid potential is only slightly less than the rectified voltage E_r acting in the equivalent detector circuit, and no matter how much the grid-leak condenser impedance may change with frequency, this impedance, being always greater than R_g, will receive most of the rectified grid voltage across its terminals.

As the proper grid condenser capacity has already been fixed at about ten times the effective grid-filament capacity, choice of the most suitable value of leak resistance must now be made. For the reception of telephone signals this selection should be such as to give an operating grid potential that meets the following conditions as far as possible: (1) the grid resistance should be high in order to reduce the radio-frequency energy consumption by the grid circuit; (2) the grid resistance should not be so high as to cause the higher audio frequencies to be poorly detected; (3) the detector voltage constant should be as small as possible, in order that a given signal will generate a large rectified voltage, thus giving high sensitivity.

The operating grid potential which best meets these requirements is a potential which makes the dynamic grid resistance approximately equal to the reactance of the effective grid-condenser capacity at the highest audio frequency that is to be preserved in the detector output. This arrangement reproduces the highest audio frequency desired about 70 per cent as well as the lower notes, because at all but the lowest audio frequencies the grid-leak condenser impedance is substantially the impedance of the effective grid capacity taken alone. A lower grid resistance gives unnecessary energy losses in the grid circuit, and in most instances a larger value of v, both of which result in lowered sensitivity. Higher values of grid resistance than that suggested give rise to undue distortion of the high notes.

In receiving radio-telegraph signals the important component of the rectified grid voltage is the audio-frequency note heard in the phones, and is usually about 1000 cycles. The detector is accordingly operated to give the maximum possible change of grid potential at this frequency, without regard to the detection of other frequencies, which normally means a more negative grid (and hence higher leak resistance) than is the case with phone reception.

The effect of the operating grid potential (and hence of grid-leak resistance) upon the quality of detection is shown in Fig. 5, which has been computed for the tube characteristics given in Fig. 3. It is seen that less negative operating grid potentials ob-

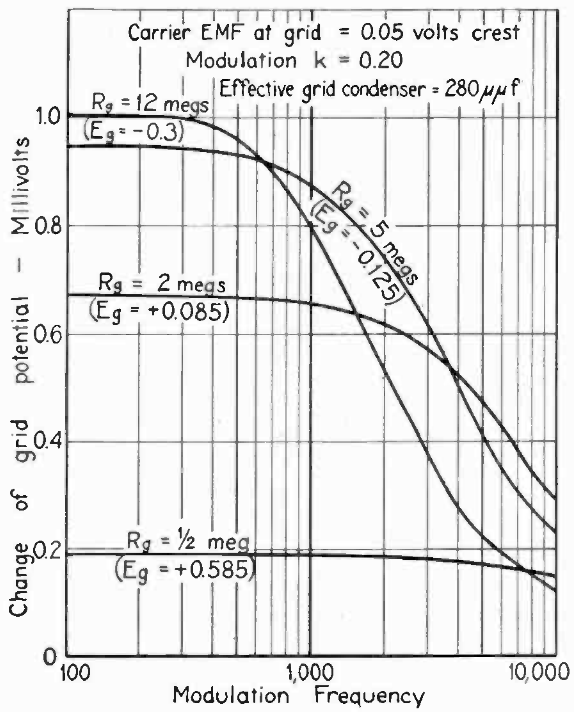

Fig. 5—Effect of Grid-Leak Resistance and Hence of Operating Grid Potential on the Performance of Detector of Fig. 2, Showing Crest Grid Potential Variation at Modulation Frequency As A Function of Modulation Frequency.

tained by the use of lower resistance grid leaks) give uniform detection for a wider range of frequencies than the more negative operating grid potentials (obtained by the use of high resistance grid leaks). A high grid-leak resistance gives better detection at low audio frequencies because the more negative operating grid potential gives a larger rectified voltage, but this gain is at the expense of poorer quality.

Assumptions Underlying the Theory of Detectors Given in Paper

The quantitative aspects of detector theory presented in this paper are subject to certain limitations. The fundamental assumptions are similar in nature to the assumptions underlying the equivalent circuit of the vacuum-tube amplifier, and are of the same order of magnitude.

The theory of detection as given holds exactly for infinitesimally small signal voltages, and its use also leads to correct results for all signal amplitudes which do not exceed the limits within which the detector current output is proportional to the square of the applied signal voltage. With high-vacuum tubes signal voltages of 0.05 volt effective and even higher come within the limit.

In the establishment of the equivalent detector circuit there is implied the assumption that the change of plate-filament voltage caused by the detection process has no effect on the action. Experiments have shown that this factor introduces no measurable error.

The treatment of detection that has been given applies to gaseous as well as high-vacuum tubes provided one works with signal amplitudes, values of ΔE, and bridge input voltages that are within the square-law limit of the tube characteristic. This requirement is easily met with hard tubes, but in gaseous tubes with "kinks" the limits are very small.

All plate-circuit rectification has been neglected. When present, such action can be computed separately, and the effects can be added to those produced by the grid action, taking into account the phase relations, which are normally more or less in opposition.

The analysis that has been made of detectors applies only to steady state conditions. The time constant of the grid circuit is so small, however, that transient changes are complete in less than the length of one cycle of the highest frequency that the detector satisfactorily reproduces.

Appendix I

Numerical Example

A radio-frequency voltage of 0.05 volts crest value modulated 20 per cent at 1000 cycles is applied to the grid condenser of the tube having the characteristics of Fig. 3, and operated at a grid potential of −0.125 volt. Essential information that would be known is:

R (giving desired grid potential)	5.0 megohms
R_g (from Fig. 3)	243,000 ohms
v (from Fig. 3)	−0.50 volts
Grid-filament tube capacity	
At radio frequencies	$20\mu\mu$f
At 1000 cycles	$80\mu\mu$f
Grid condenser	$200\mu\mu$f

The signal voltage actually applied to the grid is 0.05 (200/220) = 0.0454 volts. From Table I this voltage produces the following components of rectified grid voltage:

Direct-current component = 2.11 millivolts
1000-cycle component = 0.828 millivolts crest value
2000-cycle component = 0.0414 millivolts crest value

The 1000-cycle change of grid potential is found as follows. At 1000 cycles the impedance of the 5-megohm grid leak shunted by the effective grid condenser capacity of $280\mu\mu$f is $565{,}000 \underline{/-83 \text{ deg. } 31 \text{ min.}}$ ohms, and the impedance of the entire grid circuit is

$$565{,}000 \underline{/-83 \text{ deg. } 31 \text{ min.}} + 243{,}000 = 644{,}000 \underline{/-61 \text{ deg. } 19 \text{ min.}}$$

ohms. The 1000-cycle change of grid voltage therefore has a crest value of 0.828(565000/644000) = 0.725 millivolts.

In a similar manner the direct-current component of change of grid potential is 2.11(5000000/5243000) = 2.01 millivolts and the 2000-cycle change of grid potential is 0.0414(284000/383000) = 0.0307 millivolts crest value.

Volume 16, Number 10 *October, 1928*

SIMPLE INDUCTANCE FORMULAS FOR RADIO COILS*

By

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(Hazeltine Corporation, Hoboken, N. J.)

It is the purpose of this brief paper to present two simple formulas which the writer has found very useful for computing the inductance of the simple types of radio-frequency coils.

The new formulas are patterned after an empirical formula derived by Professor L. A. Hazeltine some years ago, for the

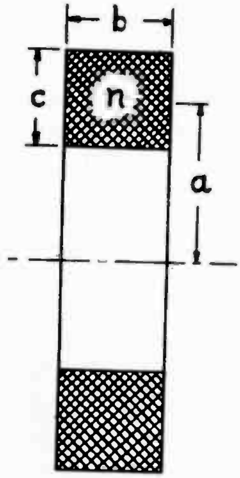


Fig. 1

inductance of a multi-layer coil. This formula follows, for dimensions in inches, according to Fig. 1:

$$L = \frac{0.8a^2n^2}{6a+9b+10c} \text{ microhenries} \tag{1}$$

This formula is correct to within about 1 per cent when the coil has approximately the shape shown in Fig. 1, such that the three terms in the denominator are about equal.

The new formulas were derived empirically from the inductance formulas and curves in Circular 74 of the Bureau of Standards. The corresponding coil formulas of this circular, however, either rely on tables or include expressions which are inconvenient to compute. For this reason there was a need for more convenient

* Original Manuscript Received by the Institute, June 18, 1928.

formulas, even with the loss of some accuracy, for use in the laboratory. The formulas to be given are easy to remember and can usually be computed with one setting of the slide rule.

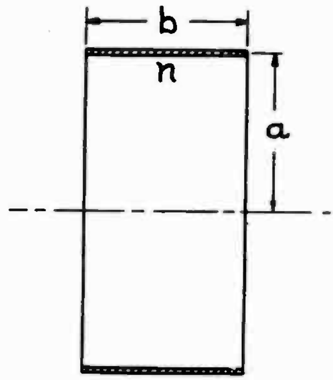


Fig. 2

One formula (derived in August, 1925) gives the inductance of a single-layer helical coil, in terms of the dimensions in inches, according to Fig. 2:

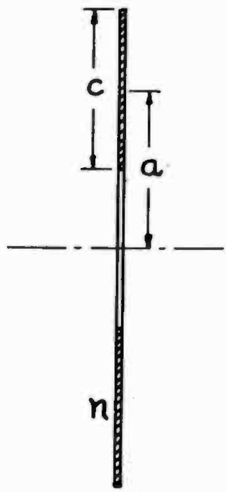


Fig. 3

$$L = \frac{a^2 n^2}{9a + 10b} \text{ microhenries} \tag{2}$$

This formula is correct to within 1 per cent for coils with $b > 0.8\,a$.

The other formula (derived in December, 1927) gives the inductance of a single-layer spiral (or helical) coil, in terms of the dimensions in inches, according to Fig. 3 (or Fig. 2):

$$L=\frac{a^2n^2}{8a+11c}\left(\text{ or }\frac{a^2n^2}{8a+11b}\right)\text{microhenries} \qquad (3)$$

This formula is correct to within 5 per cent for coils with $c>0.2\,a$. (or $2a>b>0.2\,a$).

In general, formula (2) should be used for helical coils, whenever $b>a$, since (2) is more accurate under this condition. For shorter helical coils, however, formula (3)—in parentheses—is more accurate, when $a>b>0.2a$. The two formulas (2) and (3) give the same value when $b=a$.

In both formulas (2) and (3), the accuracy may be less than the stated accuracy when there are too few turns, when the spacing between turns is too great, or when the skin effect and distributed capacity are important factors.

Volume 16, Number 10 *October, 1928*

A GANG CAPACITOR TESTING DEVICE*

By

Virgil M. Graham

(Stromberg-Carlson Telephone Manufacturing Company, Rochester, New York.)

Summary—*Testing equipment for gang capacitors for factory inspection must be simple, accurate, and reliable in operation. The test described uses two oscillating circuits, one of which is tuned by each unit of the capacitor gang in succession. The arrangement is such that the first unit acts as a standard for the other units. The zero beat method of measurement is used. The other oscillator is tuned separately and acts as a reference. The complete procedure of operation is described.*

THE gang variable capacitors of from three to five units that are used in modern single selector radio receivers offer a considerable problem when they must be tested in production or inspected in large quantities. Inasmuch as the successful operation of the receiver depends on the accuracy of this gang capacitor these tests are of utmost importance. They must be accurate and reliable in operation and for factory use must be simple. There must not be difficult initial adjustments which are liable to become disturbed when used a short time without the operator knowing that anything is wrong.

In view of all this a gang capacitor test has been devised which meets the major requirements. Two oscillators are used, the frequency of the first being controlled in three steps with a vernier adjustment, and the frequency of the second being controlled by the units of the gang capacitor which are inserted successively in the circuit.

This test is designed to read the variation of capacitance of the units of the gang with respect to the first unit as a standard. This is more important than the absolute capacitance of each unit, as the average capacitance may vary over a much larger tolerance than can the capacitance of the units with respect to each other. The gang capacitor units are tested at three positions, 0 deg., 90 deg., and 180 deg. In each position the first unit acts as a standard. The capacitors that this test was designed for are of such design that these three test positions are sufficient to insure accuracy throughout the range. Of course, if necessary more test positions could be provided.

* Original Manuscript Received by the Institute, June 28, 1928.

The first oscillator has three frequency settings, as stated above, corresponding to the three test positions of the gang capacitor. The frequency of this oscillator is three-fifths of that of the second oscillator at corresponding positions so that a zero beat can be obtained between the third harmonic of one and fifth harmonic of the other. This prevents the "pulling-in" effect. A vernier is provided in the first oscillator to compensate for variations in average capacitance of the gang capacitor.

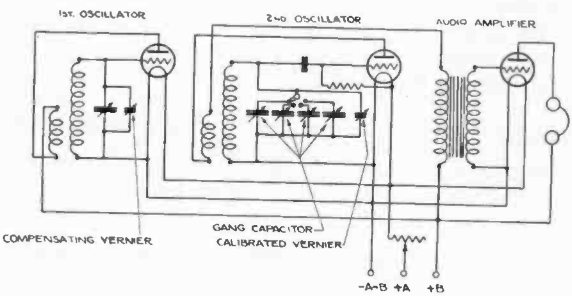


Fig. 1

The variation between units is indicated on a vernier capacitor which is connected across the second oscillator, the one in which each unit is connected successively. This vernier is calibrated in micro-microfarads.

The operation is as follows: The gang capacitor is inserted in the fixture, set at minimum (0 deg.), and the first unit is connected to the second oscillator, the calibrated vernier capacitor being set at zero. A "zero center" is used so that both plus and minus tolerances can be obtained. Next the first oscillator is set at the proper position and its vernier is adjusted so that a zero beat between the two oscillators is obtained. Now the first capacitor unit is disconnected from the second oscillator circuit and the second unit connected in. The calibrated vernier on this oscillator is adjusted until zero beat is again obtained. The reading of this vernier gives the difference in capacity between the first and second units of the gang capacitor. Of course, the first oscillator is not touched during this adjustment. The rest of the units of the gang are now connected successively and their capacitance with respect to the first unit obtained.

Now the gang capacitor is set at 90 deg. and at maximum, going through the same procedure with each of these positions.

It can be readily seen that a slow drift in the oscillators due to battery voltage changing, etc., while not desirable would not be particularly serious as the first oscillator vernier is adjusted with every gang capacitor. This means that the reference is constantly checked and as long as there are no momentary changes the outfit cannot give trouble from poor adjustment.

Fig. 1 shows the circuit of the arrangement.

Volume 16, Number 10 *October, 1928*

RADIOTELEGRAPHIC CENTER AT ROME (SAN PAOLO)*

By

G. Pession and G. Montefinale

(Rome, Italy)

Summary—*The radiotelegraphic station at San Paolo constitutes*[1] *the first and largest continuous wave radiotelegraphic installation (Poulsen arc of 250 kilowatts) constructed in Italy in 1917.*

The service with the Poulsen arc, which has been completely satisfactory, reached its greatest development in 1922, in which year there were transmitted 2,175,000 paid words directly to stations in East Africa, United States, England, Germany, Switzerland, Norway, Roumania, and ships and stations in Egypt.

The decrease in the number of transmitted words in 1923 resulted from the repairing of the Poulsen arcs and the complete replacement of the towers, for which reasons the station of San Paolo was inactive for six months, during which time the service went through the new Coltano[2] *station temporarily.*

The complete reconstruction of the 218-meter wooden towers which had been standing for only six years was a necessary consequence of the rapid war-time construction for the purpose of establishing more direct communication with America and with the colonies. After repairing the towers it was possible to erect two or more of the same type with some of the remaining timber, still in good condition; one to wer 124 meters in height, used as an anchor tower for the tail of the antenna, allowing less sag; the other 86 meters in height, used as a support for the auxiliary antennas. The reconstruction was quickly accomplished and at a low cost.

The old antenna, of the triangular net form made of square mesh, was replaced by a lighter one, of the horizontal fan type, of 16-strand phosphor bronze wires 4 millimeters in diameter. Later a multiple grounding system was constructed, using one telegraphic wire 3 millimeters in diameter.

The efficiency of the station was improved because it was possible to obtain in the antenna a current of 120 amperes for the 10,750-meter wave by applying to the arc a reduced voltage of 500 volts instead of 800 volts, which was formerly necessary.

Notwithstanding its good performance, the Poulsen arc station at San Paolo, which is located on the outskirts of Rome, caused a great deal of trouble

* Original Manuscript Received by the Institute, January 4, 1928. Paper presented at the thirty-second annual meeting of the A.E.I., Como, Italy, October, 1927. Translated from *L'Elettrotecnica*, Journal of the Associazione Elettrotecnica Italiano, XIV, No. 19; July 5, 1927.

[1] B. Micchiardi, G. Pession, G. Vallauri, "The Radiotelegraphic Station at Rome, San Paolo." *L'Elettrotecnica*, Maggio 1920, Vol. VII, N. 13–14 e Pubblicazione, N. 8. dell' Istituto E. e R.T. della R. Marina. Proc. I.R.E.. 8, p. 142; April, 1920.

[2] G. Vallauri, "The Radiotelegraphic Center at Coltano," *L'Elettrotecnica*, Gennaio 1924, Vol. IX, N. 1, e Pubblicazione, N. 28, dell' Istituto E. e R. T. della R. Marina. Refer also to earlier paper published in Proc. I. R. E.

to public and private services in the city and surrounding country. The characteristic noise and numerous harmonics brought on by the operation of the Poulsen arc are responsible for this.

In San Paolo, while the installation work was progressing on a new, powerful long-wave tube apparatus already designed to purify the harmonic waves of the Poulsen arc transmission by the addition of an adequate intermediate circuit, the short wave was utilized, which was a development of great importance rapidly accomplished in 1924. This change permitted the development of an entirely new method of transmission which attained the same results with less expensive apparatus. This apparatus has been fully described.[3,4]

I. Short-Wave Service of the San Paolo Radiotelegraphic Station

In the San Paolo station in 1926 besides the Poulsen arc transmitter of 250 kilowatts (10,750-meter wave) the following were in service:

(a) One 6-kilowatt tube transmitter operating on 66-meter wavelength.

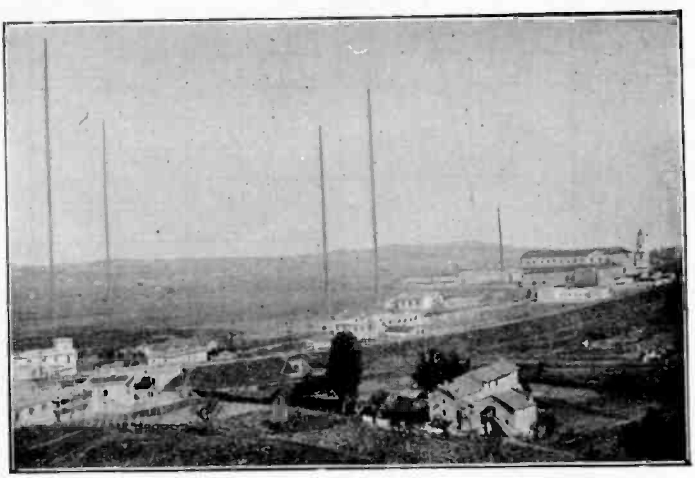


Fig. 1—View of the San Paolo Radiotelegraphic Station.

(b) One 6-kilowatt transmitting tube set operating on 32-meter wavelength.

[3] G. Pession, A. Pizzuti, "Experimental Contribution on Short-Wave Radiotelegraphy," *L'Elettrotecnica,* Marzo 1925, Vol. XII. N. 7 e Pubblicazione N. 32 dell' Istituto E. e R. T. della R. Marina.

[4] G. Pession, G. Montefinale, "Commercial Radiotelegraphic Experiments with Short Waves." *L'Elettrotecnica,* 15 Luglio 1926, Vol. XIII, N. 20 e Pubblicazione N. 36 dell' Istituto E. e R. T. della R. Marina.

With these transmitting tube sets, which showed perfect and reliable operation during the service tests and are still in use, it was possibly gradually to expedite a great part of the traffic, as may easily be seen from the following list of words transmitted by the radiotelegraphic station at San Paolo in April, 1927.

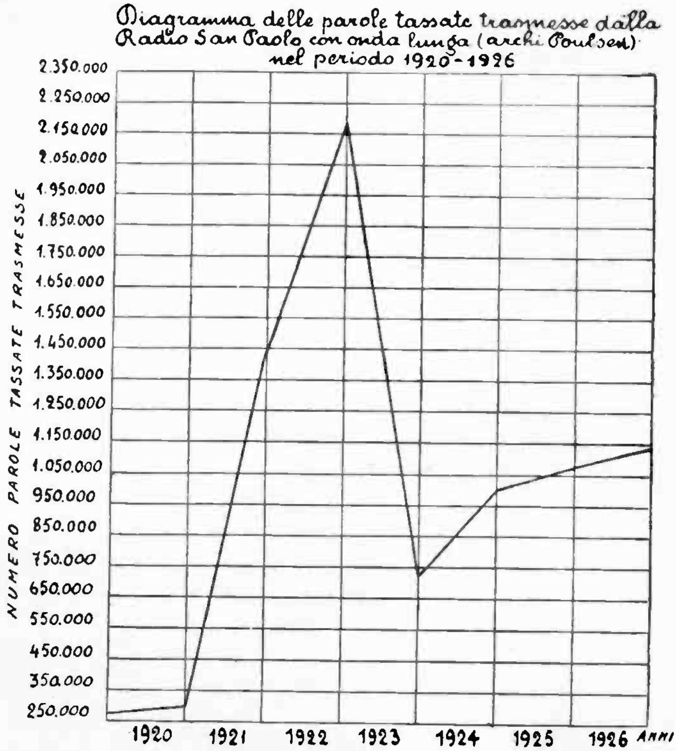


Fig. 2—Graph of the Paid Words Transmitted by the Radiotelegraphic Station at San Paolo on Long Wave (Poulsen Arc) during the 1920–1926 Period.

TABLE I

Destination	Number of Transmitted Words	
	Arc—10,750-meter Wavelength	On Short Wave
Ships	4,530	......
Far East (Pekin)	......	7,477
Afgoi (Somaliland)	......	32,522
Asmara (Eritrea)	......	54,365
Rodi	11,432	37,923
Bengasi	2,590	......
Tripoli	1,921	......
Press	21,013	9,077
News	11,811	......
Total	53,297	141,364
	Grand Total	194,661

II. Perfecting the Receiving Station

Notable improvements were made in the Monterotondo receiving station, which made possible the reception of long-waves of 600 meters and up by the use of an external receiving coil, and an ordinary antenna supported by two trees 32 meters high for the reception of intermediate waves (2000 meters) from ships. There were also specially designed antennas for short-wave reception. (Beverage).[5]

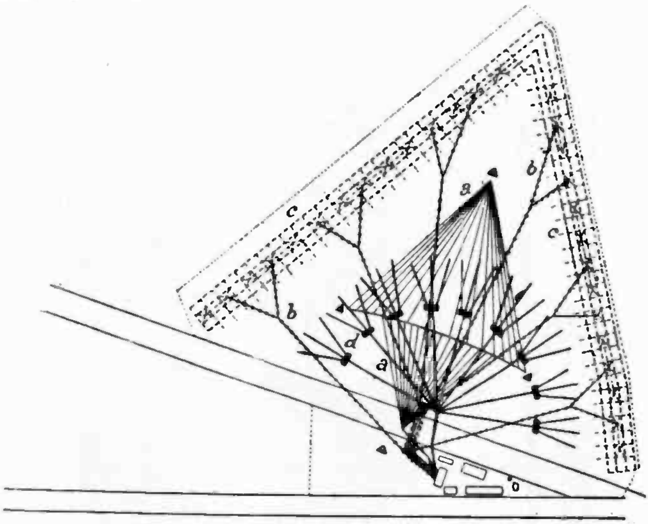


Fig. 3

It was possible to provide for the reception of signals in various wave bands as follows:

(a) Long-wave reception by means of outside loop antenna.
(b) Intermediate wave reception with ordinary antenna.
(c) Far East (Pekin) reception with 57-meter wavelength.
(d) Italian Somaliland (Afgoi) reception with 38- and 70-meter wavelength.
(e) Red Sea Colonies reception with 60-meter wavelength.
(f) Near East (Rodi) reception with 73-meter wavelength.
(g) Cyrenaica (Bengazi) reception with 53-meter wavelength.
(h) Tripolitania (Tripoli) reception with 51-meter wavelength.

[5] G. Pession, G. Montefinale, loc. cit.

The (a) service is of a sporadic character, and (b) continues day and night. All other services work on fixed time schedules.

Normally, the services (b), (c), and (d) are carried simultaneously from 4:00 P.M. to 2:00 A.M. G. M. T., which is the best time for the station to operate.

The short-wave reception for the three transcontinental stations, Pekin, Afgoi, and Asmara, and from the sea stations on the Mediterranean at Rodi, Bengazi, and Tripoli was had with

Fig. 4—Outside View of the Monterotondo Receiving Station.

great regularity under all atmospheric conditions, even during electrical storms, which are very frequent. During 1926 and also during the first months of 1927, there has not been a single service interruption, as contrasted with the many difficulties with long-wave reception which characterized the preceding years.

As an example, the monthly reports of words received by the short-wave receiving set at the Monterotondo station can be consulted.

TABLE II

SUMMARY OF THE RECEPTION WORK ON SHORT WAVE; COPIED FROM MONTEROTONDO STATION, APRIL, 1927

Station of Origin	Number of Received Telegrams	Number of Received Words
Ships	101	2,705
Pekin	617	26,447
Afgoi	2,334	52,023
Asmara	2,284	55,832
Rodi	2,405	43,882
Bengazi	258	4,222
Tripoli	90	3,463
Total	8,089	188,574

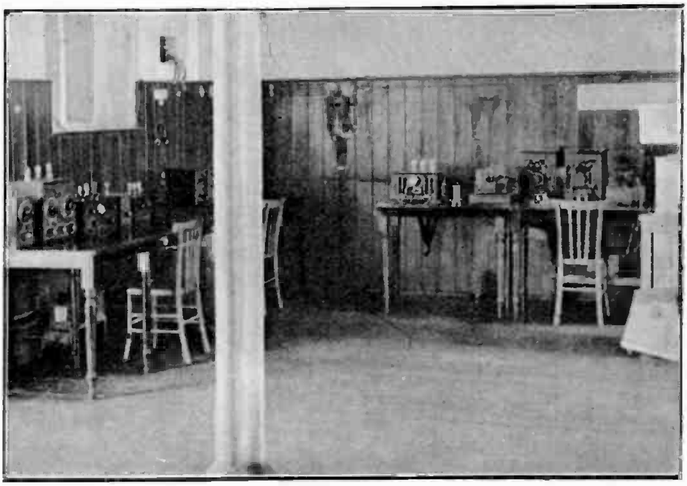


Fig. 5—Interior of the Monterotondo Receiving Station.

III. CAPACITY INCREASE OF THE SHORT-WAVE SETS

Any station similar to that of San Paolo must be able to transmit simultaneously to several corresponding stations; also to ships on the high seas at any time, or at least during the main part of the day, and to the greatest possible distance.

Experience has demonstrated that the arc installation of the San Paolo station has a range not greater than 4500 kilometers. The small 6-kilowatt short-wave stations permit better communication to a greater distance, but only for a few hours.

Therefore the problem of increasing the power of transmission arose immediately. It seemed logical to discontinue the use of long-wave sets and to substitute relatively low-power, short-wave sets at the station. As a solution of the problem the increase of the transmission power by using waves of the same order of length was therefore considered practical.

It was then decided to experiment with new types of tubes with water-cooled plates, which had the advantage of operation at relatively high power with such units connected in parallel. This would reduce the effect of the capacity between electrodes in oscillatory circuits, which is of particular importance in short and ultra short-wave work.

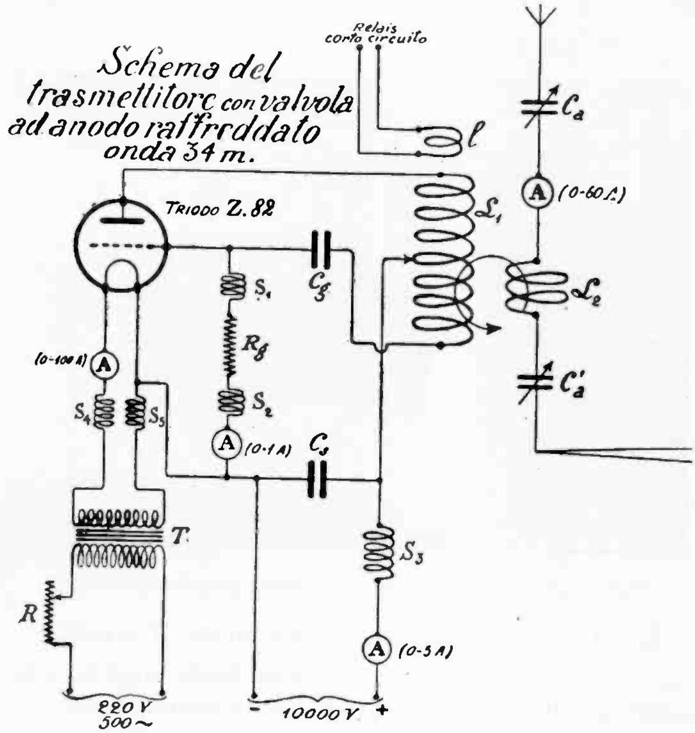


Fig. 6

The selection of tubes after the experiments favored the Ditta Philips 25-kilowatt Z.82 tubes for the production of short waves.[6]

[6] The general layout and operation of the three-electrode tube and reservoir are shown in Fig. 7. The main data for its operation are:

Voltage for Filament Lighting	16–17 volts
Current for Filament Lighting	17 amperes
Plate Voltage	about 12,000
Saturation Current	near 8 amperes
Input	25 kw
Maximum Diameter	160 mm
Maximum Length	700 mm
Internal Capacity, Plate-Grid	29 $\mu\mu$f
Internal Capacity, Plate-Filament	11 $\mu\mu$f
Internal Capacity, Grid-Filament	3 $\mu\mu$f

The details of construction of the three-electrode Z. 82 Philips tube are described in the Ditta Publication. The plate is formed of nickel-

IV. 34-Meter Short-Wave Generating Circuit with Water-Cooled Tubes

For the construction of the new transmitter sets with selected 25-kilowatt water-cooled tubes, the circuit indicated in Fig. 6 was used for the 34-meter wave.

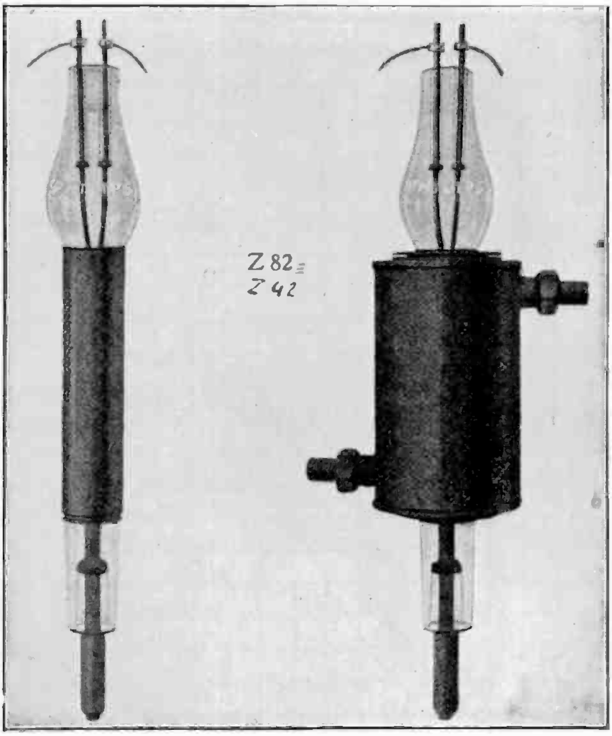


Fig. 7

The insulation of the various parts of the 25-kilowatt sets was taken into particular consideration, using special pyrex glass

iron cylindrical sheath, welded at the ends by a special process and protected by two glass prolongations that, together with the plate, complete the whole enclosure of the three-electrode tube. The filament is made of 8/10 mm. diameter tungsten wires connected in parallel. The grid is made from a cylindrical metal mesh concentric with the filament. Both ends of the filament came out at the upper neck of the glass and those of the grid at the lower one. The grid is 22 cm. long, the plate 24 cm. and the filament about 18 cm. The diameter of the plate is 6 cm.

Fig. 8 contains the plate characteristic curves of one water-cooled tube Z. 82 operated with negative grid potential of 400 volts and plate potential of 8,000, 10,000, and 12,000 volts.

insulators built according to Royal Navy design by M. I. V. A. Acqui Society (Italy).

In the regulation of the 34-meter short wave, it was found necessary to place the two impedances of the S_1 and S_2 coils on either side of the grid resistance, with the impedance S_4 and S_5 correctly proportioned at both ends of the filament. The keying

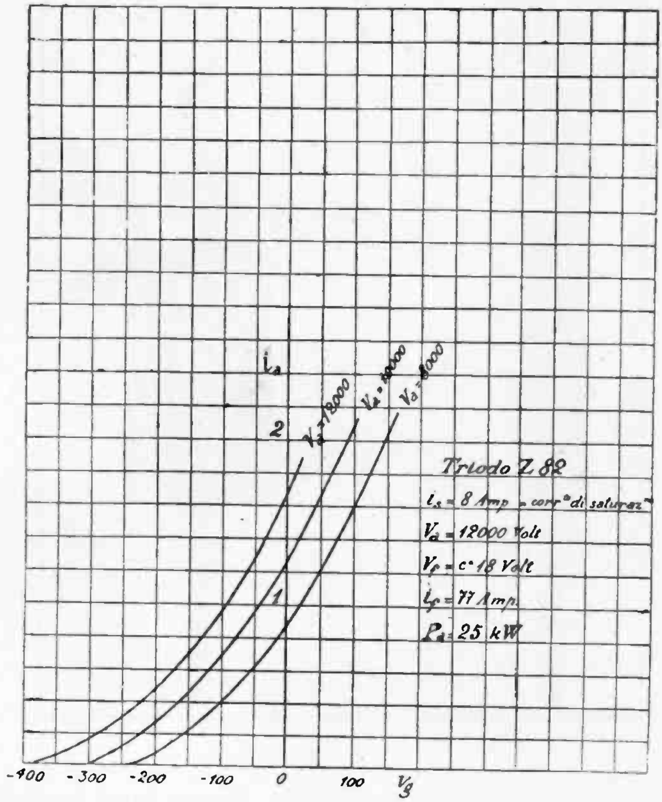


Fig. 8—Plate Performance Curves of the Three-Electrode Tube, Operated with Negative Grid Potential of 400 volts and Plate Potential of 8000, 10,000 and 12,000 volts.

was accomplished by using the absorption method (with counter wave), short circuiting the two turns of the connected inductance during the pause by means of specially designed relays.

The voltage necessary to light the filament of the 25-kilowatt three-electrode tube was furnished in exactly the same way as the other short-wave transmitter at the San Paolo station, reducing by means of a suitable transformer the 220-volt, 500-cycle current produced by a 10-kilowatt converter supplied by the 500-volt, 44-cycle city mains. The regulation of the filament lighting requires considerable precision and could be made either by varying the alternator excitation or by using a variable iron-core impedance coil of special design in series with the 220-volt primary circuit.

The plate voltage of 10,000 was obtained by rectifying the 500-cycle single-phase alternating current supplied by a 75-kilo-volt-ampere alternator (Fig. 9). The pulsating current furnished by the rectification of the 500 cycles was smoothed by means of

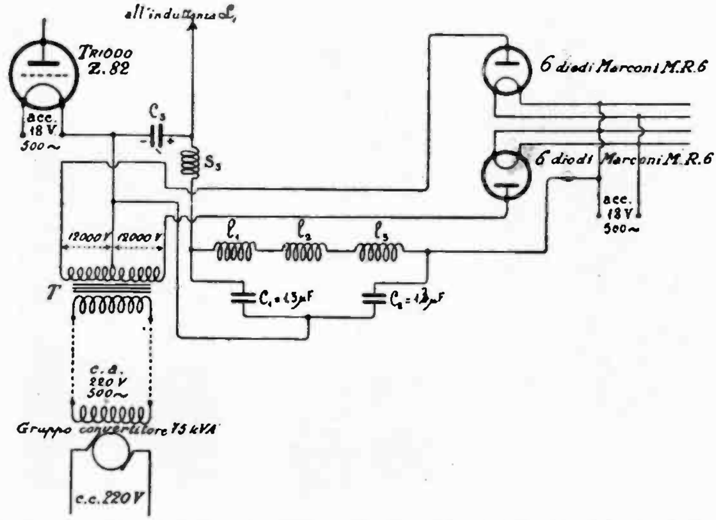


Fig. 9—Circuit of 220-volt, 500-cycle Rectifier with Six Marconi Two-Electrode Tubes in Each Side.

a filter made of impedance coils, 3 henries, each connected in series, and two C_1 and C_2 condenser banks of 1.3 μf each.

The external cooling of the plate by water circulation was arranged by a connection to the pipe which delivered the water for cooling the Poulsen arc. To obtain a convenient pressure, a tank was placed about 60 centimeters higher than the lower neck of the tube. From the tank a coiled rubber tube 12 millimeters in diameter and 10 meters in length (Fig. 10) delivered cold water to the lower orifice of the refrigerator. The water heated by the plate's dissipated energy is discharged from the upper orifice by means of another coiled rubber tube of the same length. Moreover, an efficient system of cooling was provided for the plate. Compressed air at a pressure of not less than 60 centimeters of water was used. To cool sufficiently the soldered joints between the electrode and glass of the tube, the filament connections, and the contact of the grid with the internal supports of the filament, it was necessary to use about 300 litres of compressed air per minute.

The compressed air, which in the San Paolo station is produced by a suitable electric compressor, is delivered to the inside of the tube through a system of six small tubes; these are located in the upper neck as follows: two for the filament, one for its

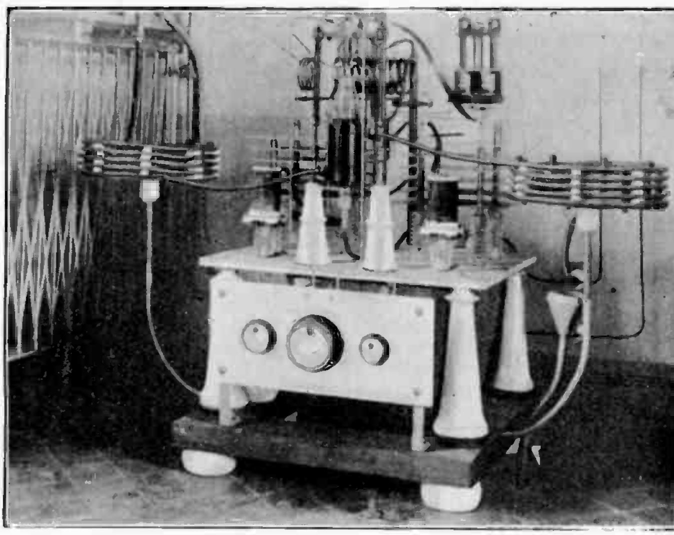


Fig. 10—Short-Wave Transmitter with Cooled (Three-Electrode) Tube.

lower support, two at both sides for the union with the plate cylinder, and one fixed at the lower neck for the union to the grid. The water tank was provided with an automatic floating device that cuts off the plate voltage when a lack of water circulation occurs.

V. Results of Experiments with the 34-meter Waves

The first test on short waves employed about 15 kilowatts, which produced a current of 24 amperes in the antenna. At Rod the signals were usually very strong. The Tien-Tsin station reported having had very strong signals during the night, using the receiver with only the ground connection. Disconnecting both antenna and ground from the receiver, signals of the strength of

8 (very strong) were received. A more complete test was made on December 7, 1926, transmitting during the first 20 minutes of every hour from 12 A.M. to 6 P.M. G. M. T. The use of the 6-kilowatt set did not provide short-wave service with distant stations.

From such tests it can be concluded that by employing 34-meter length waves with 15-kilowatt power, it was possible to give a 12 hours' continuous service during the winter season with the Far East, an 18 hours' service with Somaliland, 20 hours' service with Eritrea, and practically continuous service with the station of the Dodecaneso and North African colonies.

It was apparent from the tests that, notwithstanding the increase of power, it was impossible to eliminate the silent zones at short distances from the station, which increased at night and gradually decreased as daylight came on.

With the installation described, using 20-kilowatt power, it would be possible to have a practical daytime range of about 6000 kilometers, a distance greater than that obtained by using the old 250-kilowatt long-wave Poulsen arc.

A station identical to that of San Paolo was constructed at Spezia and exhibited at the Volta Exposition at Como.

VI. Completion of the Central Station at San Paolo in 1927

The installation at San Paolo was completed with an intermediate wave transmitter of modern type, powerful enough to establish communication with the Mediterranean Sea stations.

A 15-kilowatt tube transmitter was constructed which consisted of 12 Marconi M. T. 6 three-electrode tubes and a large inductance for coupling to the antenna, as represented in Fig. 11. The filament lighting of the M. T. 6 bulbs was made similar to that of other tube sets installed at San Paolo with 500-cycle single-phase power. The plate potential of about 6000 volts needed to operate the tube could be obtained either from the rectifier which supplied the plate potential to the 6-kilowatt short-wave set, or from the 500-cycle converter (Fig. 10) that feeds the short-wave station using the 25-kilowatt metallic tubes.

The high-frequency current generated by the set mentioned above was fed to the big antenna at San Paolo which, because of its great power of radiation and its low ground resistance, offered particularly favorable conditions. With the use of such an antenna it was easily possible to reach the 4800-meter service wave, the current at the base of the antenna being about 38 amperes. By inserting in the antenna an air condenser made by two condensers connected in parallel (each containing 26 cm by 60 cm plates separated 45 mm), a 2250-meter wave with a current of about 18 amperes was obtained.

By the use of the method just described (i.e., for 2250- and 4800-meter waves) the San Paolo station could communicate easily with every European station and any point on the Mediterranean Sea. There was also installed at San Paolo a special short-wave auxiliary set devised for those communications in which

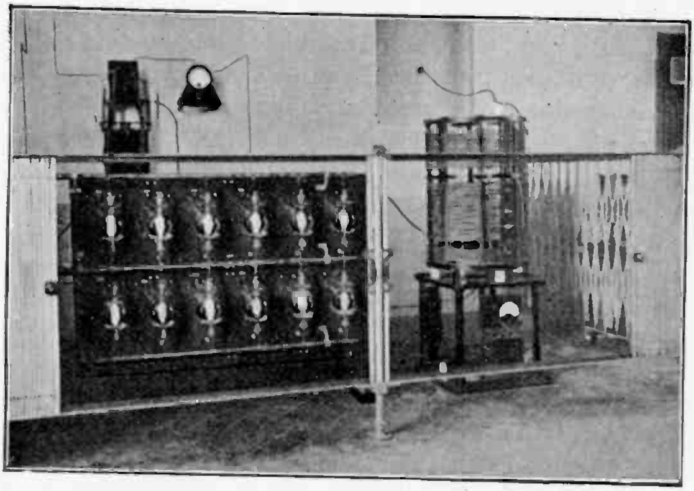


Fig. 11—15-Kilowatt Long-Wave Tube Transmitting Set.

the 32-meter (6-kilowatt) short-wave transmission was not heard (silent zone). The 3-kilowatt set was constructed entirely at the San Paolo Laboratory using the same diagram adapted for the transmitter of 25-kilowatt cooled electrodes, employing as an oscillator three Marconi M. T. 6 three-electrode tubes in parallel, and rectifying the 44-cycle public service power. This rectifier was made up of M. R. 6 two-electrode tubes, an equalizing circuit of 3 μf condensers, and a 20-henry impedance coil.

The peculiarity of such a transmitting system is that it acts synchronously with the radiotelegraphic receiving station at Rome. Operation from this station is made by means of a special telegraphic line.

After investigation, a relay system was installed by means of which the operator in service at the receiving station could light the tube filaments, apply the plate potential, and start the blower for cooling. Likewise San Paolo could transmit with short waves, not only to remote stations, which was the principal aim, but also to ships on the Tyrrhenian Sea.

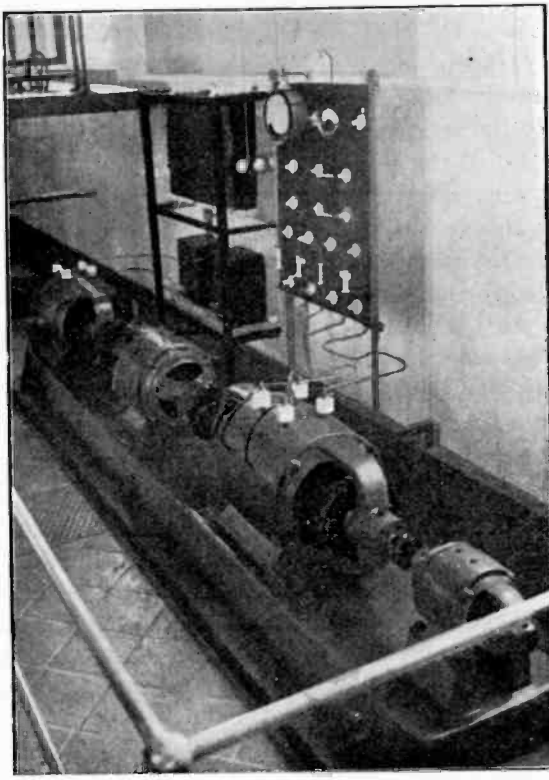


Fig. 12—High Tension Generating Unit (6000 volts) of the San Paolo Radiotelegraphic Station.

To make transmission tests using a more balanced plate voltage than was obtained by rectifying single-phase or three-phase alternating current, there was installed a high-tension generating set (Fig. 12) which furnished 6000 volts direct current necessary to operate the 66-meter wave apparatus.

This generating set built by the Ditta "Bayerische Elektricitats-Werke" is made up of a 6.9-kilowatt, three-phase, 500/290-volt, 44-cycle asynchronous motor with two 3-kilowatt direct-current generators driven directly coupled to both ends of the motor shaft, with 110-volt separate excitation, each one capable of furnishing 1 ampere and 3000 volts at 2550 r.p.m. Normally the generators are connected in series, thus obtaining the plate voltage of 6000 volts direct current.

The most important conclusion drawn from experience at San Paolo is the perfect regularity of the short wave. During service hours it was noted that the signals were of constant strength and nearly independent of atmospheric conditions. Fading occurred rarely and, in general, produced no appreciable disturbance to the service.

As a rule, all the service in connection with permanent stations and with foreign ships was performed in a satisfactory manner by using the 32-meter (6-kilowatt) short-wave transmitter while the service of the 34-meter (25-kilowatt) short wave was reserved for larger power requirements. During the winter the Pekin station received the 66-meter wave better, whereas during the summer the 32-meter was preferable.

From the numerous tests made, the behavior of the different waves used at San Paolo was perfectly understood. From 106 meters down to 32 meters (wavelengths of 106 meters, 80 meters, 66 meters, 50 meters, 40 meters, 34 meters, 32 meters were under experiment) it was clearly noticed that the longer wave shows the difference between day and night ranges better. With 106 meters and 80 meters, the day range is reduced much more than at night (about 25 times that of the day with devices used at the San Paolo station). The 50-meter wave gives a considerable day range. Going down to 40 meters, near which the silent zone begins to be noticed at night, the reception decreases rapidly even at distances of 50 to 100 kilometers, varying with the power used. After the reception has been secured in a more or less extensive zone, depending on the station and the hour, it comes back and is very intense even at a great distance.

The 32-meter wave has a day range much better than the preceding ones. At night the silent zone is remarkably complete at skip distances, ranging from 500 to 1500 kilometers, depending on the season. Using a 32-meter (6-kilowatt) wave, it is possible, for instance, to communicate during the daytime with ships on the North African and Egyptian coasts, whereas during the night communication is defective and at certain hours impossible with stations at Rodi. Frequently communication is not obtained at all even with stations at Spezia, Maddalena, Napoli, etc. On the other hand, signals from Mogadiscio, Massaua, and Pekin are very strong.

It has certainly been demonstrated that atmospheric disturbances decrease as the wavelength decreases. The following is an example: at one of the stations in Somaliland a 70-meter (6-kilowatt) set was operated together with a 38-meter set with smaller input. On many evenings reception at Monterotondo was impossible when using 70-meter wavelength on account of atmospheric disturbances, while it was easily obtained with 38-meter wavelength. For this reason the 38-meter wave was used to clear up the traffic.

Some stations in the Far East have reported satisfactory reception during the day for many hours, on a 15-meter wavelength.

As to the properties of the short waves over close ranges, the observations made at San Paolo correspond perfectly with those obtained at the Laboratory at Schenectady, with wavelengths of about 33, 65, and 109 meters.[7]

Some technical experiments that were conducted will be briefly described here. In particular:

1. To find the most convenient type of antenna for both transmission and reception.

2. To improve the stability of the frequency and the tone modulation.

Nothing positive was found for the transmitting antenna since none of the numerous experiments yielded results either better or worse than the rest.

It could be proved that there was a perfect equivalence between the vertical 30 deg. to 40 deg. angle type V antenna excited by a neighboring electrical field vibrating with a certain number of semi-waves (as are those previously described in other publications[8]) and the simple antenna slightly inclined, similar to that known as the Hertz type, the radiating part of which is formed of a single wire and a convenient Hertzian double wire feed at the center.

No noticeable difference was found in the intensity of the signals by varying the height of the suspension point successively. As an example there could be cited the experiment conducted September 13, 1926, when the antenna wires were extended

[7] M. L. Prescott, "Tests of Radio Propagation on Short Wavelengths." *General Electric Review*, 30, No. 2; February, 1927.

[8] G. Pession, G. Montefinale, loc. cit.

horizontally 5 meters above the ground during transmission with a 66-meter wave. There was obtained in the stations in contact with other stations such as Pekin, Afgoi, and Chisimaio the same intensity of signals as that of stations transmitting with high antenna.

Similarly, the commonly-used 0.011 μf fan-form antenna of 3500-meter natural wavelength was tested, transmitting with a short wave. Even with this the corresponding distant station did not show any difference in strength of signals in the telephone. Identical results have been found using simple, single-conductor antennas and the flat or tubular multiple conductor, which have been used normally in the service with intermediate and long-wave transmission.

In regard to the reception, it was proved conclusively that of all types of antennas described above, the best proved to be the horizontal one of very little elevation and grounded at the other end of the receiving set.

With this antenna, known as the Beverage antenna,[9] it is possible to obtain stronger signals than with the vertical one, especially at night, together with a remarkable immunity from atmospheric disturbances.

One night when some experiments on atmospheric disturbances were being carried out during a very violent storm with many electrical discharges that made impossible any services using long-wave transmission and necessitated grounding the telegraphic line, the best reception from Rodi, Asmara, and Afgoi was noted. Only occasionally some letters were lost in the noise of the storm that caused a deluge upon the station and short-circuited the receiver.

After testing various types of receiving sets it was found that the superheterodyne circuit was the best. For practical purposes, however, a simplified receiver with a regenerative tube in series with an audio-frequency stage through an audio-frequency filter and two stages of amplification was preferred.

The signals were very strong and constant and their intensity could be well regulated upon the filter coupler by a very loose coupling. The received voltage was sufficient to override atmospheric disturbances. Small variations in frequency were easily followed without causing the operator to lose the signals. This set utilized a Wheatstone Recorder.

[9] G. Pession, G. Montefinale, loc. cit.

Tests were conducted to determine the shortest distance to which the transmission of duplex service was possible with certain wave differences. With the filter, this distance could be reduced to a minimum, using a slightly different wavelength. Actually, it was fixed at 500 meters as the minimum practical distance with which the San Paolo station receiver could operate, when the 34-meter transmitter was being used. For other lengths, as 38-meter or more, this distance became greater.

In regard to tests made to improve the stability of frequency, the following results were obtained:

With the simple diagrams and schemes used, it was impossible to obtain a pure and constant note, although well-rectified direct current was used to supply the plate. This failure was blamed on the use of alternating current for lighting the filament, but even more on the irregularity of tube operation. The capacity of the tube is an essential element in determining wavelength. This capacity undergoes certain variations during operation caused either by the unavoidable small vibration or by the capacity being shunted by the internal resistance of the tube. The latter is not perfectly constant. The note became worse with the increase of power as well as with the shortening of the wavelength. The tone of transmission in the San Paolo station was sufficiently constant and clear to permit good reception. It was considered unnecessary to use a more complicated diagram and scheme (oscillatory excitation and crystals) which would be justified only in the case of rapid and commercial service. For practical purposes, the simple sets of the San Paolo station had been demonstrated to be sufficient for the service required, when conducted by skilled personnel.[10]

The variations of frequency over rather long periods of time, which before were serious, proved to be greatly dependent on the variations of the voltage applied to the filament. To eliminate this, a separate voltage regulator was used for each set.

The remarkable improvements made in the radiotelegraphic center of San Paolo, Rome, during 1926 and 1927 were particularly accomplished by Lieutenant Baccarani Ugo, the radiotelegraph operator in charge of the San Paolo station, and Antonelli Fabrizio, who constructed the sets and conducted the test and experiments.

[10] In the course of 1928 the long-wave transmission and reception at San Paolo has practically ceased. All the traffic of 400,000 monthly paid words is developed only with short-wave sets.

Volume 16, Number 10 *October, 1928*

Discussion on
ON THE DISTORTIONLESS RECEPTION OF A MODULATED WAVE AND ITS RELATION TO SELECTIVITY*

(F. K. VREELAND)

R. Raven-Hart†: Dr. Vreeland does not appear to have taken into consideration the "demodulating" effect of a stronger on a weaker signal, to use the term suggested by Dr. Beatty[1].

If the condition stated by Dr. Beatty, that the carrier wave of the weaker signal must be reduced to one-tenth that of the stronger one, is valid (and personal observations would lead me to believe that even this condition is too stringent, at least for French tubes: it depends of course on the degree of linearity of the detector characteristic), then the selectivity resultant on reducing the interfering signal strength to 1.5 per cent of the signal carrier frequency cannot be considered as merely "passable."

In fact, sufficient selectivity would be obtained with a curve intermeditate to those for effective resistances of 1 and 2 per cent on Dr. Vreeland's Fig. 3, and such a curve would give a response at 10 kilocycles distance of about 40 per cent of the carrier, assuming curves such as Dr. Vreeland shows.

If, however, curves such as those given by Mr. Jones[2] are assumed, this value of 40 per cent becomes more like 70 per cent which is probably acceptable, especially in view of the fact that these extreme frequencies are rarely transmitted in practice.

* Presented at the Annual Convention of the Institute of Radio Engineers, January 9, 1928. PROC. I.R.E., 16, 255; March, 1928.

† Consulting Engineer, Paris, France.

[1] "The Apparent Demodulation of a Weak Station by a Stronger One." *Wireless Engineer;* June, 1928.

[2] PROC. I.R.E., 16, 671; May, 1928.

Volume 16, Number 10 *October, 1928*

A DECIMAL CLASSIFICATION OF RADIO SUBJECTS; AN EXTENSION OF THE DEWEY SYSTEM*

PREPARED BY
BUREAU OF STANDARDS, WASHINGTON, D. C.

IN 1923 the Bureau of Standards published Circular 138, "A Decimal Classification of Radio Subjects—An Extension of the Dewey System."[1] The reference numbers used in the monthly list of references to current radio literature now pnblished in the PROCEEDINGS of the Institute of Radio Engineers are according to this classification. The Bureau of Standards would be glad to receive suggestions or criticisms on the following proposed revision of this circular.

I. Need for Classification

The radio laboratory of the Bureau of Standards has, in common with other workers in the radio field, felt the need for a systematic scheme of classification for subjects in radio science and engineering. This need has been felt not only for use in classifying the references to current radio publications but also for classifying other radio material, such as drawings, books, reports, etc. In an effort to fill the need for a radio classification the present extension of the Dewey decimal system has been prepared.

Such a system makes it easy to place books on related subjects near together on the shelves or to file references on the same subject all in the same group and not by the order of their addition to the collection or file. If a classification is to be of the most use any part of it must be capable of expansion, or it must be possible to disregard any part of the classification without interfering with the usefulness of the remaining parts. These requirements are met by the classification given below.

II. The Dewey Decimal System of Classification

Under the Dewey decimal system,[2] of which the present classification is an extension, classification is by subject, numbers

* Original Manuscript Received by the Institute, August 24, 1928.

[1] Copies of this circular may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., price ten cents.

[2] M. Dewey. Decimal classification and relative index for libraries, clipping notes, etc. 10th Ed. Lake Placid Club, N. Y. Forrest Press, 1919.

being used to show the relative positions of the books, cards, or other material. The numbers, therefore, show both what the material is (that is, its subject matter) and where the material is (that is, its location on the shelves or in the files). In the classification list the indentation and the figures prefixed to each item show the rank of each subject in the classification.

Accompanying the classification is an index which is arranged in the usual alphabetical order. References are made in this index to the subject classification number rather than to pages or to arbitrary shelf numbers. The index is used in determining the number to assign to a given item or material or to learn where to place it in the files. The index is also used by any person desiring to locate the material covering a given subject. The reference number tells immediately where all material on that and on related subjects can be found.

a. Outline of Classification

The whole subject of radio is put in its proper place in the Dewey classification—621.384. The relation of this place to the general field is shown by the following table.

Class	600.	Useful arts
	20.	Engineering
	1.	Mechanical
	.300	Electrical
	.080	Communication
	.004	Radio

In a strictly radio library or office it is convenient to represent the figure 621.384 by "R" and this abbreviation is used below in the further classification of radio. Thus, R211 indicates 621.384.211.

While some of the details of the Dewey system itself seem at the present time to be illogical (for example, electrical engineering a subdivision of mechanical engineering), the system has been widely adopted, and confusion would result from attempts to change it into a more logical form. The Dewey system has some general features which are found especially advantageous. For example, all general material under a given class is put under the class itself (usually having a final figure 0). The ninth division under any class is frequently reserved for miscellaneous items which are as yet of too small importance to classify separately; this should not be confused with the first item (0) under each class which is used for general material applied to many or all of the subdivisions under it.

b. Detailed Form Classification

The Dewey classification as well as the extension for radio is mainly by subject or content, regardless of form. For material covering a general field special form subdivision of the subject is found practically useful. For classification as to form the following set of numbers may be used in connection with the number corresponding to any subject covered.

01 Theory; methods; programs.
02 Textbooks; outlines; manuals.
03 Cyclopedias; dictionaries.
04 Essays; addresses; lectures; letters; papers.
05 Periodicals; magazines; reviews; bibliography; publications.
06 Societies; associations; transactions; exhibitions.
07 Education; training; museums.
08 Tables; calculations; charts; maps.
09 History; progress; development; biographical.
001 Statistics.
002 Quantities; cost.
003 Contracts; specifications.
004 Designs; drawings.
005 Executive; administrative; rules.
006 Working; maintenance.
007 Laws; regulations.
008 Patents.
009 Reports of tests; bulletins.

The sequence of figures constituting the form number is simply placed to the right of the sequence of figures constituting the class number. If the class number already ends in one or two zeros, as 500 or 510, these zeros are disregarded in making up the combined number. Thus a periodical on any subject has the subject number followed by 05.

Examples:

R505.	Periodicals on applications of radio.
R510.5	Periodicals on applications of radio to navigation.
R526.105	Periodicals on radio-beacon systems.
R526.100.7	Laws regarding radio beacons.

Thus the classification of any subject may be expanded to meet the needs of an individual file. The complete number gives in a condensed form an indication of what the material is as well as its location in the files.

III. Classification of Radio Subjects

a. Details of Use

In the classification of radio subjects the main features of the Dewey system as to subject and form classification are retained.

The class (R800) is anomalous. This space in the classification is actually used for non-radio matter. Such material should, however, be given its regular class number according to the Dewey system. If it were arranged in strictly numerical order, some of this material would come before radio and some after radio. By choosing arbitrarily to use the space denoted by R800 for this purpose it is possible to arrange the non-radio material in classified order, but to keep it subordinate to a larger volume of radio material. Accordingly, a number of non-radio items are included where R800 comes in the list under Section IV below but given their number according to the complete classification.

In filing a specific book or paper under a given class or subdivision, its title may be indexed by the classification number plus a small letter, the assignment being according to subject, author, chronological order of accession, or any other consideration depending on the circumstances.

In a card file of references to periodical literature, it is convenient to arrange the cards under each final class or subdivision in chronological order or in alphabetical order by the names of authors.

The needs of individual collections of files vary widely and expansion of the system can be made by any person using the system. The following classification table is given as a classification which in itself meets the needs of small collections or files. Persons interested in a particular subject or subjects will find it advantageous to expand the parts in which they are interested and to use the classification as given for those parts in which they have only a general interest.

In Section IV below there is given a detailed extension of this classification which has been evolved to meet the filing needs of the Radio Section of the Bureau of Standards. In that table there will be found examples of detailed extensions to meet particular circumstances.

In cases where files of an organization are numbered according to an extended system and are made available to another organization using a less extended system, the detailed portion of the classification numbers can be removed. An example of this is the monthly lists of References to Current Radio Literature published by the Bureau of Standards.[3] The reference numbers in the Bureau's own files are according to the table given in Section IV, e.g., an article on radio-beacon systems for aircraft (visual type) is filed under R526.12. This may be filed in a less extended file under R520 (aircraft radio), R526 (radio as navigation aid), or R526.1 (beacon systems for aircraft) depending on how brief a filing system is being used.

b. Classification Table

R000 Radio Communication
(Material of a general nature for which no specific classification can be used and which relates to the field as a whole).

R100 Radio Principles
(Material having to do with underlying theory).
R110 Radio Waves
(Transmission phenomena and theory, atmospherics).
R120 Antennas
R130 Electron Tubes
R140 Circuit theory and effects
R150 Generating apparatus
R160 Receiving apparatus
R170 Interference
R190 Other radio principles

R200 Radio Measurements and Standardization
(Methods of and apparatus for measurement)
R210 Frequency
R220 Capacity
R230 Inductance
R240 Resistance, current, voltage, etc.
R250 Generating apparatus
R260 Receiving apparatus
R270 Intensity
(Field intensity, signal intensity, noise, etc.)
R280 Properties of materials
R290 Other radio measurements

R300 Radio Apparatus and Equipment
(Component parts or apparatus, not complete communication systems)
R310 Antennas
R330 Electron tubes
R350 Generating apparatus
R360 Receiving apparatus
R380 Parts, instruments
R390 Other radio apparatus and equipment

R400 Radio Communication systems
(Complete communication systems or parts of a system which are considered in relation to the complete system).

[3] Proc. I.R.E. and Radio Service Bulletin.

R410 Modulated-wave systems
R420 Continuous-wave systems
R440 Remote control (by wire)
R460 Duplex and multiplex systems
R470 Radio-frequency carrier wire systems
R480 Radio relay systems
R490 Other systems

R500 APPLICATIONS OF RADIO
(Radio as an instrument in other arts and industries)
R510 Marine
R520 Aeronautics
R530 Commercial and special services
(Commercial communications, press, railroads, mining, etc.)
R540 Private
(Amateur)
R550 Broadcasting
R560 Military
R570 Remote control by radio
R590 Other applications

R600 RADIO STATIONS
(Equipment, operation and management)
R610 Equipment
R620 Operation and management

R700 RADIO MANUFACTURING
R710 Factories
R720 Processes
R740 Sales

R800 NON-RADIO SUBJECTS
(Material of interest but not a part of radio. Give numbers according to the Dewey system.)

R900 MISCELLANEOUS RADIO
(Material which has no specific place. See R000).

IV. Extensions of Radio Classifications

For larger collections and files a still more detailed extension might be required. The form classification (Sec. II, 2) is very useful for detailed extensions, and may be used under any item in the classification, as occasion requires.

The following extension of the subject classification has been developed for filing material in the Radio Section, Bureau of Standards. Form classifications are not given in the table except under R000, but may be made automatically, anywhere in the classification as occasion requires. Radio reference lists and other material published by the Bureau are classified according to this table.

V. Extended Classification Table as Used in Bureau of Standards Files

The extended classification table as used in the Bureau of Standards files is not reproduced here since it is that given on pages 7 to 21 of the present Circular 138 with only minor changes.

BOOK REVIEW

Radio Engineering Principles, By Henri Lauer and Harry L. Brown. Second Edition. McGraw-Hill Book Company, Inc., 370 Seventh Avenue, New York City. 301 pages, 227 illustrations. Price $3.50.

"Radio Engineering Principles" now appears in a second edition, thoroughly revised in accordance with the latest practice of the radio art. As the title indicates, the authors confine themselves to principles, rather than describing particular instruments and devices, such as broadcast and ship transmitter installations and commercial and broadcast receivers. The theory of radio transmission and reception is unfolded by direct description and simple mathematics rather than by the conventional method of physical analogies.

The first two chapters are concerned with electrical and magnetic phenomena; the third with antenna systems and radiation; the fourth and fifth with damped and undamped wave telegraphy; the balance of the book with vacuum tubes and their application to every phase of transmission and reception. This incomplete summary of the text is given only to show that a proper balance, in the light of the modern importance of the vacuum tube, has been maintained by the authors. This adequate treatment of the vacuum tube and its applications is particularly thorough and scholarly. The quantitative theory of oscillation generation and the theory of push-pull amplification are two examples of especially good mathematical presentation. The authors make generous acknowledgment to many sources, some of them decidedly unfamiliar foreign references.

The book is particularly suited as a text for shorter radio courses, given as training to student electrical engineers, and as a general reference text. It deserves a place in every professional radio engineer's library.

Edgar H. Felix †

† Writer and Broadcast Consultant, Ridgewood, N. J.

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 ten 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.

R 100. Radio Principles

R113 Eckersley, T. L. The polarization and fading of short-wave wireless. *Nature* (London), **121**, p. 707, May 5, 1928. *Experimental Wireless* (London), **5**, p. 397, July, 1928.

(The received rays are shown to be circularly or elliptically polarized, an effect which has not been heretofore observed on long-distance stations just outside the skip distance. Effect of earth's magnetic field in changing the plane of polarization is followed up for very short waves (14-50 m). A unidirectional receiving antenna was used. These phenomena attributed to a double refraction phenomenon producing the circular polarized waves).

R113 Hollingworth, J. The polarization of radio waves. *Proceedings* Royal Society of London, **119A**, pp. 444-464; June, 1928.

(General discussion on polarization of radio waves due to Heaviside layer. A modified method is given for studying the effect of frequencies less than 30 kc).

R120 O'Neill, H. M. Characteristics of certain broadcasting antennas at the South Schenectady development station. Proc. I.R.E., **16**, pp. 872-889, July, 1928.

(Characteristics of various antennas used for broadcasting. Measurements at the station discussed. Effect of signal strength as measured locally for different antenna heights and effect of high steel towers on antennas operated at 380 meters are treated).

R126 Parker, H. Radio grounds for broadcast receivers. *Radio* (San Francisco), **10**, pp. 29-30; August, 1928.

(Data on resistivity of soil for best grounds for broadcast reception).

R130 Prince, D. C. Four-element tube characteristics as affecting efficiency. Proc. I.R.E., **16**, pp. 805-821; June, 1928.

(Study of ratio of grid and plate currents of symmetrical tubes (cylindrical grids and plates) shows that it is quite different from that with ordinary commercial tubes. The difference appears to be due to combination of secondary emission from the plate and unsymmetrical arrangement of the grid wires).

R132 Williams, N. H. The screen-grid tube. Proc. I.R.E., **16**, pp. 840-843; June, 1928.

(Emphasis of paper on the very high amplification (up to eighty times per stage) which can be obtained by use of screen-grid tube. Shows that the current through the tube is approximately independent of the plate voltage and therefore the voltage amplification is given by the product of the mutual conductance and the lead impedance).

* Original Manuscript Received by the Institute, August 13, 1928.

R134.45 David, M. Super-reaction. (Super-regeneration), *L'Onde Electrique*, **7**, pp. 217-260; June, 1928.

(Discussion of work done to date on super-regeneration).

R 200 RADIO MEASUREMENTS AND STANDARDIZATION

R201 Marrison, W. A. Thermostat design for frequency standards. PROC. I.R.E., **16**, pp. 976-980; July, 1928.

(Special design of thermostatic control for frequency standardization. Thermal system arranged so that the variations reaching the object to be controlled are materially reduced below those existing at responding element. This is accomplished by using a layer of material which attenuates temperature variations between the object to be controlled and the region about the responding element.)

R230 Useful data charts—Inductance, capacity and frequency—shortwave band. *Wireless World and Radio Review*, **23**, pp. 82-83; July 18, 1928.

(Handy chart for calculation of above).

R 300. RADIO APPARATUS AND EQUIPMENT

R330 McLachlan, N. W. The output stage and the Pentode. *Wireless World and Radio Review*, **22**, pp. 30-33; July 11, 1928.

(New electron tube for use as loudspeaker tube. Curves and characteristics of tube are given).

R382 Replogle, D. E. Additional notes on iron core reactances. *QST*, **12**, p. 46; August, 1928.

(Design chart for filter reactors).

R 400. RADIO COMMUNICATION SYSTEMS

R431 Carson, J. R. The reduction of atmospheric disturbances. PROC. I.R.E., **16**, pp. 966-75; July, 1928.

(Analysis of an arrangement which provides for high-frequency selection plus low-frequency balancing after detection for reduction of atmospherics).

R 500. APPLICATION OF RADIO

R520 Hanson, M. P. Aircraft radio installations. PROC. I.R.E., **16**, pp. 921-65; July, 1928.

(Technical aspects of aircraft radio design and installation given. Illustrates trend of development during recent years).

R520.5 Jolliffe, C. B. and Zandonini, E. M. Bibliography on aircraft radio. PROC. I.R.E., **16**, pp. 985-99; July, 1928.

(List of two hundred fifty seven references to domestic and foreign periodicals).

R526.1 Smith-Rose, R. L. Directional wireless and marine navigation rotating loop beacons. *Nature* (London), **121**, p. 745, May 5, 1928. *Experimental Wireless* (London), **5**, p. 402, July, 1928.

(Radio-beacon system of directional wireless transmission developed by the Royal Air Force, Great Britain. This beacon may be of value to marine navigation. At distances over 60 miles over sea night effects change the true bearing somewhat. Rotating loop transmitting system seems to have certain advantages over the rotating loop receiving system).

R526.1 Dellinger, J. H. and Pratt, H. Development of radio aids to air navigation. PROC. I.R.E., **16**, pp. 890-920; July, 1928.

(Technical description of the system developed by the Bureau of Standards on a radio-beacon system and telephone service from ground to aircraft).

GEOGRAPHICAL LOCATION OF MEMBERS ELECTED

September 5, 1928

Transferred to the Fellow grade

New Jersey	Freehold, 54 Court Street	Englund, Carl R.
	South Orange, 332 Melrose Place	Hartley, R. V. L.
New York	New York City, R. C. A., 66 Broad Street	Beverage, Harold H.
	New York City, 195 Broadway	Blackwell, O. B.
	New York City, 64 Broad Street	Kroger, Fred H.
	New York City, R. C. A., 66 Broad Street	Ranger, Richard H.
	New York City, General Electric Co., 120 Broadway	Young, Owen D.
	Schenectady, General Electric Co.	Baker, W. R. G.

Transferred to the Member grade

Illinois	Chicago, 2022 The Engineerr Bldg.	Turner, George S.
Maryland	Baltimore, Room 13, Custom House	Sterling, George Edward
Massachusetts	Auburndale, 21 Lasell Street	Clapp, James K.
	Cambridge, 10 Wyman Road	Weeks, Paul T.
New Jersey	Newark, 200 Mt. Pleasant Avenue	Rypinski, Maurice C.
New York	Grasmere, S. I.	Grimes David
	Great Neck, L. I.	Rigney, Douglas
	New York City, 40 Broad Street	Blenheim, William J.
	New York City, R. C. A., 70 Van Cortlandt Park So.	Engel, Francis H.
	New York City, 420 Lexington Avenue	Melhuish, Harold T.
	New York City, R. C. A., 66 Broad Street	Winterbottom, W. A.
Pennsylvania	East Pittsburgh, 124 Avenue A	Sutherlin, Lee

Elected to the Member grade

California	Coronado, P. O. Box 362	Pierce, Francis E.
	Palo Alto, Federal Teldgraph Co.	Brower, William M.
Dist. of Columbia	Washington, Radio Division, Dept. of Commerce	Downey, W. E.
Illinois	Chicago, 2022 The Engineering Bldg.	Sloan, F. V.
New York	Rochester, 25 Leighton Avenue	Bickford, Milton F.
	Rochester, 25 Leighton Avenue	Haugh, A. T.
Ohio	Barberton, Ohio Insulator Co.	Hillebrand, W. A.
Peru	Lima, c/o Marconi's Wireless Telegraph Co., Ltd.	Madgwick, G.

Elected to the Associate grade

Arkansas	Hot Springs, 122 Harrell Avenue	Peel, DeLacy J
California	Los Angeles, 741½ S. Alvarado	Richards, A. H.
	Los Angeles, 1224 Wall Street	Sorge, Barthold W.
	Palo Alto, 804 Bryant Street	Dow, Clifford J.
	Santa Barbara, c/o Lamb Electric Co.	Cooper, Harold Grant
	Yosemite, c/o Ahwahnee Hotel	Campbell, Wm. N.
Connecticut	Hartford, 52 Girard Avenue	Briggs, Perry Orswell
	Hartford, 1711 Park Street	Meserve, G. Donald
	Stamford, Y. M. C. A.	Carlson, Einar C.
	Waterbury, P. O. Box 188	Cohen, Edward
Delaware	Claymont	Tatnall, Joseph S.
Dist. of Columbia	Washington, 2067 Park Road, N. W.	Gillaland, Ted R.
	Washington, 3320–19th Street, N. W.	Zandonini, Elizabeth M.
Georgia	Atlanta, A. T. & T. Co., 193 S. Pryor St.	Bellinger, Andrew L.
	Columbus, 2303 Hamilton Avenue	Lewis, William J.
	Fort Benning, Radio Station	Allen, Otis T.
	Savanah, S. S. *City of Savanah*, Chief Radio Op.	Rushing, Wallace E.
Illinois	Chicago, 1648 N. La Salle Street	Cohen, Hans
	Chicago, 1035 Belden Avenue	James, Gerald W.
	Chicago, 711 Buckingham Place	McCullah, Arthur B.
	Collinsville, 307 W. Main Street	Gasparotti, Ralph G.
	Joliet, Box 1037	Crowley, Wm. J., Jr.
	Oak Park, 916 South Lombard Avenue	Roe, Douglas J.
Indiana	Terre Haute, 705 So. 20th Street	Brooks, Kenneth Earle
	Valparaiso, 307 Monroe Street	Hershman, J. B.
	Valparaiso, Dodge's Institute	Larrowe, Harvey F.
Iowa	Sioux City, 302 Pierce Street	Kerby, Edward J.
Kentucky	Owensboro, Ken-Rad Corporation	Wuertz, John L.
	Paducah, P. O. Box 440	Shelton, Raymond W.
Maryland	Baltimore, 10 E. Centre Street	Leight, Edward Roy
Massachusetts	Beverly, c/o Neptron Corporation	O'Neill, George D.
	Boston, 30, 20 Egleston Street	Wolf, Edwin A.
	Chicopee Falls, Westinghouse Radio Lab.	Brewer, Noble E.
	Dedham, 116 Riverside Drive	Cowan, Edward J.
	East Springfield, 92 Windemere Street	Madsen, Carl J.
	Lynn, 89 New Park Street	Litle, Roy Scott

Michigan	Detroit, 3760 Jefferson Avenue E.	Bailey, Stuart L.
	Detroit, Marine P. O., Steamer *W. H. McGean*	Leonhardt, Charles C.
	Wyandotte, 344 Orchard Street	Steffin, V. J.
Minnesota	Minneapolis, 4512 Harriet Avenue	Sharpless, William M.
	St. Paul, 1795 Lincoln Avenue	Cotton, Richard J.
Missouri	St. Joseph, 635 N. 22nd Street	Bauer, Fritz
	Springfield, 517 E. Walnut Stteet	Hicks, Kenneth F.
New Jersey	Bloomfield, 118 Washington Street	Newell, Guy
	Caldwell, 14 Farrington Street	Wheeler, C. M.
	Camden, 220 Cooper Street	Reeser, Delbert A.
	East Orange, 10 Kensington Place	Clarry, Harold E.
	Fort Hancock	Mallon, William H.
	Glen Ridge, 163 Linden Avenue	Scherer, W. M.
	Hoboken, Stevens Tech	Paulding, Herbert L.
	Jersey City, 276 Summit Avenue	Sullivan, S. Edward
New York	Brooklyn, 2172–72nd Street	Hajim, Jack
	Buffalo, 281 Emslie Street	Roberts, Alfred E.
	Edgemere, L. I., 447 Beach 46 Street	Carduner, William
	Ithaca, Cornell University, Physics Dept.	Verman, Lal Chand
	New York City, 211 Bedford Park Blvd.	Baker, Brothwell H.
	New York City, 631 Eagle Avenue Bronx	Fielding, Edward J.
	New York City, 144 E. 208th Street	Howard, Edward J.
	New York City, 1 Broadway, S. S. *Michael Tracy*	Keily, Delbar P.
	New York City, 67 Broad Street, Inter. Stand. Elec. Co.	Putnam, R. E. A.
	New York City, 67 Broad Street, Inter. Stand. Elec. Co.	Sanborn, J. W.
	Rochester, Box 5, Brighton Station	Worrell, Richard A.
	Schenectady, 12 Snowden Avenue	Meahl, Harry R.
	Schenectady, 11 Grove Place	Spitzer, Edwin E.
	Southampton, Box 488	Homer, Edward C.
	Whitestone, L. I., 14th Avenue, and 166th Street	Adler, Benjamin
	Woodhaven, L. I., 9001–78th Street	Jahnsen, Oscar H.
Ohio	Cleveland, Engineer's National Bank Bldg.	Gove, Edward L.
	Dayton, 432 Ludlow Arcade Bldg.	Gerstle, John
	Dayton, 267 Park Street	Zimmerman, Robert F.
	Greentown	Myers, Willard Daniel
	Hamilton, 533 Ridgelawn Avenue	Probst, John E.
Oklahoma	Tulsa, 5 Skelly Oil Co., Radio Dept.	Lovell, Herman J.
	Tulsa, 436 South Gillette Avenue	Phillips, H. W.
	Tulsa, c/o KVOO, Voice of Oklahoma	Sans, Eddleman E.
	Tulsa, 204 Central National Bank Building	Thomspon, W. H.
	Tulsa, 218 E. Latimer Street	Wilson, O. G.
Pennsylvania	Harrisburg, 217 Walnut Street, c/o Mandarin Restaurant	Lee, William J.
	Palmyra, 113 E. Cherry Street	Balsbaugh, Clair L.
	Palmyra, 13 E. Main Street	Krieder, James L.
	Philadelphia, 2506 N. 34th Street	Borland, Albert S.
	Tarentum, 1008 Crescent Street	Jones, Roy L.
	Wilkinsburg, 1103 Center Street	Mumma, Earle L.
Tennessee	Memphis, 1292 Linden Street	Cowles, Alfred L.
Texas	Houston, c/o Rice Institute	Waters, James S.
Virginia	Norfolk, Station WTAR	McConnel, W. G.
	Norfolk, 117 W. Main Street, Pocahontas S. S. Co.	Trigger, V. H.
Washington	Puyallup, Experiment Station	Shoup, Allen
	Seattle, c/o Postmaster, U. S. S. *Black Hawk*	Hodges, Arthur T.
	Seattle, Dept. of Lighting and Power	Ross, J. W.
	Seattle, 5811–5th Avenue, N. E.	Winningham, H. W.
West Virginia	Wheeling, 1229 Main Street	Risley, F. S.
Wisconsin	Milwaukee, 1395 Prospect Avenue	Weiss, Tobias
	Waukesha, 1107 White Rock Avenue	Golding, Robert M.
Brazil	Sao Paolo, Avenida Sao Joao 24	Cesar, Amarel
Canada	Edmonton, Alberta, 1732–89th Street	Ryley, Raymond
	Hamilton, Ontario, 185 Sanford Avenue N.	Weber, Rennie I.
	Nanaimo, B. C., c/o Spencer Rooms	Mawson, John T., Jr.
	Timmins, N. Ontario, P. O. Box 1827	Newman, John R.
	Toronto, Ontario, 474 Palmerton Blvd.	Price, Harold W.
	Winnipeg, 529 Dominion Street	Pound, Harris D.
China	Peking, University of Communications, Electrical Dept.	Nieh, C. R.
England	Bath, Kennington Road, Warwick Villa	Young, Alfred W.
	Birkenhead, 11 Dawson Avenue	Purcell, James
	Bradford, W. Yorks, Allerton Road, 33 Bullroad Avenue	Haigh, Norman E.
	Caversham, Reading, 4 Matlock Road	Hill, Ernest N.
	Frinton-on-Sea, Shirley, Old Road	Harries, John Henry O.
	London, N. 7, 15 Courtney Road	Downing, Geo. E. C.,
	London, N. W. 3, 85 King Henry's Road	Ferdinando, Christie
	Upminster, Essex, "Hilly's," Cedar Gardens	Jones, John E. Rhys.
India	Hyderabad Sind, Gidu Road, Porch House	Samtani, R. C.
New Zealand	Wellington, 248 The Terrace	Taylor, James O.

Elected to the Junior grade

California	Los Angeles, 219 South Alexandria Avenue	Dawson, W. Robert
Connecticut	Mystic, 21 W. Mystic Avenue	Wheeler, Lester B.
Illinois	Chicago, 3128 Warren Avenue	Demikis, Anton, Jr.
	Chicago, 2735 N. Tripp Avenue	Wegner, Charles W.
	Pittsfield, Box 514	Lewis, Rupert S.
Indiana	Valparaiso, 156 S. Franklin Avenue	Barber, D. G.
Iowa	Clarinda, 514 Main Street	Huntsinger, P. R.
Massachusetts	Cambridge, 11 Carlisle Street	Sullivan, Edwin T.
New York	Brooklyn, 322 E. 31st Street	Gabel, Morris
	Brooklyn, 1819 Newkirk Avenue	Rippere, R. Oliver
	New York City, 1297 Lexington Avenue	Bruggeman, John T.
	New York City, U. S. S. *Gresham*, Barge Office Rm. 10	Mandell, Benjamin F.
Oregon	Falls City	Paul, Byron R.
Pennsylvania	Ambridge, 303 Maplewood Avenue	Svegel, Peter J.
	Harrisburg, 1712 Forster Street	Chambers, William B.
Canada	Parry Sound, Ontario, Box 175	Crump, Albert E.

APPLICATIONS FOR MEMBERSHIP

Applications for transfer or 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 transfer or election of any of these applicants should communicate with the Secretary on or before November 3, 1928. These applications will be considered by the Board of Direction at its November 7th meeting.

For Transfer to the Fellow grade

New York	New York City, 282 West End Avenue	Dreher, Carl

For Transfer to the Member grade

California	Hollywood, KMTR Radio Corp., 1025 North Highland Avenue	Van Why, Forbes William
Illinois	Chicago, University of Chicago, Ryerson Lab.	Hoag, J. Barton
New Jersey	Madison, 14 Fairwoods Road	Manning, Charles T.
England	London, W. 12, Emlyn Road	Hardy, Harold

For Election to the Member grade

Dist. of Columbia	Washington, 4302 Brandywine St., N. W.	Davis, Thomas McL.
Massachusetts	W. Somerville, 53 Francesca Avenue	Kolster, Charles C.

For Election to the Associate grade

Alabama	Phenix City	Moore, C. M.
California	Berkeley, 2112 Addison	Howard, L. W.
	Burlingame, 908 Morrell Avenue	Michalic, Charles Tom
	Hollywood, 1301 Martel Avenue	Kratz, C. F.
	Marshall, c/o Radio Corporation of America	Lawrence, Lloyd H.
	Oakland, 643 Poirier St.	O'Brien, Daniel L., Jr.
	Orange, P. O. Box 145	Charbonneau, L. H.
	San Francisco, 140 New Montgomery, Room 1024	Stewart, Ronald B.
	San Francisco, KFWI, 1182 Market St., Room 203	Weir, F. Torres
	San Pedro, U. S. S. *Procyon*	Granum, Alfred M.
	Santa Ana, 1334 S. Parton St.	Sleeper, J. Lloyd
Georgia	Atlanta, 684 Durant Place	Gue, E. M.
	Atlanta, c/o Radio Station WSB	Shropshire, A. W.
	Columbus, 731 Broad St.	Cowart, Frank P.
	Columbus, South Georgia Power Co.	Davis, James C.
Illinois	Chicago, 3814 Madison St.	Haire, A. F.
	Chicago, 1119 So. Wood St.	Korbel, George William
	Chicago, c/o R. C. A., 100 W. Monroe St.	McCune, R. H.
	Chicago, 4137 Jackson Blvd.	Strandjord, Millard F.
	Chicago, 29 No. Morgan Street	Trier, Stanley S.
	Rantoul, Chanute Field, Communications Section	Fiechtner, Theodore G.
	Rockford, 1506 School St.	Johnson, Art A.
Kansas	Atchison, 202 N. 2nd St.	Dimond, Benjamin Dan
Louisiana	New Orleans, 528 N. Hennessy St.	Salzer, Herman M.
Maine	Belfast, c/o R. C. A.	Morris, Hedley B.
Massachusetts	Braintree, 149 Hollis Ave.	Robinson, Philip F.
	Cambridge, Harvard University, Pierce Hall, Room 204B	Samoiloff, Leon
	Chatham, Box 631	Robinson, Forrest D.
	Chathamport, Radio Hotel	Lee, Walter O.
	North Cambridge, 128 Clay Street	Grenier, Henry N.
	Medford, 16 Higgins Avenue	Yorks, William Ray
	South Boston, 157 N. Street	Brown, George W.
Michigan	Crystal Falls, 225 Superior Ave.	Lee, Raymond R.
Missouri	Kansas City, 2803 Linwood Blvd.	Schulze, Heri T.
Nebraska	Norfolk, P. O. Box 226	Leeman, Wilson
New Jersey	Cliffwood, Box 31	Jansky, Karl G.
	East Orange, 106 North Walnut St.	Edison, Theodore M.
	Long Branch, 58 Washington St.	Watson, Paul Edwin
	Weehawken, 2 Fourth St.	Girard, E. J.
New York	Brooklyn, 896 Troy Avenue	Riccobono, Sebastian
	Buffalo, 20 Ullman St.	Mahler, George P.
	East Rockaway, L. I., 47 Waldo Ave.	Van Duyne, Eugene Douglas

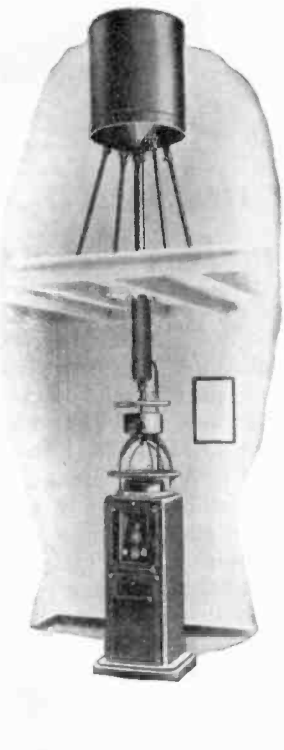
	Kenmore, 37 Princeton Blvd.	Voll, Harry F.
	New York City, 161 West 140th Street	Cox, Lloyd V.
	New York City, 562 W. 183rd Street	Gati, Bela
	New York City, 50 W. 57th Street	Leonard, John M.
	New York City, Mackay Radio and Tel. Co., 67 Broad Street	Nivison, T. E.
	New York City, 19 Grove Street	Reardon, Daniel
	Riverhead, L. I., P. O. Box 1077	Tammaro, Joseph Carl
	Rocky Point, Radio Central	Draigh, Canton V.
	Schenectady, 172 Nott Terrace	Sohon, Harry
	Schenectady, 9 N. Church Street	Woodworth, John L.
North Carolina	Charlotte, Y. M. C. A.	Saylor, J. G.
Ohio	Cleveland, 1240 East 167th Street	Shaw, John Joseph
	Fostoria, 642 Lynn Street	Elsea, Farrell F.
	Shiloh, Box 112	White, Kenneth E.
Pennsylvania	Allentown, 806 Union Street	Thomas, Chas. V.
	Pittsburgh, West Penn. Bldg., 14 Wood Street, Room 1304	Sunnergren, Arvid P.
	Waverly, Box 163	Mach, Dahl W.
	Wilkes-Barre, 429 George Ave.	Speicher, Ellsworth J.
Rhode Island	Providence, 42 Greenwich Street	Maker, Albert Edwin
South Dakota	Yankton, 318 W. First Street	Seils, Harry A.
Tennessee	Knoxville, P. O. Box 531	Adcock, S. E.
	Memphis, 43 So. Barksdale	Dowler, R. B.
Texas	Dallas, 3106 St. John Drive	Hinsch, Lincoln A.
	Livingston	McClanahan, C.
Washington	Seattle, 7708 Latona Ave.	Brandt, Oscar T. D.
	Seattle, 904 Telephone Bldg.	Budden, F. W.
	Seattle, 3234 Belvidere Ave.	Hamilton, Edward A.
	Seattle, Pacific Tel. and Tel. Co.	Schreiber, Ernst H.
	Seattle, 4026 Evanston Ave.	Sletmoe, A. M.
West Virginia	McMechen, 1104 Caldwell St.	Hicks, William Ray
Wisconsin	Watertown, 314 Water St.	Ebert, Sylvanus J.
Australia	Melbourne, East Camberwell, 6 Beech St.	Fitts, Rupert Alfred
Canada	Victoria, B. C., 2084 Newton St.	Hawkins, Ernest
	Ottawa, 21 Florence St.	Donaldson, Bruce W.
China	Hong Kong, c/o Electrical Dept., P. W. D.	Logan, James Stanley
England	Derbyshire, Buxton, 2 Wood Cliffe	Smith, Harold Ingleby
	Middlesex, Shipperton, Pharaoh's Island, "Kantara"	Henderson, Walter B.
Japan	Shizuoka-Ken, Ogasagun, Kakegawa-cho Kandaiji	Yokoyama, Tetsumi

For Election to the Junior grade

California	Los Angeles, 1311 Citrus, Hollywood	Fox, B. M.
Nebraska	Clay Center	Hertel, Roger H.
New York	Brooklyn, 6 Bay 23rd St.	Liebner, Barney
	Buffalo, 78 East St.	Ferger, Herbert
	Jamestown, 200 Hallock St.	Ellis, James G., Jr.
	Lancaster, 69 Aurora St.	Pictor, Robert Ezra
Pennsylvania	Altoona, 602 E. Grant Ave.	Youngkin, E. E.
	Philadelphia, c/o Atwater Kent Co.	Reid, Floyd Freeman
	Philadelphia, 5737 N. Lawrence St'	Trumpy, J. Walter
	Scranton, 1618 Monsey Ave.	Batzel, Charles R.
Wisconsin	Milwaukee, 1278 W. 24th St.	Moorbeck, Clinton
England	Manchester, Trafford Park, Metro-Vickers	Thomas, Guy Henry
	Wiltshire, Swindon, 7, Pinehurst Road	Humphreys, Leonard W.

The new Kolster Radio Compass provides

Greater Safety—
Visual Bearings—
Simple, Positive Operation



From its aluminum pedestal to the new enclosed loop, the new Kolster Radio Compass [Type AM-4490] embodies every improvement radio science has to offer. The insulated cylindrical housing of the loop affords complete protection against wind, ice, snow, and spray. A tiny lamp flashes the signals of nearby stations, while for long-distance bearings, a special Kolster eight-tube receiver with a new circuit especially designed for radio compass work provides the maximum of selectivity and sensitiveness.

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Kolster Radio is also setting new standards of performance in broadcast receiving sets for the home.

KOLSTER RADIO CORPORATION

200 Mt. Pleasant Avenue
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UNITED SCIEN. LAB
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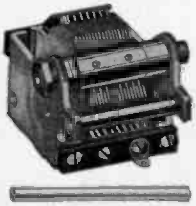
CONDENSERS

Standard Production Units

Universal Compact Type UXB Brass Condenser (Note Removable Shaft)



1st—The new United Scientific Type UXB condensers are so designed that their assembly is greatly simplified. This feature speeds up your production.

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3rd—They have patented leveled brass rotors and stators.

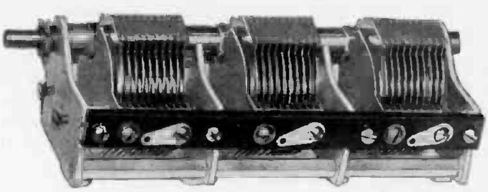
4th—Precision spacing assures accurate calibration.

5th—The removable shaft can be adjusted to any desired length and is therefore adaptable to ganging in any number.

6th—Universal mounting permits clockwise or counter clockwise rotation. Integral frame lugs are provided for sub-panel mounting.

7th—Modified straight-line frequency wave takes care of all present day broadcasting wavebands.

Type UXB Three Gang Condenser



This fine job, which is small and compact is especially suited for shielded work. The popular type UXB Condensers are used. They can be had in either .005MF or .00035MF Capacities.

Let the USL Engineers co-operate with you in solving your condenser problems. We are always glad to quote on special specifications.

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The Pyrohm is Built *to Carry the Load!*

AEROVOX Fixed and Tapped Vitreous Enamelled Pyrohm Resistors are made in a wide range of resistance values and wattage ratings to suit every power supply requirement. They are built to the same high standards as Aerovox Mica Condensers, Socket Power Condensers and Filter Condenser Blocks.

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"... the weakest link"

An antenna, like a chain, is no stronger than its weakest insulating link.

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"TESTED FOR ONE THOUSAND POUNDS"—stamped on an Isolantite insulator means that this insulator actually has been subjected to one-half ton loading before shipment!

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made to run the *full* race!

ANY horse can make a good start . . . . . . But it takes real stamina to *finish!* ¶So it is with batteries. *Staying* power is the quality to look for—unfailing power over a long period of service. Millions prefer Burgess *Chrome* Batteries for just this reason. They hold up . . . . They *last.* ¶Next time, buy black and white striped Burgess *Chrome* Batteries. You are certain to get longer and better service for your money.

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AmerTran Push-Pull Amplifier—First stage AmerTran DeLuxe and second stage AmerTran Push-Pull for two Power Tubes. AC or DC sets, 171 or 210 type tubes. Price, east of Rockies—less tubes, $60.00.

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The audio amplifier is the basis of tone quality. Since broadcasting came into being, AmerTran products have been the Standards of Excellence for Radio Reproduction. How many times have you heard the question asked, perhaps asked it yourself, "Is it as good as AmerTran?" As long as that question is asked, there can be no doubt as to the standing of AmerTran products in the radio industry.

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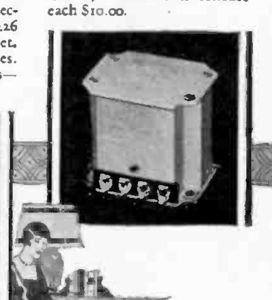

Push-Pull Amplifier, ABC Hi-Power Box and Push-Pull Power Stage licensed under patents owned or controlled by RCA and may be bought complete with tubes.

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High Grade Acoustical Engineer

LARGE midwestern radio manufacturer requires the services of a high grade acoustical engineer to develop loud speakers. Must be thoroughly grounded in electrical and acoustical theory and competent to take charge of development work. Give education, experience, salary required and any other pertinent information in first letter.

Address replies to Box 812.

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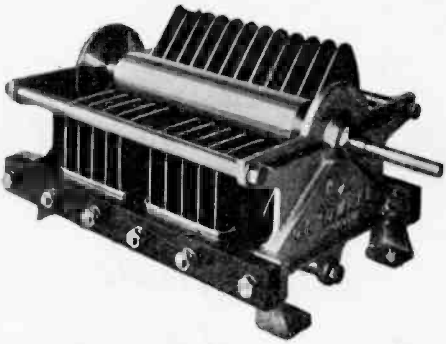

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It is wise to profit by the experiences of others and avoid the pitfalls of needless experimenting.

High Voltage Transmitting Condensers
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"There is a CARDWELL for every tube and purpose."

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Prompt and efficient servicing of radio receivers and accessories instills confidence, stimulates sales and benefits the entire radio industry. Rapid commercial progress will inevitably follow the general adoption by dealers and servicemen of testing equipment which insures a complete and speedy diagnosis of all receiver troubles. The two instruments by Weston illustrated herewith make possible a new era of efficiency in servicing practice.

The first of these is the Weston Model 533 Counter Tube Checker which operates direct from any A. C. source of supply—and requires no batteries. It will test every type of tube—A. C. or D. C.—having filament voltages of standard ratings from 1.5 to 7.5 volts, including rectifying types.

The instrument shown at the left is the Weston Model 537 A. C. and D. C. Set Tester. A complete outfit for thoroughly checking and locating troubles on any receiver made. No accessories needed. Simple to operate. Eliminates guesswork and uncertainty and makes anyone, with a little practice, *a radio servicing authority.*

These two instruments provide light, compact and reliable equipment for all who are engaged in research and manufacturing work as well as in radio servicing. Write for Circular J fully describing all instruments in the Weston radio line.

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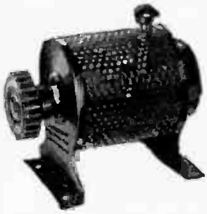
SPEED CONTROL CLAROSTAT

REG. U. S. PAT. OFF.



GRANTED a good signal and a satisfactory kino-lamp or neon glow tube, the heart of successful television reception is the scanning disk. This member should have the proper arrangement of holes for the necessary "lines" of the television image being received, and it should be revolved at the *proper speed* and also in *perfect step* with the transmitter scanning disk.

The SPEED CONTROL CLAROSTAT has been developed to serve both *proper speed* and *perfect step* functions. It provides a perfect speed control for the universal or the condenser motor, operating on A.C. or D.C., up to 1/8th horsepower, together with a phase-shifting push-button to bring the disk into step.

Note the neat, compact, practical appearance of this device. A special power type Clarostat of 80-watt rating is contained in the sturdy, ventilated metal casing with mounting feet. Connections are made to screw terminals, protected by removable end plate. Motor speed is controlled from dead stop to practically full speed, so that any small motor may be used if its rated speed is above that required for television purposes.

Practical television is only possible with stepless, adjustable resistance for scanning disk motor control. In combination with the STANDARD CLAROSTAT for controlling the voltage applied to the kinolamp for necessary contrast between lights and shadows, the SPEED CONTROL CLAROSTAT spells television success.

There's a CLAROSTAT for Every Purpose

From the delicate grid leak function served by the GRID LEAK CLAROSTAT, to the grid bias and plate control functions of the —50 type power tube, served by the POWER CLAROSTAT, you will find a Clarostat available for every radio purpose. From the requirements of remote volume control, served by the TABLE TYPE CLAROSTAT, to the precise fixed resistance arrived at by actual trial as provided by the DUPLEX CLAROSTAT, you will find a Clarostat available for every radio purpose. From a resistance range of a few ohms to a resistance range of many megohms, you will find a Clarostat available for every radio purpose. Think of *CLAROSTAT*, and you have the entire resistance field in mind.

Write for data regarding the Speed Control Clarostat as well as other Clarostat products. Also, if you are the radio engineer or production manager of a radio company, ask to be placed on our mailing list to receive our technical data bulletin, issued every so often to help you solve your resistance problems.

Clarostat Manufacturing Company, Inc.

MEMBER R.M.A.

Specialists in Variable Resistors

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CLAROSTAT

REG. U. S. PAT. OFF.

ARCTURUS
A-C LONG LIFE TUBES

NEW *and Different* Construction Brings NEW *and Better* Results

BY the elimination of the ceramic between the heater and the cathode of A-C tubes, Arcturus engineers achieve two important results:

First, the elimination from the internal tube structure of an insulating material that is extremely difficult to degasify.

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These are only two facts in the design of Arcturus Tubes. But, they are characteristic of the engineering considerations that make Arcturus Tubes—both standard fifteen volt and low voltage tubes—outstanding in performance, quick action and long, uniform life. The result—*the finest A-C Tubes that can be made!*

Engineering Facts Have a Utility Significance to the Ultimate Listener

Arcturus Radio Co.
255 Sherman Avenue
Newark, N. J.

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A-C LONG LIFE TUBES

CONDENSERS·RESISTANCES

RHEOSTATS··MOUNTINGS

POTENTIOMETERS··PLUGS

It is in the Polymet Factory that the Radio Industry's confidence in Polymet Products is built.

Tolerances are carefully set and rigidly adhered to. Precision machinery and inspection of the strictest, safeguard Polymet's reputation for dependable, high quality, power supply parts.

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One of the Polymet Products—the Filter Block Assembly. Made well, looks well, functions well.

Ask for the Polymet Catalogue showing the complete line of Polymet Products.

POLYMET·PRODUCTS

Potter Condensers

for

Quality

Long Life

Uniformity

Economy

The public is now ready to replace troublesome radio sets with a new and modern type and demand performance that will give pleasure for years to come.

Insure the operation of your radio set by using Potter Condensers built to meet your requirements in a factory devoted to the exclusive manufacture of Condensers from the best of materials with our special process and impregnating compound.

Leading manufacturers now use Potter Condensers after careful test and successful use in the past. There is a Potter Condenser for every requirement and each should be selected with care.

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The Remedy For Man Made Static

Modern conveniences unfortunately gave no thought to radio reception upon entering the home of set owners and as a result radio programs were spoiled by interference from oil burners, ice machine motors, violet rays, vacuum cleaners, fans, etc.

Fortunately there is a remedy for these electrical disturbances which interfere with broadcast programs.

Simply connect a Potter Interference Eliminator to the line circuit at the point where the interfering device is connected and it will drain the disturbance preventing its reaching the radio set.

A Condenser Assembly For Every Use

Potter Manufacturing Company

North Chicago, Illinois

A National Organization At Your Service

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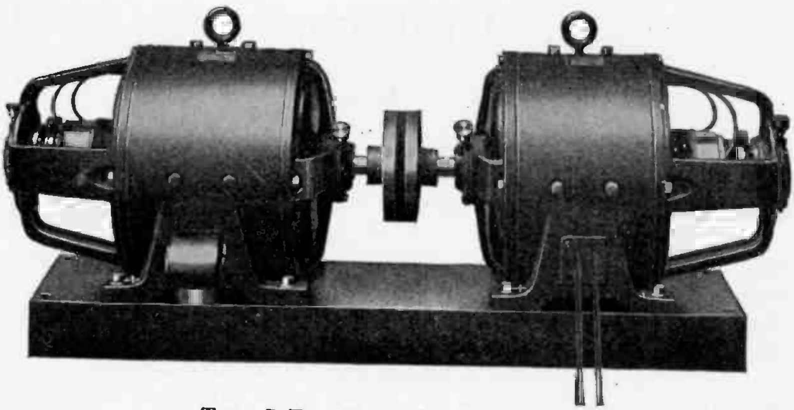
HIGH VOLTAGE GENERATORS MOTOR-GENERATORS AND DYNAMOTORS



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"ESCO" two and three unit sets have become the accepted standards for transmission. The "ESCO" line consists of over 200 combinations. These are covered by Bulletin 237D.

Our engineers are always willing to cooperate in the development of special sets.

"ESCO" is the pioneer in designing, developing and producing Generators, Motor-Generators, Dynamotors and Rotary Converters for all Radio purposes.

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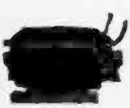

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for *Television Experimental Work*

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3—*No aging after long use*
4—*Adequate current capacity*
5—*Rugged, solid-molded construction*
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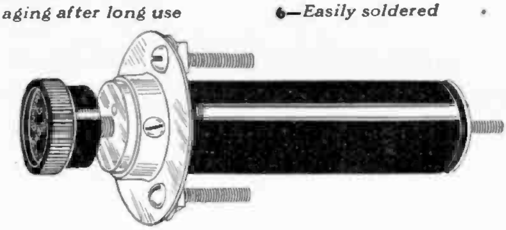

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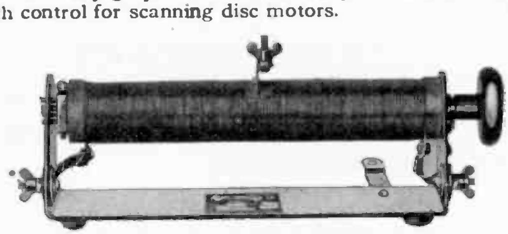
This remarkable graphite compression rheostat, and other types of Allen-Bradley graphite disc rheostats provide stepless, velvet-smooth control for scanning disc motors.



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Industrial and Laboratory Division
DEPT. R-3
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ALL-WIRE RESISTANCES

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THESE resistances are widely preferred for B-Eliminator construction and power work due to their non-varying accuracy and ability to carry the heavy current loads without deterioration.

Their ingenious, air-cooled design is an exclusive Electrad feature. In addition to keeping the units cool, it permits the winding of a larger resistance wire in smaller space, providing a much finer regulation of voltage.

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[***See that your radio set is equipped with Strowger Automatic condensers***]

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STROWGER AUTOMATIC CONDENSERS

MADE BY

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Wanted

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The Volume Control

THE volume control of a radio set is one of the parts most used and subjected to the most wear. Care must be taken to choose the type that will give longest, trouble-free service—a type that will not introduce noise to interfere with the quality of reception after a short period of service.

Centralab Volume Controls have a patented rocking disc contact that eliminates all wear on the resistance material. This feature adds to the smoothness of operation in that a spring pressure arm rides smoothly on the disc and NOT on the resistance. The bushing and shaft are thoroughly insulated from the current carrying parts. This simplifies mounting on metal panel or sub base and eliminates any hand capacity when the volume control is in a critical circuit. Full variation of resistance is obtained in a SINGLE TURN of the knob.

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Price—$6.50

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As an R.F. amplifier, its efficiency has been most successfully demonstrated—giving a voltage amplification per stage of from 3 to 10 times that of the ordinary "A" tube.

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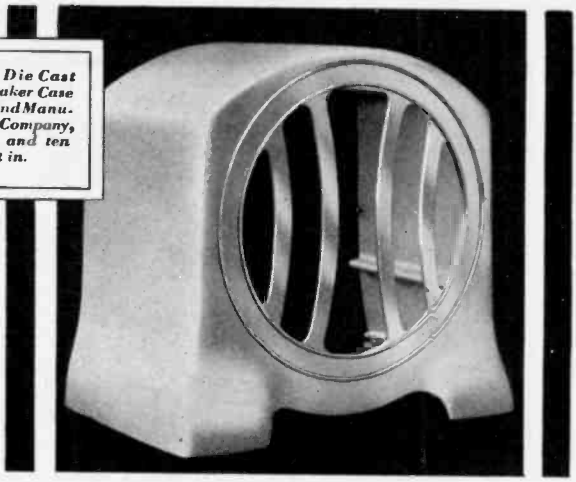

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Alumac Die Castings of Alcoa Aluminum are ideal for loud speaker housings, and for chasses, bases and cabinets, condenser cradles and drum dials.

Alcoa Aluminum is far lighter than other die casting metals and possesses equal or greater strength. It rates high in electrical conductivity.

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For Strength, Lightness, Economy

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8. The Measurement of Choke Coil Inductance	C. A. Wright & F. T. Bowditch
9. Radio Communication	Guglielmo Marconi
10. On Round the World Signals	E. O. Hulburt
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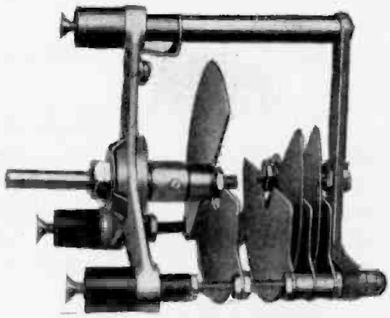

A condenser specially constructed for tuning high frequency receivers or transmitters (low power). The large semi-variable air tank condenser may be adjusted to any specified capacity so that the small single plate shunted condenser will then become a vernier control to this large capacity. The maximum capacity of the rotating unit is adjustable so that with a correctly proportionated inductance, any narrow frequency band may be spread over the entire range of the rotar dial scale.

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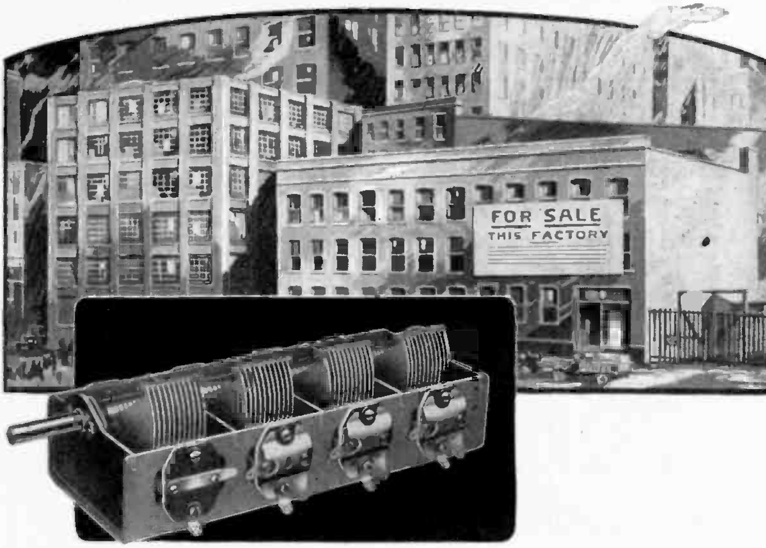

DOES your production cost curve show a tendency to mount and threaten the stability of your business? Whether or not you have cause to worry, let Scovill help you cut overhead and clear the way for new profits. Radio changes are often so rapid that the manufacture of new and improved parts forces the sale of obsolete numbers at cost or less. By making Scovill one of your producing units you can regulate production changes at will. Tremendous manufacturing facilities enable Scovill to fill orders of any quantity. Tools, dies or machinery required for special work are designed and built within the Scovill plant. Call in a Scovill representative.

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Elkon were the originators and still make the only dry High Capacity Condenser. Unlike any of the so-called dry condensers which depend on moisture for their action, Elkon condensers are baked in ovens at 200 degrees to be sure that all of the moisture is out before sealing in their cans.

Standard size of can is 2" x 2" x 6¾", capacities to 4000 mfd. Voltage 12. Special sizes and capacities may be made where quantities are sufficient.

Elkon Dry Condensers are used by the leading manufacturers of "A" Eliminators, and are also being specified this year by some dynamic speaker manufacturers and set manufacturers who want a high capacity condenser in small space. Submit specifications for samples.

ABSOLUTELY DRY!

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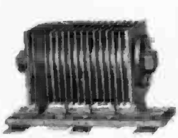
There is an ELKON Dry Rectifier for *your* problem

No matter what the problem of rectification, Elkon has or can build a rectifier for your individual problem.

There are sixteen standard rectifiers covering a wide range of voltages and current carrying capacities.

An engineer will appreciate the inherent quality of Elkon rectifiers as soon as he looks at one—and they are as efficient as they look. The self-healing feature, exclusive with Elkon, is but one guarantee of their long life. Send your specifications for a sample which will answer your problem.



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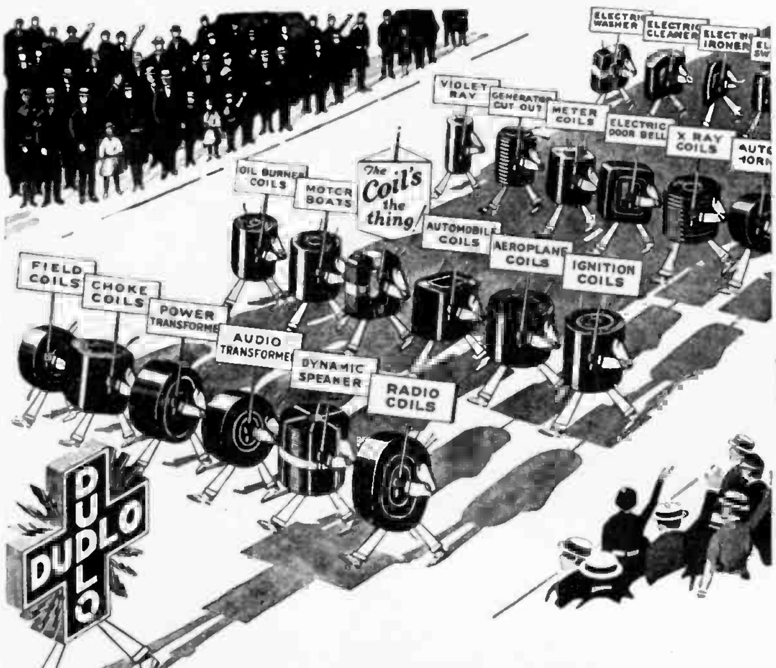

...in the Vanguard of Progress

The Coil's the thing that heads the procession of progress in electrical development. Every engineer knows that no electrical apparatus or instrument is any better than its coils—and they in turn are no better than the wire in their windings.

So when we stop to think, we are forced to give full credit to the humble coil which, hidden in the vitals of the apparatus, does its work quietly and efficiently—an unfailing worker which seldom has the opportunity to go on dress parade.

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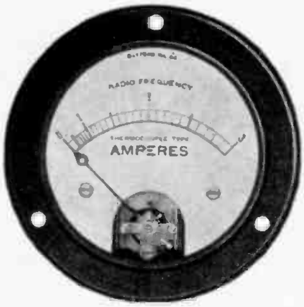

Pattern No. 64

Radio Frequency Ammeter

Still the Standard

Jewell thermo couple ammeters for high frequency work are still the standard of the amateur fraternity for making current measurements at radio frequency, for they completely fulfill the requirements of accuracy, low loss and high overload.

The thermo couples of these ammeters, which are available in various sizes, are made from special electric furnace alloys of non-oxidizing nature. A guaranteed overload capacity of 50% is an indication of their ruggedness. The loss in the instrument is held to less than one-half of the minimum required by the Navy.

The Pattern No. 64 high frequency ammeter has a three inch, black enameled case. Scales are silve ed with black characters and movement parts are silver plated. All Jewell instruments have zero adjusters.

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"28 Years Making Good Instruments"

Jewell Electrical Instrument Co.

1650 Walnut St., Chicago

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W.C. BRAUN COMPANY

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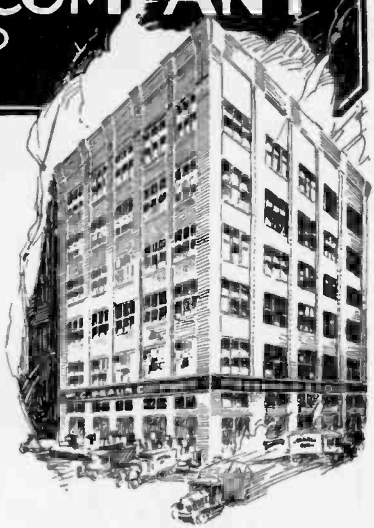

Official Distributors for Leading Radio Products

AS the world's largest distributors, jobbers and wholesalers of a varied line of radio products, the W. C. Braun Co. offers to manufacturers, dealers and custom set builders, a most useful and necessary service.

For the dealer and custom set builder we furnish a quick, easy, convenient and economical means of securing any merchandise desired on instant notice by letter, wire or in person. To be able to secure such service, all under one roof, without going to the trouble of buying from a dozen or a hundred different sources, certainly is a service that is well worth while to the manufacturer as well as to the Radio Trade.

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Headquarters for Custom Set Builders

We are headquarters for the parts of the country's leading parts manufacturers' products, used in the leading circuits. Parts and supplies for any published radio circuit, whether short wave or broadcast, are immediately available from our stock.

Manufacturers desiring a distributing outlet furnishing world-wide service, are invited to take up their problems with us. Dealers, custom set builders and engineers will find here an organization keyed to fill their needs promptly and efficiently and a request on their letterhead will bring a copy of the Braun's Radio Buyers' Guide —the bible of the radio industry.

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GREBE RADIO
TRADE MARK

The first comprehensive use of the alphabet in signaling is attributed to Julius Africanus, a Roman general. He communicated between his troops by means of torches held aloft to represent different letters of the alphabet.

It is to a comprehensive understanding of the exacting demands of those who insist upon something "just a little better" in every phase of life that the Grebe Synchrophase A-C Six owes its perfection.

It was designed for those who want something more than the mere convenience of alternating current, light-socket operation; for those who want, in addition to relief from battery worries, the intrinsic quality that has made the Grebe such an outstanding leader in every phase of radio development.

If you aren't satisfied with something just good enough, you'll appreciate the tone quality, range and selectivity of this fine receiver; its freedom from A-C hum; illuminated single dial and other new improvements which truly enable you to "get it *better* with a Grebe."

A demonstration of the Grebe Synchrophase A-C Six will convince you of its superiority. Hear it today or send for Booklet I, which fully explains this new set.

Other Grebe sets and equipment: Grebe Synchrophase Seven A-C, Grebe Synchrophase Five, Grebe Natural Speaker (Illustrated), Grebe No. 1750 Speaker.

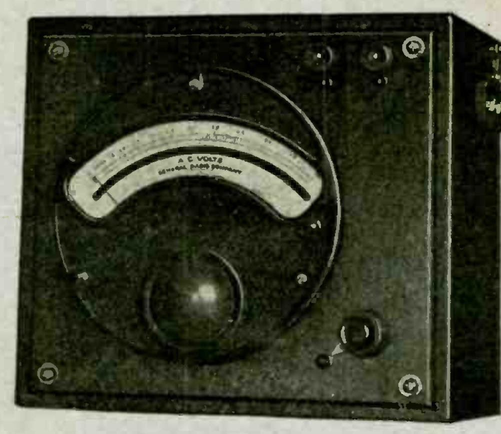
GREBE SYNCHROPHASE
A-C Six RADIO

A. H. Grebe & Co., Inc., 109 W. 57th St., New York City
Factory: Richmond Hill, N.Y. *Western Branch:* 443 S. San Pedro St., Los Angeles, Cal.
Makers of quality radio since 1909

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

Type 426-A

Thermionic Voltmeter



TYPE 426-A
THERMIONIC VOLTMETER
Range 0-3 Volts
Price $160.00

The Type 426-A Thermionic Voltmeter possesses several features not usually found in such instruments. All external circuits have been eliminated. The single battery required is contained in a compartment with the instrument case. The Type 426-A Thermionic Voltmeter uses a tube of low filament consumption and requires only 22.5 volts. Provision is also made for connecting an external battery.

Under usual conditions the calibration will be maintained to within 0.5% up to about 1000 hours. The wave-form error is slight, a 20% third harmonic in the wave produces an error of but 0.4% in the meter reading. The voltage calibration is reliable over the entire audio-frequency range. The frequency error is less than 2% of full scale at 20 kilocycles and less than 3% at 300 kilocycles.

The meter is contained in a walnut case with battery compartment. This instrument is fully described in Catalogue E, a copy of which will be sent on request.

GENERAL RADIO COMPANY

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