VOLUME 18 MAY, 1930 NUMBER 5

PROCEEDINGS

of

The Institute of Radio Engineers

Form for Change of Mailing Address or Business Title on Page XLIX

JOINT MEETING

of the

Institute of Radio Engineers

and the

Radio Manufacturers' Association

●

Civic Auditorium

Atlantic City, N. J.

June 3, 1930

PROCEEDINGS OF

The Institute of Radio Engineers

Volume 18 | May, 1930 | Number 5

Board of Editors

ALFRED N. GOLDSMITH, *Chairman*

STUART BALLANTINE — G. W. PICKARD

RALPH BATCHER — L. E. WHITTEMORE

J. W. HORTON — W. WILSON

Contents

PART I

PART II

Technical Papers

Copyright, 1930, by the Institute of Radio Engineers

The Institute of Radio Engineers

GENERAL INFORMATION

The PROCEEDINGS of the Institute is published monthly and contains papers and discussions thereon submitted for publication or for presentation before meetings of the Institute or its Sections. Payment of the annual dues by a member entitles him to one copy of each number of the PROCEEDINGS issued during the period of his membership.

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

Back issues are available in unbound form for the years 1918, 1920, 1921, 1922, and 1926 at $9.00 per volume (six issues) or $1.50 per single issue. For the years 1913, 1914, 1915, 1916, 1917, 1919, 1923, 1924, and 1925 miscellaneous copies (incomplete unbound volumes) can be purchased for $1.50 each; for 1927, 1928, and 1929 at $1.00 each. The Secretary of the Institute should be addressed for a list of these.

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

Bound volumes are available as follows: for the years 1922 and 1926 to members of the Institute, libraries, booksellers, and subscription agencies at $8.75 per volume in blue buckram binding and $10.25 in morocco leather binding; to all others the prices are $11.00 and $12.50, respectively. For the year 1929 the bound volume prices are: to members of the Institute, libraries, booksellers, and subscription agencies, $9.50 in blue buckram binding; to all others, $12.00. Foreign postage on all bound volumes is one dollar, and on single copies is ten cents.

Year Books for 1926, 1927, and 1928, containing general information, the Constitution and By-Laws, catalog of membership, etc., are priced at seventy-five cents per copy per year. The 1929 Year Book is available to members at $1.00; to non-members, $1.50.

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

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

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

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

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

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

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

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

Published monthly by

THE INSTITUTE OF RADIO ENGINEERS, INC.

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

BUSINESS, EDITORIAL, AND ADVERTISING OFFICES,

Harold P. Westman, *Secretary*

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

SUGGESTIONS FOR CONTRIBUTORS TO THE "PROCEEDINGS"

Preparation of Paper

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

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

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

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

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

Publication of Paper

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

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

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

INSTITUTE SECTIONS

Section	*Chairmen*	*Secretaries*
ATLANTA	H. P. Thornton	Philip C. Bangs, 23 Kensington Rd., Avondale Estates, Ga.
BOSTON	George W. Pierce	Melville Eastham, 30 State St., Cambridge, Mass.
BUFFALO-NIAGARA	L. Grant Hector	E. C. Waud, 235 Huntington Ave., Buffalo, N. Y.
CHICAGO	H. E. Kranz	J. H. Miller, Jewell Electrical Inst. Co., 1650 Walnut St., Chicago, Ill.
CINCINNATI	R. H. Langley	W. W. Boes, 622 Broadway, Cincinnati, Ohio
CLEVELAND	D. Schregardus	C. H. Shipman, 14805 Ardenall Ave., East Cleveland, Ohio
CONNECTICUT VALLEY	Q. A. Brackett	F. C. Beekley, 96 S. Main St., W. Hartford, Conn.
DETROIT	A. B. Buchanan	W. R. Hoffman, 615 West Lafayette Blvd., Detroit, Mich.
LOS ANGELES	T. C. Bowles	Charles S. Breeding, 1187 N. Normandie Ave. Hollywood, Calif.
NEW ORLEANS	Pendleton E. Lehde	Anton A. Schiele, 1812 Masonic Temple, New Orleans, La.
PHILADELPHIA	J. C. Van Horn	*Acting Secretary* E. T. Darlington, 2848 Idaho Road, Camden, N. J.
PITTSBURGH	A. J. Buzzard	C. F. Donbar, 233 South Starr Ave., Bellevue, Penna.
ROCHESTER	E. C. Karker	A. R. Barfield, Valley Appliances, Inc., Rochester, N. Y.
SAN FRANCISCO	Donald K. Lippincott	Paul R. Fenner Custom House, San Francisco, Calif.,
SEATTLE	Austin V. Eastman	Abner R. Willson, 8055—14th Ave., N. E., Seattle, Wash.
TORONTO	J. M. Leslie	G. E. Pipe, 90 Chestnut St., Toronto, Canada
WASHINGTON	C. B. Jolliffe	J. B. Brady, Ouray Bldg., Washington, D. C.

GEOGRAPHICAL LOCATION OF MEMBERS ELECTED APRIL 2, 1930

Elected to the Fellow Grade

England	Essex, Weatheroak, Danbury	Eckersley, T. L.

Transferred to the Member grade

California	Los Angeles, 607 N. Mansfield Ave.	Perkins, L. J.
Dist. of Columbia	Washington, Chevy Chase Apts.	Gross, Gerald C.
Massachusetts	Boston, 169 Marlborough St.	Cabot, George E.
New Jersey	East Orange, 216 N. Oraton Parkway	Isler, Samuel
	Neptune, 1115-6th Ave.	Shafer, J. Peter
New York	Buffalo, 52 Locust St.	Brown, Stanley W.
	Buffalo, Buffalo Broadcasting Station	Chamberlain, A. B.
	New York City, Pier 9, North River	Muller, Fred
	Schenectady, 1454 Glenwood Blvd.	Snyder, Norman

Elected to the Member grade

New Jersey	Newark, 79 Manchester Pl.	Levine, I. B.
New York	New York, City College	Taylor, E. Gordon
China	Canton, Lingnan University	Knipp, Arthur
Japan	Tokyo, 1278 Omeri, Araishiku	So, M.

Elected to the Associate grade

California	Bolinas, c/o R. C. A. Communications, Inc.	Muller, John H.
	Burbank, 126 N. Sparks St.	Shaw, Theodore S.
	Los Angeles, 2219 Merton Ave., Eagle Rock	Church, Stanley M.
	Los Angeles, 547 S. Western Ave.	Hassen, Gunnar B.
	North Palo Alto, 501 Laurel Ave.	Byrne, Paul F.
	Richmond, 700-22nd St.	Trolese, Louis
	San Francisco, 328 Customhouse	Homsy, John H.
	San Francisco, 311 California St.	Kaufman, Jack
	San Francisco, N. B. C., 111 Sutter St.	Kennedy, David W.
	San Francisco, 140 New Montgomery St., Room 1021	MacMahon, A. E.
	San Pedro, *U. S. S. West Virgina*, c/o Postmaster	Anderson, W. A.
Connecticut	New Haven, 280 Whalley Ave.	Lenzner, Emil
	New Haven, 367 Elm St.	O'Connell, J. D.
	New Haven, 43 Clifford St.	Pierce, E. H.
	New Haven, 367 Elm St.	Willis, J. S.
Dist. of Columbia	Washington, 262-15th St. S. E.	Calvert, F. G.
Delaware	Bethany Beach	Meyers, R. E.
Illinois	Chicago, 4440 N. Laporte Ave.	Johnson, E. T.
	Chicago, 3303 S. Claremont Ave.	Martens, R. L.
	Chicago, 7034 Merrill Ave.	Reed, P. B.
	Chicago, 4236 N. Spaulding Ave.	Ruskin, Henry
Indiana	Angola, 512 W. South St.	Ax, Leland S.
	South Bend, P. O. Box ..868	Crockett, David R.
Iowa	Davenport, 1525 Grand Ave.	Snyder, Reed E.
Kentucky	Hopkinsville, 2121 S. Main St.	Grimwood, F. O.
	Newport, 216 Main Ave. (Clifton)	Richards, A. P.
Louisiana	New Orleans, 201 Magazine St.	Collins, J. C.
	New Orleans, 6014 Catina St.	Havlicek, J. W.
Massachusetts	Cambridge, 18 Ware St., Harding Apts. (12-A)	Ammon, W. B.
	Chicopee Falls, Westinghouse Elec. and Mfg. Co.	Lee, Donald C.
	Dorchester, 121 Draper St.	Feldman, Sarley M.
	Springfield, Westinghouse Elec. and Mfg. Co., Page Blvd.	Weber, C. A. M.
Michigan	Bay City Radio Station WPCM	Wesser, C. H.
	Detroit, 3303 Sturtevant Ave.	Bond, Orville J.
	Detroit, 446 S. Eastlawn	Jackson, C. H.
	Jackson, 226 Orange St.	Schonert, K. E.
Missouri	Rock Port	Wolf, Ray O.
	St. Louis, 720 S. 4th St.	Ferris, Harry J.
New Jersey	Audubon, 107 S. Logan Ave., Apt. 2	Darragh, W. C.
	Bound Brook, c/o WJZ	Gullans, John H.
	Camden, 1576 Norris St.	Brail, S. L
	Guttenberg, 317 24th St.	Pramshefer, T. W.
	Jersey City, 61 Gautier Ave.	Nolte, C. L.
	Montclair, 114 Midland Ave.	Sandford, R. Y.
	West Orange, 23 Oxford Ter.	Vose, George E.
New York	Astoria, L. I., 2373-27th St.	Heller, Joe
	Brooklyn, 24 Bay 7 St.	Rice, A. J.
	Brooklyn, 1818-61st St.	Tucker, M. H.

New York (cont.)	Brooklyn, 1452-55th St.	Zeiger, Louis B.
	Buffalo, 241 S. Elmwood Ave.	Landis, Oren J.
	Buffalo, 41 N. Putnam St.	Miller, E. C.
	Canandaigua, 66 N. Main St.	Goering, R. A.
	Elmhurst, L. I., 189 Forley St.	Hotchkiss, Earle
	Flushing, L. I., 42-43-147th St.	Davis, Clinton S.
	Hamilton, 67 Main St.	Janes, R. B.
	Jamaica, L. I., 150-05-88th Ave.	Bernhardt, E. E.
	Mount Vernon, 220 Westchester Ave.	Podell, Samuel
	New York City, 147 W. 23rd St.	Ansley, Arthur C.
	New York City, c/o Postmaster, *USS Eagle 58*	Dodge, F. R.
	New York City, 179 Greenwich St.	Egert, Samuel S.
	New York City, 280 Broadway	Florenz, H. A.
	New York City, 233 W. 120th St.	Fung, J. H.
	New York City, 58 E. 93rd St.	Keene, K. W.
	New York City, 77 Irving Pl.	Maddocks, James H.
	New York City, 711 5th Ave., c/o National Broadcasting Co.	Martin, W. G., Jr.
	New York City, 195 Broadway, c/o A. T. and T. Co.	Mattin, W. H.
	New York City, 817 E. 175th St.	Morozoff, Harry
	New York City, 463 West St.	Olander, L. W.
	New York City, 1060 Fox St., Bronx	Samuels, G. J.
	New York City, 601 W. 162nd St.	Schlesinger, B. S.
	New York City, 23 Lexington Ave., George Washington Hotel	Taber, Ira DeWitt
	New York City, c/o Postmaster	Tellman, Herbert A.
	New York City, 326 Broadway, c/o R. C. A.	Williams, H. F.
	New Rochelle, 19 Park View Ave.	Matthews, B. W.
	Richmond Hill, L. I., 108-15-103rd Ave.	Saphir, Frank
	Schenectady, 208 Union St.	Tucker, W. E.
	Scotia, 202 Ballston Ave.	Smith, H. M.
Ohio	Bluffton, 155 Thurmey St.	Steiner, Harold R.
	Cincinnati, 3452 Colerian Ave.	Best, Paul J.
	Cincinnati, Box #20, Station I	Hoffman, Ralph
	Cincinnati, 2415 Auburn Ave.	Tumleson, J. F.
	Cleveland, 3562 E. 151st St.	Broz, B. G.
	Cleveland, Radio Station WHK, Engineers' National Bank Bldg.	Drysdale, N. M.
	Cleveland, 11126 Glenbro Dr.	Durcanshy, Mike
	Dayton, General Motors Radio Corp., Miami Chapel Rd.	Newill, E. B.
	Lakewood, 2097 Lincoln Ave.	Kope, Carl A.
	Louisville, Box. #105	Noreen, Carl O.
Oklahoma	Norman, 729 Asp Ave.	Tomme, M. B.
	Oklahoma City, 3032 North Place	Booth, W. J.
	Oklahoma City, Radio Station KFJF,	Downey, C. E.
	Oklahoma City, 1623 W. 6th St.	Farris, Glen
	Oklahoma City, 1414 N. Penn.	Mooney, J. B.
Pennsylvania	Bradford, 21 Thompson Ave.	Gimera, George
	Flemington, Box 194	Kunkle, C. F.
	Harrisburg, 23 S. Front St.	Maurer, E. E.
	Kutztown, 183 Main St.	Sharadin, F. A.
	Lansdowne, 17 N. Lansdowne Ave.	Simons, Russell
	Nanticoke, 44 Coal St.	Hutchko, Francis J.
	Norristown, 624 Chain St.	Davis, G. C.
	Philadelphia, 615 E. Woodlawn Ave., Germantown	Hutcheson, C. J., Jr.
South Carolina	Columbia, Box #72, University of South Carolina	Karick, Bert F.
Tennessee	Nashville, 715 N. 2nd St.	Mason, A. E.
Texas	Abilene, 258 Pine St.	Manciell, M. C.
	Beaumont, c/o Sun Oil Co., Box #790	Bush, C. R.
	Dallas, Baker Studios, Radio Station WFAA	Ellis, W. C.
	Dallas, 2022 Commerce	Parkinson, Lee D.
Virginia	Richmond, 4609 Devonshire Rd.	Steere, J. A.
Washington	Pullman, Box #331, College Station	Hatfield, L. N.
	Pullman, 683 College Station	Kuntze, E. L.
	Seattle, Calhoun Hotel	Dailey, A. C.
	Seattle, 6544 Holly Ter.	Foster, C. H.
	Seattle, 1723 Naomi Pl.	Mullaney, H. F.
	Walla Walla, 601 Washington St.	Elam, D. W.
Wisconsin	Middleton	De Soto, C. B.
	Milwaukee, 220 Meinecke Ave.	Kruse, C. C.
	New Glarus, Box #373	Becker, S. J.
Wyoming	Cheyenne, c/o Boeing Air Transport	Lawrenz, Wm. L.
Australia	Malvern, Victoria, 72 Union St.	Barthold, G. L.
	Sydney, 66 City Rd.	Horton, G. H.
South Australia	Adelaide, 33 Hewitt Ave., Rose Park	Adams, C. H.
	Strathalbyn, Dawson St.	Goldfinch, H. R.
Canada	Montreal, Que., 168 Beaconsfield	Barbour, J. H.
	Montreal, Que., 240 Percival Ave.	Carrick, W. E.
	Montreal, Que., P. O. Box #1435	Lord, Wm.
	Montreal, Que., Room 601, Keefer Bldg.	Wallace, O. C. R.

Canada (cont.)	Sioux Lookout, Ont., Dept. Lands and Forests	Watson, J. E.
	Sudbury, Ont., 98 Cedar St.	Kniffen, L. D.
	Winnipeg, Man., 520 Jubilee Ave.	Ellinthorpe, J. W.
	Winnipeg, Man 128 Lanark St.	Gillingham, A.
	Winnipeg, Man., 502 Sherburn St.	Vale Ronald
	Yamachiche, Que., Canadian Marconi Co.	Bird, C. H. R.
Colombia	Bogota, c/o Cia. Radio Universal, National City Bank	Siemens, R. H.
England	Bedford, Shortstown, 7 Central Ave.	Disley, Arthur
	Birmingham, 502 Slade Rd., Erdington	Finchley, F.
	Bournemouth, The Huon, Branksome Hill Rd.	Chapman, J. P. J.
	Bradford, Yorkshire, Commercial Bank Bldg.	Langstaff, H.
	London, W. 12, 91 Mellitus St., Shepherds Bush	Ogden, S.
	Stoke-on-Trent, 417 London Rd., West End	Humphreys, W. F.
Holland	Amsterdam, Tilanusstraat 66	Nouman, H. J. J.
Ireland	Limerick, Mount View, Jonesboro Ave.	Kennedy, M. F.
Japan	Shimizumura, near Kumamoto City, c/o Shimizuhosozo	Tsuji, Uichiro
	Ibarakiken, Hiraiso Musen	Iso, E.
	Osaki, near Tokyo, Teishinsho-Denki-Shikenjo	Takaya, Michihiro
	Ibarakiken, Isohamamusen	Tanimura, I.
	Osakimachi, near Tokyo, Ministry of Communications, Electro-technical Laboratory	Jimbo, S.
Philippines	Cebu, Opon	Minoza, Maximiano
Sweden	Stockholm, Alsten	Rolf, Bruno

Elected to the Junior grade

California	Los Angeles, 1042 Stone St.	Ourieff, Paul
	Whittier, 614 N. Bright	Eagle, Roy D.
Massachusetts	Melrose, 28 Rowe St.	Flanders, W. Hubert, Jr.
New York	New York City, 155 West 82nd St.	Sandifer, Norwood H.
	New York City, 155 West 82nd St.	Stauffer, Robert Writner
	Port Jervis, 12 Neversink Ave.	Rutan, Paul D.
	Rochester, 81 Eiffel Place	Norris Edward
Texas	San Antonio, 402 E. Locust	Hyman, Kenneth R.
Hawaii	Honolulu, P. O. Box 2390, c/o J. T. McIntyre	Murai, Fred H.

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 May 31, 1930. These applicants will be considered by the Board of Direction at its June 4th meeting.

For Transfer to the Member grade

Massachusetts	Springfield, 47 Florence St.	Hutcheson, J. A.
Ohio	Norwood, 3934 Ivahoe Ave	Blair, R. M.

For Election to the Member grade

Massachusetts	Tufts College	de Mars, Paul A.
New York	Bayside, L. I., Parker Court Apts.	Trautwein, Paul K.
Ohio	Barberton, c/o Ohio Insulator Co.	Snyder, E. B.
	Dayton, Wright Field	Mitchell, Hugh
Washington	Seattle, 4216 West Findlay St.	Robinson, A. K.

For Election to the Associate grade

Arkansas	Little Rock, c/o Radio KLRA	Logan, E. Warren, Jr.
	Little Rock, 1920 Main St.	Simmons, G. A., Jr.
California	Compton, 123 B-West Olive St.	Smith, F. E.
	Hollywood, 1613 Vista del Mar	O'Harra, Paul Cross
	Long Beach, 835 West Third St.	Gray, William
	Los Angeles, Los Angeles Junior College	Kennedy, Douglas
	Los Angeles, 340 S. Cloverdale Ave.	McCullough, F. S.
	Palo Alto, c/o Federal Telegraph Co.	Morrison, G. K.
	Palo Alto, 1145 Middlefield Road	Woodbury, E.
	San Diego, c/o U. S. S. Rigel, U. S. Des. Base	Hamlin, F. E.
	San Rafael, 365 Mission Ave.	Lyman, Harry J.
Connecticut	New Haven, 270 Sherman Ave.	King, Cary J., Jr.
Dist. of Columbia	Washington, 3237 Hiatt Pl. N. W., Apt. 46	Rittenhouse, J. P.
Florida	Hialeah, Box No. 488	Rowan, F. C.
	Hialeah, 1302 Northwest Second Ave.	Sherwood, L. F.
Illinois	Chicago, Room 703, Monadnock Bldg.	Gray, Kline
	Chicago, 7708 South Shore Drive	Harrell, Fred E.
	Chicago, 1300 N. Dearborn St.	Kelsey, Elizabeth L.
	Chicago, 7641 Paxton Ave.	Nichols, D. O.
	Chicago, 11931 Eggleston Ave.	Reed, Clifford J.
	Chicago, 3300 Federal St.	Sear, Arthur W.
	Chicago, 3341 Berteau Ave.	Wiegrefe, E. J.
	Lockport, 1010 Madison St.	Carter, O. M.
	Melrose Park, 165 N. 35th Ave.	Searles, Ansel A.
	Plano, P. O. Box No. I	Leitch, G. L.
	Rantoul, Chanute Field	Akre, R. O. S.
Indiana	Valparaiso, 60 Jefferson Ave.	Audrain, R. M.
	Valparaiso, 308 Monroe St.	Evans, H. D.
	Valparaiso, 451 Greenwich St.	Ligtenberg, Wm.
	Valparaiso, 308 Monroe St.	Repass, W. D.
	Valparaiso, 451 Greenwich St.	Steinbrech, J. M.
Kansas	Kansas City, 239 North Thorpe	Thompson, E. J.
Kentucky	Clinton	Weatherford, H. N.
	Grayson	DeHart S. B.
Maryland	Annapolis, P. G. School, U. S. Naval Academy	Layne, F. C.
	Baltimore, 3718 Kate Ave.	Rodgers, J. W.
Massachusetts	Chatham, Box. No. 265	Dillon, W. F.
	Cliftondale, 25 Jackson St.	Tripp, A. B.
	Springfield, 565 Page Blvd.	Gubin, Samuel
	Taunton, 282 Bay St.	Godfrey, J. S.
	Wollaston, 97 Willow St.	Kennard, K. F.
Michigan	Detroit, 1365 Cass Ave., Room 1321	Carter, Rex B.
	Detroit, 2041 McDougall Ave.	Denstaedt, E. C.
	Detroit, 101 Westminister	Lehmann, McKenna
	Detroit, 4471 Lakepointe Ave.	Sheridan, R. J.
	Holland, 88 E. 13th St.	Tysse, Henry L.
	Wyandotte, 2332-10th St.	Bednarek, W. J.
Missouri	St. Louis, 1318 Clara Ave.	Bergtold, A. L.
	St. Louis, 3622 McRee Ave.	Sampson, John C.
	St. Louis, 4004 Maffitt Ave.	Schaffer, D. W.
	St. Louis, 4820 Kossuth Ave.	Welhoelter, Milton
	St. Louis, 3829 Greer Ave.	Wirts, C. C., Jr.
Montana	Butte, 224 S. Main St.	Derr, C. R.
Nebraska	Lincoln, 925 S. 32nd St.	Harvey, H. C.
New Jersey	Bloomfield, 72 Watsessing Ave.	Roush, G. F.
	Boonton, c/o Aircraft Radio Corp.	Parkes, A. W., Jr.

New Jersey (cont.)	Camden, 1160 Kenwood Ave.	Cioffari, Bernard
	Collingswood, 13 Odgen Ave.	Shoup, F. F.
	East Orange, 82 N. Arlington Ave.	Curtis, R. C.
	Jersey City, 248 Palisade Ave.	Gross, Ralph
	Long Branch, 688 Broadway	Goodwin, E. A.
	Newark, 159 N. 12th St.	Geiges, Karl S.
	Oaklyn, 76 Kendall Blvd.	Alexander, J. E.
	Oaklyn, 1115 White Horse Pike, Cedar Court Apts.	Fowler, L. T.
	Oceanport, Box No. 18	Denniston, E. E.
	Trenton, 45 Barnt Ave.	Donohue, E. F.
	Upper Montclair, 5 Emerson Pl.	Caughey, W. K.
New York	Astoria, L. I., 3043–31st St.	Sollima, Joseph
	Brooklyn, 23 Bay 7th St.	De Meyer, Harold
	Brooklyn, 1627 West 13th St.	Mazzola, J. R.
	Brooklyn, 2106 Bedford Ave.	Murray, Allan J.
	Brooklyn, 34 Moore St.	Siegal, Jack
	Brooklyn, 202 S. Oxford	Sullivan, F. T.
	Greenport, 305 Front St.	Boerum, H. S.
	Mamaroneck, Halstead Ave. and 5th St.	Herdman, W. P.
	Monticello, 246 Broadway	Fleischer, A. P.
	New York City, U. S. S. Texas, c/o Postmaster	Hixson, J.P.
	New York City, 862 E. 169th St.	Lebow, Samuel
	New York City, 36 Market St.	Newcombe, Jack
	New York City, 1186 Lexington Ave.	Pattee, J. R.
	New York City, 463 West St.	Wurmser, A. V.
	New York City, U. S. S. Bushnell, c/o Postmaster	Zamba, John
	Riverton, 301 Bank St.	Holst, P. F. G.
	Schenectady, 448 Third St.	Van Alstyne, A. J.
	Scotia, 134 Riverside Ave.	Schaper, A. W.
North Carolina	Charlotte, Box No. 237	Parker, J. C.
	Tarboro, Box No. 247	Shaw, H. B., Jr.
North Dakota	Devil's Lake, 604 Fourth St.	Norton, T. S.
Ohio	Cincinnati, 3441 Wilson Ave.	Epstein, Jesse
	Cincinnati, 545 Purcell Ave.	Hentz, E. G.
	Cincinnati, Univ. of Cincinnati Dormitory	Jordan, J. F.
	Cincinnati, Crosley Radio Corp.	Kidd, Andrew
	Cincinnati, 1725 Elmore St.	Squires, C. E.
	Cincinnati, Room 920 Chamber of Commerce Bldg.	Valentine, F. C.
	Cleveland, 7704 Dearborn Ave.	Roebuck, Neel
	Cleveland, 9708 Adams Ave.	Stanton, Sol.
	Cleveland, 2269 Ashland Road	Willard W. C.
	Columbus, 914 Ellsworth Ave.	Young, D. A.
	Custer	Talmage, W. L.
	Dayton, 371 Kenilworth Ave.	Baker, J. R.
	Dayton, 249 East Peach Orchard Road	Biddle, W. G.
	Dayton, 1310 Kumler Ave.	Goldston, Henry
	Springfield, R. F. D. No. 3	Bushong, V. L.
	Springfield, Radio Station WCSO	Kratz, L. M.
	Urbana, R. F. D. No 7	Sulenbinder, Arthur
	Youngstown, 223 Kyle St.	Carlson, N. G.
Oklahoma	Oklahoma City, 3921 Shields Blvd., R. 8	Cordell, W. G.
Pennsylvania	Chester, 322 E. 8th St.	Baylor, H. M.
	Narberth, Fairview Farms	La Fore, J. A., Jr.
	Nickleville	Rumberger, Carl S.
	Philadelphia, 548 Ellet St., Mt. Airy	Brown, R. D., Jr.
	Philadelphia, 125 Apsley St.	Gilbert, W. E.
	Philadelphia, 32 N. Fifth St.	Illingsworth, F. H.
	Philadelphia, 4213 Van Kirk St.	Walker, Harold
	West Philadelphia, 1730 Martlon Ave.	Jennings, E. C.
South Dakota	Emery	Janssen, R. J.
Texas	Dallas, 2515 Maple Ave.	Curll, Van C.
	Dallas, 218 Alcalde St.	Wilkinson, Lee A.
	Houston, 1603 Welch St.	Hunt, J. W.
Vermont	Burlington, 81–85 Main St.	Siegel, Harold S.
Virginia	Arlington	Dresser, O. C.
	Culpeper	Jones, H. R.
Washington	Seattle, R. 13, Box No. 207	McCash, P. V.
	Tacoma, 4001 East B St.	Beatty, D. L.
Wisconsin	Milwaukee, 730 Hubbard St.	Schweizer, M. J.
	Sheboygan, 1221 Ashland Ave.	Troeglen, Karl, Jr.
Brazil	Rio de Janeiro, Voluntarios de Patria 86	Lima, A. C. de Silva
Canada	Toronto, Ont., 345 Adelaide St. West	McLean, L. V.
Channel Islands	Guernsey, 6 Contree Mansell	Adams, A. M.
England	Bradford, 90 Leeds Old Road	Fennessy, J. R.
	Cambridge, St. John's College	White, F. W. G.
	Chelmsford, Essex, 26 Nursery Road	Amey, S. H.
	Ipswich, Suffolk, 35 Carr St.	Wilby, R. A.
	Leytonstone, Essex, Zennor House, Whipps Cross Road	Ullyett, Kenneth
	Upminster, Essex, 20 Cedar Gds.	Connell, W. H.
	Wetherby, Yorks, 16 High St.	Wetherill, J. E.
France	Paris, 29 Rue de Lisbonne, c/o Co. des Lampes	Kahn, Pierre O.
Japan	Tokyo, c/o Japan Wireless Telegraph Co., Marunouchi	Shuzui, Saburo
New Zealand	Christchurch, 20 Fitzgerald St.	Gerity, L. P.

For Election to the Junior grade

California	Monrovia, 529 King St.	Barnard, T. A.
	Santa Barbara, Radio KDB, Faulding Hotel	Campbell, C. W.
Dist. of Columbia	Washington, 2026 F St., N. W.	Bullock, J. W.
Illinois	Highland Park, 388 Walker Ave.	Berg, B. V.
	Peoria, 510 Windom St.	Clark, Bruce
Indiana	Gary, 366 Hancock St.	Gustafson, C. L.
	Princeton, 502 S. Seminary St.	Clark, R. K.
	Rensselaer, 604 Jefferson St.	Halstead, W. H.
	Valparaiso, 451 Greenwich St.	Cone, W. W.
	Valparaiso, Stiles Hall	Fleming, Carl
	Valparaiso, 405 Monroe St.	Phillips, V. G.
	Valparaiso, P. O. Box No. 455	Rosenberg, B. L.
Iowa	Ames, Box N, Station A	Lewis, J. R.
	Britt, R. F. D. No. 3	Mickelson, Silas
	Des Moines, 1753 East Grand Ave.	Peavey, E. A.
	Mount Vernon, 306 First Ave. So.	Beranek, L. L.
Michigan	Ludington, c/o P. M. Ry.	Fenton, K. G.
Nebraska	Clay Center, Box No. 203	Omer, G. P., Jr.
New York	Buffalo, 299 Franklin St.	Mundie, E. M.
	Colden	Robinson, M.
	New York City, 186 Second Ave.	Weitzman, Irwin
North Carolina	Pittsboro	Roberson, R. E.
Ohio	Dayton, 305 Park St.	Braden, Paul F.
	Lima, 125 Miller Ave.	Arnett, T. T.
Pennsylvania	Johnstown, 1123 Franklin St.	Lohr, L. H.
Virginia	Dunn Loring	Harris, R. T.
Wisconsin	Kenosha, 6227 Sheridan Road	Hanson, Gordon
Canada	St. Hyacinthe, Que., 219½ Cascades	Marceau, Jules P.

OFFICERS AND BOARD OF DIRECTION, 1930

(Terms expire January 1, 1931, except as otherwise noted)

President

Lee de Forest

Vice-President

A. G. Lee

Treasurer

Melville Eastham

Secretary

Harold P. Westman

Editor

Alfred N. Goldsmith

Managers

J. H. Dellinger

R. A. Heising

L. M. Hull

R. H. Manson

A. F. Van Dyck

Arthur Batcheller
(Serving until Jan. 1, 1932)

C. M. Jansky, Jr.
(Serving until Jan. 1, 1932)

J. V. L. Hogan
(Serving until Jan. 1, 1933)

R. H. Marriott
(Serving until Jan. 1, 1933)

Junior Past Presidents

Alfred N. Goldsmith

A. Hoyt Taylor

Board of Editors

Alfred N. Goldsmith, *Chairman*

Stuart Ballantine
Ralph Batcher
J. W. Horton
G. W. Pickard
L. E. Whittemore
W. Wilson

JOHN H. MORECROFT

President of the Institute, 1924

John H. Morecroft was born in Staffordshire, England, September 19, 1881, and when but eight years of age was brought to the United States by his parents.

His early schooling was obtained in the public schools of Syracuse, New York, and later in 1904, he received his E.E. degree from the University of Syracuse.

After a year as foreman of a machine shop he spent two years at Syracuse University in the Liberal Arts school from which he was graduated in 1907. During these two years he was an assistant in the engineering school.

From 1907 to 1909 he instructed in the electrical department of the Pratt Institute, spending practically all of his spare time in the laboratory of Dr. M. I. Pupin.

In 1909 he became an instructor in electrical engineering at Columbia University, becoming an assistant professor in 1910, subsequently advancing through the ranks to the position of professor, which he has now held for several years.

During the War, he was engaged by the U. S. Navy as a scientific expert, and worked on submarine detection schemes; with Professors Pupin and Wills, he developed the supersonic echo method. He was sent to England and France during the latter part of the war as liaison officer for the navy.

He is a Fellow of the Institute of Radio Engineers, American Institute of Electrical Engineers, and the American Physical Society, a member of Phi Beta Kappa, Tau Beta Pi, Sigma Xi, and Epsilon Chi. At the 1929 Commencement, Syracuse University invested him with the honorary degree of Doctor of Science.

In 1923 he became vice-president of the Institute, succeeding to the presidency in 1924. During 1924 and 1925 he was a manager of the Institute.

He has written several books on radio engineering and has served on many committees of both the Institute of Radio Engineers and the American Institute of Electrical Engineers, besides carrying on a wide consulting practice.

INSTITUTE NEWS AND RADIO NOTES

Special Notice Concerning New York June Meeting

Although New York meetings are usually held on the first Wednesday of each month, except during July and August, no New York meeting will be held in the month of June. Instead, a meeting will be held in Civic Auditorium, Atlantic City, Tuesday, June 3, 1930. This will be a joint meeting of the Institute and the Engineering Division of the Radio Manufacturers' Association, which organization will then be holding its June Trade Show.

A paper on methods of testing loud speakers in connection with commercial manufacture will be presented by members of the Bell Telephone Laboratories at the 10 A.M. session.

A number of papers on the production testing of broadcast receivers will be delivered by prominent manufacturers at the afternoon session at 2 P.M.

By means of these arrangements, it will be possible for members of the Institute to attend what would normally be the New York June meeting and the Radio Manufacturers' Association Trade Show with a minimum amount of inconvenience.

April Meeting of the Board of Direction

The April meeting of the Board of Direction was held on the 2nd day of the month at the office of the Institute, 33 West 39th Street, New York City, at 4:30 P.M. The following Board members were present: Lee de Forest, president; Melville Eastham, treasurer; Arthur Batcheller, J. H. Dellinger, R. A. Heising, R. H. Manson, R. H. Marriott, A. F. Van Dyck, and H. P. Westman, secretary.

The following were transferred or elected to the higher grades of membership in the Institute: elected to the Fellow grade: T. L. Eckersley; transferred to the Member grade: S. W. Brown, G. E. Cabot, A. B. Chamberlain, G. C. Gross, Samuel Isler, L. J. Perkins, and J. P. Schafer; elected to the Member grade: A. R. Knipp, I. B. Levine, Fred Muller, M. So, and E. G. Taylor.

One hundred and fifty-one Associate members and nine Junior members were elected.

Beverly Dudley, who was previously assistant technical editor of *QST* of the American Radio Relay League and technical editor of the radio magazine of the *Chicago Evening Post*, has assumed the assistant secretaryship of the Institute. His present work will take him into intimate contact with the standardization projects of the Institute.

Proceedings Binders

Because of the enlarged size of the PROCEEDINGS published during 1929, many of our members find that they are unable to fit the twelve issues into the standard binder which has been available in the past.

We are pleased to announce that a larger size of binder is now available which will hold the twelve issues published during 1929.

When ordering the larger size be sure to specify that the large binder is desired. They are available at $1.75 each and the member's name will be stamped on it for 50 cents additional. The smaller size of binder is still available at $1.50.

Associate Application Form

For the benefit of members who desire to have available each month an application form for Associate membership, there is printed in the PROCEEDINGS a condensed Associate form. In this issue this application will be found on page XXXIII of the advertising section.

Application forms for the Member or Fellow grades may be obtained upon application to the Institute office.

The Committee on Membership asks that members of the Institute bring the aims and activities of the Institute to the attention of desirable and eligible non-members. The condensed form in the advertising section of the PROCEEDINGS each month may be helpful.

Radio Signal Transmissions of Standard Frequency

MAY AND JUNE, 1930

The following is a schedule of radio signals of standard frequencies for use by the public in calibrating frequency standards and transmitting and receiving apparatus as transmitted from station WWV of the Bureau of Standards, Washington, D. C.

Further information regarding these schedules and how to utilize the transmissions can be found on pages 10 and 11 of the January, 1930 issue of the PROCEEDINGS, and in the Bureau of Standards Letter Circular No. 171, which may be obtained by applying to the Bureau of Standards, Washington, D. C.

Eastern Standard Time	May 20	June 20
10:00 P.M.	4000	550
10:12	4400	600
10:24	4800	700
10:36	5200	800
10:48	5800	1000
11:00	6400	1200
11:12	7000	1400
11:24	7600	1500

Committee Work

Committee on Admissions

A meeting of the Committee on Admissions was held at 10 A.M. on April 2, 1930 in the office of the Institute, the following being present: R. A. Heising, chairman; Arthur Batcheller, R. H. Marriott, J. S. Smith, and A. F. Van Dyck.

The committee considered seventeen applications for transfer or election to higher grades of membership in the Institute.

Committee on Constitution and Laws

A meeting of the Committee on Constitution and Laws was held at 10 A.M. on April 2, 1930 at the office of the Institute, the following being present: R. H. Marriott, chairman; Melville Eastham, W. G. H. Finch, H. E. Hallborg, R. A. Heising, and G. W. Pickard.

Committee on Membership

The Committee on Membership held a meeting at 7 P.M. on March 12, 1930, at the office of the Institute. In addition to I. S. Coggeshall, chairman, the following were present: F. R. Brick, S. R. Montcalm, and A. F. Murray.

Committee on Sections

At 7 P.M. on March 31st, a meeting of the Committee on Sections was held at the office of the Institute, the following being present: Austin Bailey, chairman; D. H. Gage, C. W. Horn, and B. E. Shackleford.

Standardization

Technical Committee on Radio Receivers—I.R.E.

Two meetings of the Technical Committee on Radio Receivers of the Institute were held. The first at 10 A.M., March 13, was attended by E. T. Dickey, chairman; Wilson Aull, C. M. Burrill, G. C. Crom, Jr., C. E. Dean (representing W. A. MacDonald), Malcolm Ferris, E. J. T. Moore (representing V. M. Graham), and H. P. Westman, secretary.

The second meeting of this committee was held at 10 A.M. on April 3, those present being: E. T. Dickey, chairman; C. M. Burrill, Malcolm Ferris, E. J. T. Moore (representing V. M. Graham), W. A. MacDonald, Beverly Dudley, assistant secretary, and H. P. Westman, secretary.

Both of these meetings were held at the office of the Institute.

Technical Committee on Electro-Acoustic Devices—A.S.A.

The Technical Committee on Electro-Acoustic Devices under the American Standards Association procedure held a meeting on April 11 at 10 A.M. at the office of the Institute of Radio Engineers. The following were present: Irving Wolff, chairman; L. A. Bostwick, E. D. Crook, J. W. Fullmer (representing H. B. Smith), W. B. Greenwood (non-member), Benjamin Olney, J. L. Reynolds, H. A. Wheeler, Adney Wyeth (representing W. P. Powers), Beverly Dudley, assistant secretary, and H. P. Westman, secretary.

Institute Meetings

Atlanta Section

On March 21st a meeting of the Atlanta Section was held at the Blue Boar Cafeteria, Atlanta, Georgia, vice-chairman Harry Dobbs presiding. H. L. Wills, vice-president of the Georgia Power Company, gave a talk on "The Personal Hazards of the Modern A-C Receiving Sets" which was discussed by most of the fourteen members in attendance.

The resignation of H. P. Thornton as chairman of the section was accepted and Harry Dobbs, vice-chairman, became acting chairman until the next election, which is scheduled for the May meeting of the section.

Boston Section

At the meeting of the Boston Section of the Institute held on February 7, 1930, a paper by G. W. Kenrick and G. W. Pickard on "Radio Wave Propagation Phenomena" was presented.

Discussion of the paper was made by Professors Kennelly and Pierce. The attendance was one hundred and fifty-five.

Buffalo-Niagara Section

A joint meeting was held of the Buffalo-Niagara Section of the Institute of Radio Engineers and the Niagara-Frontier Section of the American Institute of Electrical Engineers on March 21, 1930 at the Hotel Statler, Buffalo. R. T. Henry, chairman of the section of the American Institute of Electrical Engineers, presided.

At this meeting, Dr. Phillips Thomas, of the Research Department of the Westinghouse Electric and Manufacturing Company, delivered a paper on "By-Products of Radio". This was followed by a paper on "The Human Element in Accident Causation" which was given by Frank E. Redmond, Educational Director of Associated Industries of New York State, Inc.

Chicago Section

The March meeting of the Chicago Section was held at The Press Club on the 21st of the month. H. E. Kranz, chairman, introduced the speaker of the evening, Dr. Lee de Forest, president of the Institute, whose subject for the evening was "The Past, Present, and Future of Radio in its Broader Aspects". The general discussion which followed the paper was participated in by Messrs. Arnold, Forbes, Gawler, Jenkins, Kranz, and Wilcox.

A constitution along the general lines suggested by the Institute headquarters was approved by the membership.

Two hundred and forty members and guests were in attendance.

Cincinnati Section

R. H. Langley presided at the March 27th meeting of the Cincinnati Section held at the Chamber of Commerce meeting rooms. T. A. Hunter presented a paper on "The Application of Radio Technique to Neuropsychistry".

A second paper on "Recent Developments in Receiver Measuring Equipment" was delivered by C. G. Feliz.

These papers were discussed by Messrs. Austin, Glover, Loftis, and Peterson.

Twenty-four members and guests were present.

Cleveland Section

At the February 28th meeting of the Cleveland Section held in the Physics Laboratory of the Case School of Applied Science, two papers were presented. The first speaker, E. T. Huddleson, spoke on "Rise of Amateur Radio." This was followed by H. A. Tummonds, who described the "Short-Wave Activities at the Cleveland Air Races of 1929."

Following these two papers, motion pictures of the work of the Cleveland Wireless Club at the air races were shown by Frank Heisler.

The final activity of the evening was a demonstration by Professor Martin of Case School of several experiments with an oscillator generating frequencies corresponding to wavelengths in the neighborhood of 2.5 meters.

The meeting was presided over by the Chairman of the Section, D. Schregardus, and sixty-two members and guests were present.

The March meeting of the Cleveland Section was held on the 28th of the month at the Physics Laboratory, Case School of Applied Science, D. Schregardus, chairman, presiding.

A paper on the Cleveland Police Radio System was delivered by E. L. Gove of broadcast station WHK.

The second paper of the evening concerned "Police Methods of Identification", and was presented by L. G. Koestle, Superintendent, Bureau of Identification, Police Department.

Thirty members and guests attended the meeting.

New Orleans Section

The February 28th meeting of the New Orleans Section was held at Loyola University. P. E. Lehde presided and the forty members and guests present enjoyed very much the showing of the film, "Wizardry of Wireless." A general discussion followed its showing.

Philadelphia Section

At the March 12th meeting of the Philadelphia Section held in the auditorium of The Franklin Institute, Chairman J. C. Van Horn presiding, one hundred members and guests heard the presentation of the paper, "Transmission Characteristics of Short-Wave Telephone Circuits" by the author, R. K. Potter, of the American Telephone and Telegraph Company.

Two papers were presented at the next meeting of the section held on April 1 in the same auditorium. J. C. Van Horn, chairman of the section, presided and introduced Dr. Alfred N. Goldsmith who was present at the meeting. After a brief speech, Dr. Goldsmith introduced the speakers of the evening.

L. P. Wheeler, of the U. S. Naval Research Laboratory, delivered a paper on "The Master Circuit of Crystal Controlled Transmitters", which was followed by a paper by W. R. G. Baker of the R. C. A.-Victor Company who spoke on "What Kind of an Engineering Organization Is Necessary to Lead the Radio Industry".

A number of the one hundred and sixty members and guests who attended the meeting participated in the discussion.

San Francisco Section

George T. Royden presented a paper on "The Mackay Radio Communication Network" before the February 28th meeting of the San Francisco Section held at the Engineers' Club. D. K. Lippincott, chairman, presided.

The paper covered a brief historical sketch of the Mackay Radio Net and a complete description of the present network now in operation. The discussion which was entered in by many of the sixty members and guests attending covered many points in detail.

A paper on "Television" outlining the problems in general and giving a detailed description of a cathode-ray tube receiver was presented at the March 12, 1930 meeting of the section by Philo T. Farnsworth.

One hundred and thirty members and guests attended the meeting at the Engineers' Club, D. K. Lippincott presiding.

Seattle Section

On April 4th a meeting of the Seattle Section was held at the Physics Hall, University of Washington. Austin V. Eastman presided at the meeting and introduced Paul M. Higgs, who presented a paper on "Optics of Radio Transmission", together with a laboratory demonstration showing many of the spectacular and peculiar characteristics of high-frequency waves. The similarity in the behavior of light and radio waves was demonstrated.

Messrs. Eastman, Kleist, Libby, and Willson participated in the discussion.

Sixty-four members and guests attended the meeting.

Toronto Section

On February 12, the Toronto Section enjoyed a paper by Malcolm Ferris of the Radio Frequency Laboratories on the subject, "A Simplified Standard-Signal Generator for the Factory Testing of Radio Receivers." Mr. Ferris described a simple form of microvolter wherein percentage modulation and carrier voltage are predetermined by design, being checked experimentally. This address was illustrated by lantern slides and a demonstration was given by a locally-built generator.

The paper was discussed by Messrs. Fox, Hackbusch, Lowrie, Rogers, Smith, and others of the seventy-six members and guests who attended the meeting.

H. O. Merriman, inductive interference engineer of the Dept. of Marine and Fisheries of Ottawa, delivered a paper on "The Work the Radio Branch, Dept. of Marine and Fisheries, Is Doing to Locate and Correct Radio Interference of Broadcast Programs" at the meeting of the section held on March 12, 1930. The lecture was not only illustrated by a number of slides showing methods used, but a demonstration by an oscillograph showing wave forms of different kinds of interference was given. The discussion was participated in by Messrs. Dalton, Fox, Hackbusch, Leslie, Lowrie, Mott, Pipe, Price, and Smith, who brought forth a number of interesting points and valuable information.

Seventy-five members and guests attended the meeting.

Washington Section

R. K. Potter, of the American Telephone and Telegraph Company, delivered a paper, "Transmission Characteristics of a Short-Wave Telephone Circuit" before the March 13th meeting of the Washington Section held at the Continental Hotel, Washington, D. C. C. B. Jolliffe presided and one hundred and thirty-two members and guests attended.

The paper was discussed by Dr. Jolliffe, Dr. Taylor, and Messrs. Mirick and Robinson.

Part II

TECHNICAL PAPERS

Proceedings of the Institute of Radio Engineers
Volume 18, Number 5 *May, 1930*

NEW PIEZO OSCILLATIONS WITH QUARTZ CYLINDERS CUT ALONG THE OPTICAL AXIS*

By

August Hund and R. B. Wright

(Radio Section, Bureau of Standards, Washington, D. C.)

Summary—*It is shown that oscillations of a new type can be produced using a quartz cylinder cut along the optical axis. Some of the electrode mountings used were suggested by Röntgen's experimental work and the more recent work of Tawil. In order to produce these oscillations it was necessary to use new adaptations of regenerative circuits as the driving circuit.*

These oscillations were studied experimentally through the medium of glow discharge patterns, a phenomenon of ionization produced by the quartz cylinder oscillating in a few millimeters of helium. They were studied theoretically by comparing the observed frequencies of oscillation with the computed values for the three different types or modes of vibration. Both studies indicate that these oscillations are of a true piezo-electric character.

Introduction

IN RELATION to crystalline quartz cylinders cut along the optical axis, E. P. Tawil[1] describes a new phenomenon which he states to be different from piezo-electric phenomena and suggests that it be called "strepho-electricity." In the description it is shown how opposite electrical charges appear respectively on the cylindrical surface and the ends when such a cylinder is subjected to a torsion about its cylindrical (and optical) axis. The charges thus produced appear to be proportional to the variation of the torsional strain. Moreover, the polarity of these charges reverses when the direction of torsion is reversed, and, in addition, the polarity is dependent upon the optical structure of the quartz, or specifically, upon the optical rotation thereof.

In 1890, W. C. Röntgen,[2] experimenting with static torsional forces on this same type of quartz cylinder cut along the optical axis, found that a twist about this axis produces charges of opposite polarity in consecutive quadrants around the cylinder, as is indicated in Fig. 1. A, B, C, D, E, and F denote points of neutrality around the cylinder (which is assumed perpendicular to the plane of the paper) when ordinary piezo-electric effects occur, whereas α, β, γ, and δ mark such points of zero surface charge on the envelope when torsional stresses are act-

* Dewey decimal classification: 537.65. Publication approved by the Director of the Bureau of Standards of the U. S. Department of Commerce.

[1] "Nouveau mode de developpement d'electricite par torsion dans les cristaux de quartz." ("New method of producing electricity by torsion on quartz crystals.") *Comptes Rendus*, 187, *pp.* 1042–44; Dec. 3, 1928.

[2] Wied, *Ann. d. Physik*, 39, 16, 1890.

ing. Those polarities indicated in the figure within by two concentric circles denote the charges developed by torsional stress, while those within the single circles refer to ordinary piezo-electric polarizations. A result such as indicated in this figure does not seem to be correct for quartz, considering its three piezo-electric axes, which should ordinarily lead one to expect six alternate charges around the cylinder. Röntgen himself doubted the outcome of his experiment somewhat and

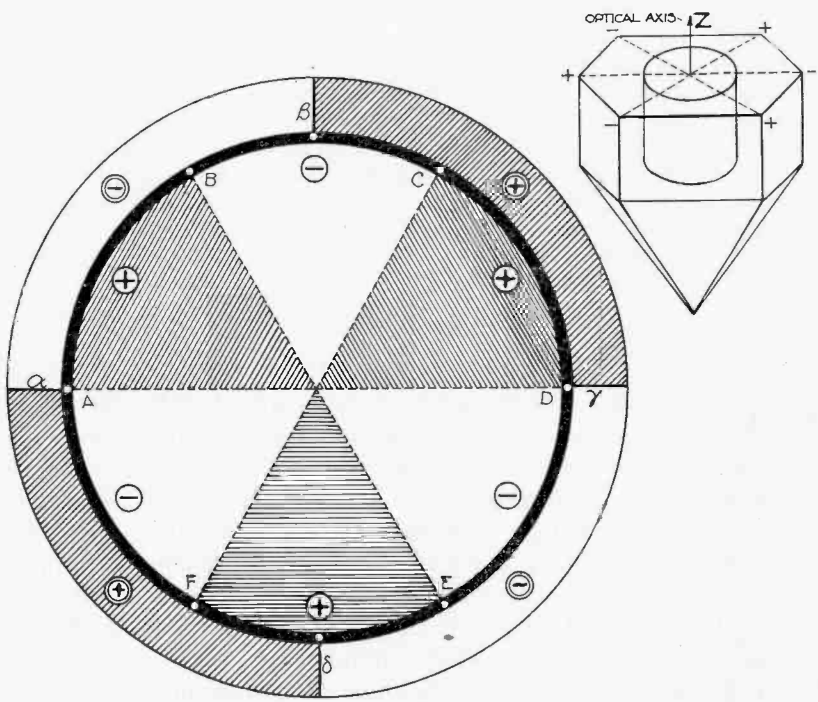


Fig. 1—Charges on quartz cylinder (both when normal and when torsional strains exist).

repeated it with the same result; a result which would be in direct contradiction to W. Voigt's theory[3] if the cylinders used were accurately oriented.

Both the above experiments dealt with *static* torsional forces. One of the purposes of this paper is to show that *dynamic* torsional forces can produce electric effects, and vice versa. A second purpose is the demonstration of new oscillations produced with cylinders cut parallel to the optic axis, which oscillations, incidentally, may be ex-

[3] W. Voigt, "Lehrbuch des Kristallphysik," pp. 879–891; see conclusions on page 891.

plained theoretically without conflicting with Voigt's theory. A third purpose of this paper is to show that these oscillations embody true piezo-electric action.

Circuits Used in the Experiments

Ordinary circuits[4] cannot be used for producing oscillations of this type. This is due, no doubt, partially to the fact that the modulus δ_{14}

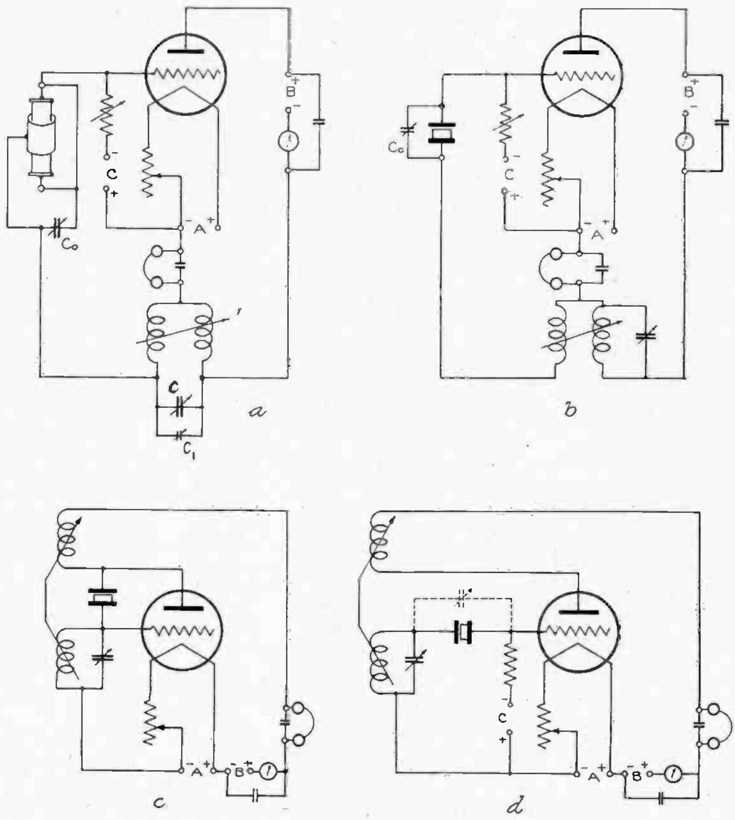


Fig. 2—Driving circuits for oscillations.

which has the value of only $+1.45\times10^{-8}$ c.g.s. electrostatic units, is operative in the case of torsional oscillations, whereas the modulus responsible for the more usual "Curie cut" oscillations has the value

[4] In which the piezo-electric element is connected either between the grid and the filament, or between the grid and the plate, and in which a condenser in parallel with a coil is employed in the anode branch. (For details, see Proc. I. R. E., 14, 447–469; August, 1926.)

$\delta_{11} = -6.45 \times 10^{-8}$ c.g.s. electrostatic units.[5] It was therefore necessary to resort to circuits which are so regenerative that they are on the verge of self-oscillation. The arrangements *a*, *b*, *c*, and *d* of Fig. 2 were found to work satisfactorily. In the systems *a* and *b* a small condenser C_0 is employed for adjusting the feed back. In the system *d* a small condenser may or may not be used across the piezo-electric element.

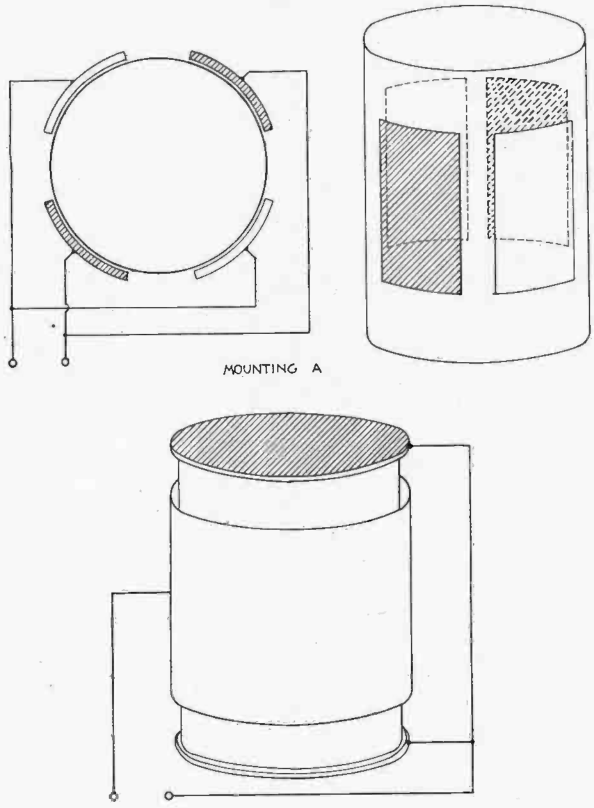


Fig. 3—Electrode mountings for new oscillations.

Electrode Mountings

The experiments by Röntgen, as well as the recent investigation by Tawil, suggest two mountings, shown in Fig. 3, *A* and *B*, respec-

[5] Here each of the three different types or modes of vibration, including both their respective fundamentals and modes of higher frequency, must be distinguished from the other two. The three different types or modes of vibration referred to are: (1) longitudinal vibration; (2) transverse or bending vibration; (3) torsional vibrations. This paper describes the first known successful attempt to produce torsional vibrations along the optical axis.

tively. These will be referred to throughout the paper as mountings *A* and *B*. It is seen that mounting *A* consists of four electrodes placed around the cylinder, of which alternate ones are of the same polarity,

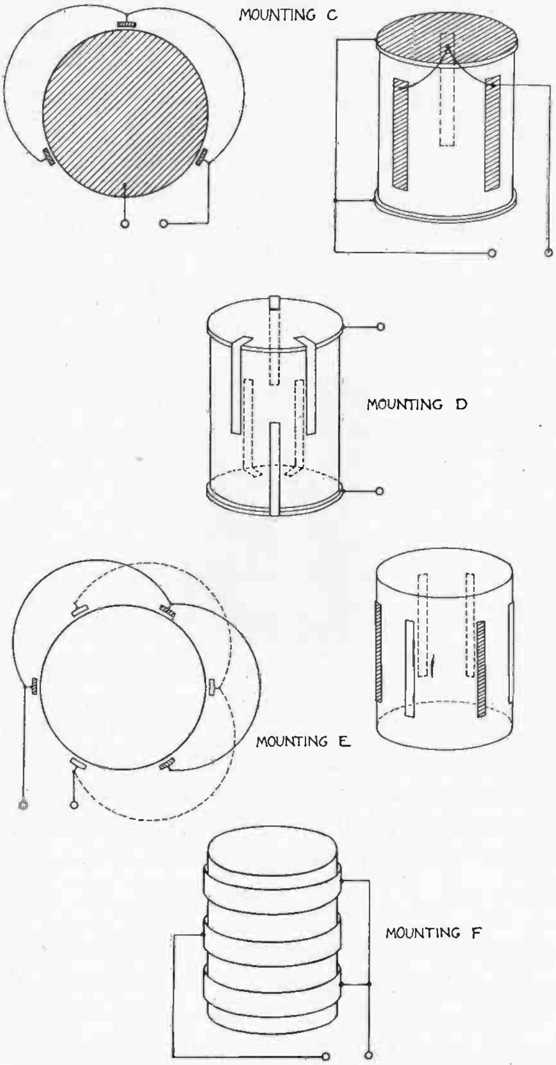


Fig. 4—Other electrode mountings for new oscillations.

while for mounting *B* a cylindrical electrode acts with respect to the two end electrodes, which are in parallel.

Other mountings with which oscillations were obtained are indicated in Figs. 4 and 23. Mounting *C* consists of three electrodes properly located with respect to the three piezo-electric axes, connected in parallel to form one terminal, while the other terminal is formed by the two end disks in parallel.

Mounting *D* consists of two sets of three electrodes each. One set connects to the upper end disk, and the other to the lower disk. The electrodes of the upper set, like those of the lower set, are spaced 120 deg. apart around the cylinder, one set having an angular displacement of 60 deg. with respect to the other.

Mounting *E* consists of six metal strips around the cylinder, alternate ones being interconnected. No end disks were used in this case. This electrode system corresponds closely to the piezo-electric structure of the cylinder.

Mounting *F* consists of three rings around the cylinder, the two end ones being opposite in polarity to the central one.

Fig. 5—186 kc, mounting *B*, height 38.3 mm, dia. 24.715 mm.

Mounting *G* (see Fig. 23) consists of six strips around the upper portion of the cylinder, and six strips around the lower portion, adjacent strips being always of opposite polarity. Mountings of this nature were made by fixing strips to the inside of a glass tube which was placed around the quartz cylinder.

Experimental

A. Experiments with Mounting *B*. For studying different modes of vibration, either the dust method of Kundt,[6] or the glow discharge method of Giebe and Scheibe[7] are convenient means. Since the glow discharge method has advantages over Kundt's procedure, it was used.

[6] A. Kundt, "Über eine einfache Methode zur Untersuchung der Thermo-Elektricität and Piezo-Elektricität der Krystalle," ("On a simple method for the investigation of thermoelectricity and piezoelectricity of crystals"), *Berlin Akademie*, **16**, 421, 1883.

[7] E. Giebe and A. Scheibe, "Sichtbarmachung von hochfrequenten Longitudinalschwingungen piezoelektricher Kristallstäbe," ("Luminous effects of high frequency longitudinal vibrations of piezo-electric crystals"), *Zeits. f. Phys.*, 33, 335, 1925, and *Elektrotechnische Nachrichtechnik*, 5, 63–82; February 1928.

Glow discharges under a gas pressure of several millimeters of mercury were produced in neon, in helium, in a mixture of both, and in nitrogen, but most of the photographs shown here were of the quartz cylinder oscillating in helium.

When using mounting *B* the upper disk was omitted in order that the end pattern might be observed. This mounting, as well as all others, consisted of electrodes of aluminum. In this way the sputtering of the crystal was avoided. The air-gap between the crystal and the cylindrical electrode of mounting *B* was about 1 mm.

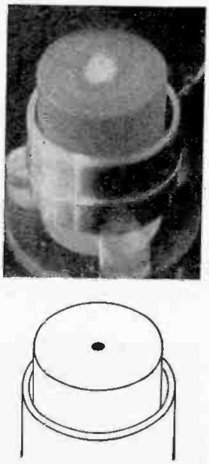


Fig. 6—118 kc, mounting *B*, height 36.67 mm, dia. 24.715 mm.

Fig. 5 shows a cylinder in oscillation, with discharge effects along the optic axis. On pursuing the study of this type of discharge, it was found that for a higher gas pressure (and, incidentally, with a cylindrical cut crystal whose height was slightly less than the one shown in Fig. 5) a small spherical discharge appeared, rising some distance above the crystal as shown in Fig. 6. The crystal oscillation for this case produced a steady alternating current of 118 kc. With the same cylinder an axial glow similar to that shown in Fig. 5 appeared at a frequency of 179 kc. By properly adjusting the voltage of the oscillation by means of the feed back, however, the various patterns, *a*, *b*, *c*, and *d* shown in Fig. 7 could be produced.

As may be readily understood by a comparison of the photographs with the diagrams which accompany them, it was difficult to get faithful photographic reproductions. In many cases the patterns as they appeared to the eye consisted of designs beautiful in their detail. Four of these cases are to be found in Fig. 7. The pattern shown in Fig. 7*a* looked like a small equilateral triangle with a circular glow inside. The dotted portions indicate discharges from the pattern over the surface

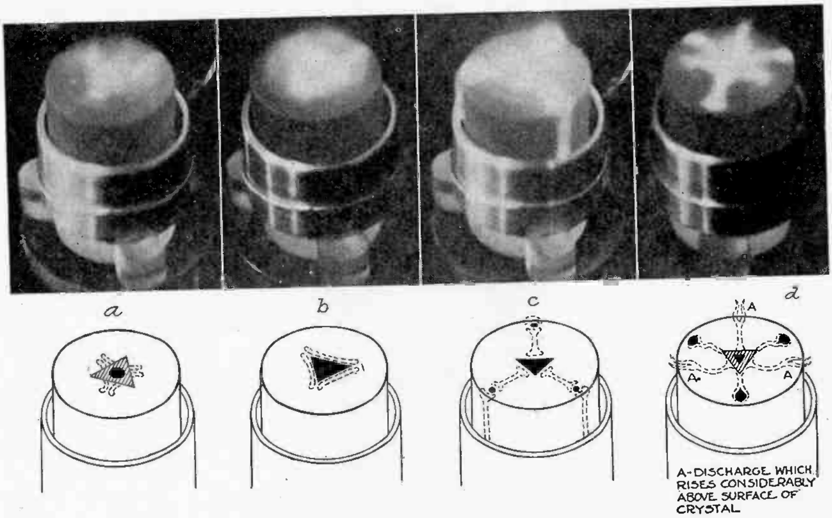


Fig. 7—179 kc, mounting B, height 36.67 mm, dia. 24.715 mm.

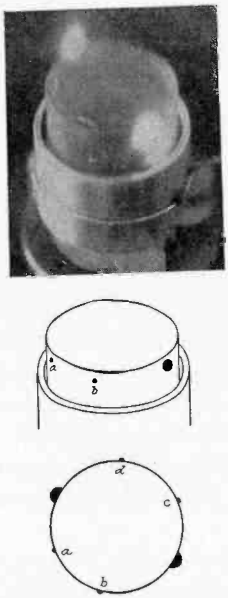


Fig. 8—288 kc, mounting B, height 36.67 mm, dia. 24.715 mm.

towards the cylindrical electrode. In Fig. 7*b* only a triangular glow appeared, whereas in *c* a triangular glow appeared in the center with three circular glows, spaced 120 deg. around the end face of the cylinder. For these discharge patterns and all the others, the dotted lines indicate discharges between surface-charge patterns, or between surface-charge patterns and the electrode or electrodes around the cylinder.

Generally speaking, the 179-kc oscillation (Fig. 7) was always characterized by a triangular pattern, whereas to the 118-kc oscillation of Fig. 6 there always corresponded a circular pattern at the center.

The same cylinder oscillated also at 288 kc, with a discharge pattern as shown in Fig. 8. It will be noted that two diametrically located large circular glow discharges were accompanied by four small discharge points *a*, *b*, *c*, and *d* spaced evenly around the envelope of the cylinder, completing in a way the hexagonal formation which one would expect on account of the three piezo-electric axes.

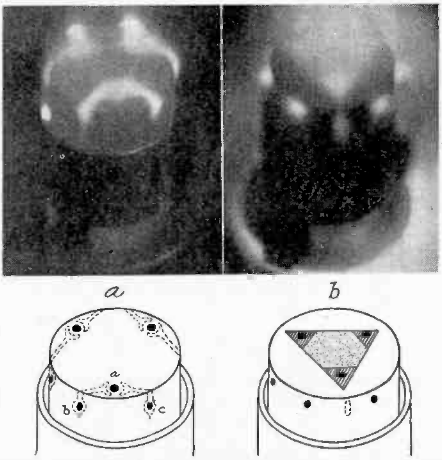


Fig. 9—269 kc, mounting *B*, height 38.3 mm, dia. 24.715 mm.

Fig. 9*a* shows three circular surface discharges on the top of the crystal, which were located at the corners of an equilateral triangle. There were also six circular surface discharges around the cylinder which indicate again the hexagonal structure of the quartz. The discharges from the corners of the hexagon to those of the triangle probably occur alternately, since points *b* and *c*, as shown in the figure, must be of opposite polarity. In other words, it is very probable that the discharge from *a* to *b* occurs during one half cycle and the discharge from *a* to *c* during the succeeding one. The patterns shown in Fig. 9*a* and 9*b* were obtained with the same cylinder oscillating at the same frequency in helium. The difference in the patterns is due to a difference in the pressure of the helium gas, a lower pressure being used in the case of Fig. 9*b*.

Fig. 10 shows the case of a 301-kc oscillation. The piezo-electric symmetry of the cylinder can in this case be interpreted only from the three circular surface discharges on the top face.

Fig. 11 shows a pattern for which the circular surface discharges on the top face were at the corners of two equilateral triangles. The corners of the smaller triangle were the midpoints of the sides of the larger triangle. In addition, around the cylindrical envelope, near the top face, three more surface discharges were visible. They indicate again part of the hexagonal structure of the quartz.

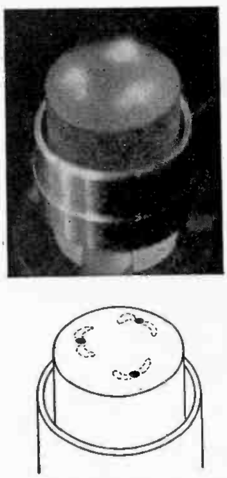


Fig. 10—301 kc, mounting B, height 36.67 mm, dia. 24.715 mm.

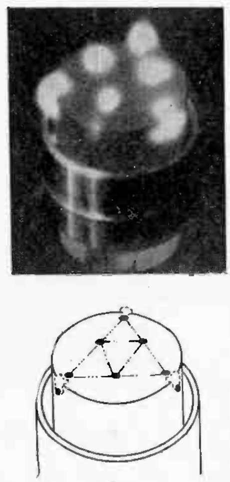


Fig. 11—394 kc, mounting B, height 36.67 mm, dia. 24.715 mm.

Fig. 12 indicates most strikingly the piezo-electric nature of this class of oscillations. The circular surface discharges accompanying this frequency of oscillation appear around the envelope near the top face, while for the case of the 296-kc oscillation they are to be found as shown in Fig. 13, on the top face, somewhat inside the circumference.

At this point it was deemed important to find out whether those circular surface discharges which appear on top, or those appearing around the envelope, mark the three piezo-electric axes of the crystal. To determine this it was first necessary to locate these axes. With this end in view the quartz cylinder was suspended between two parallel plates to which 20 kv (taken from a d-c source) were applied. In an electrostatic field of this strength the crystal readily turned itself into such a position that one of the three piezo-electric axes was along the lines of force, that is, perpendicular to the plates. From this test it was found that the glow discharge of the 331-kc oscillation (Fig.

12) marked exactly the piezo-electric axes of the cylinder, while the six surface discharges of Fig. 13 appeared halfway between these axes, as is indicated in the figure.

Another interesting glow discharge occurred with a 262-kc oscillation, shown in Fig. 14. Again we find six discharge spots on the top face which produced six space discharges, which in turn ran together forming a discharge ring somewhat above the cylinder. From the ring-shaped discharge six space discharges ran radially outwards and then down the cylinder toward the cylindrical metal electrode.

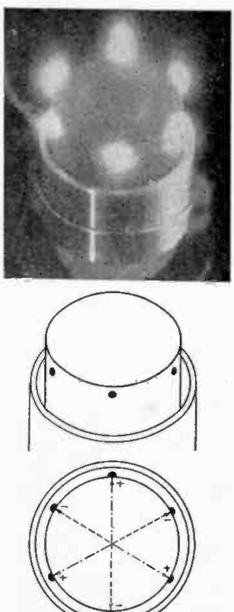


Fig. 12—331 kc, mounting *B*, height 36.67 mm,dia. 24.715 mm.

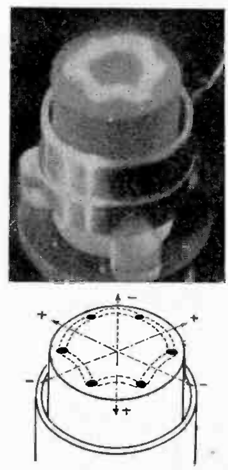


Fig. 13—296 kc, mounting *B*, height 36.67 mm, dia. 24.715 mm.

Fig. 15 shows a display which accompanied the 174-kc oscillation, and Fig. 16 that for the 186-kc oscillation, which latter consisted of a space charge globule elevated somewhat above the center of the top face and resting, so to speak, on its own discharge, which emanated from it in a downward direction, in the form of a tripod.

In Fig. 17 is depicted a beat phenomenon between the two frequencies at which the cylinder was being simultaneously oscillated. On going up to still higher frequencies, the 440-kc oscillation shown in Fig. 18 was found. It consists of large and small discharge spots. Except for the three envelope discharge points these were found to lie on the indicated hexagon. The three large discharge points did not form an equilateral triangle in this case, but this may conceivably happen for higher modes of vibration.

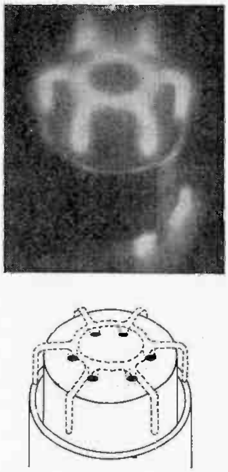


Fig. 14—262 kc, mounting *B*, height 36.67 mm, dia. 24.715 mm.

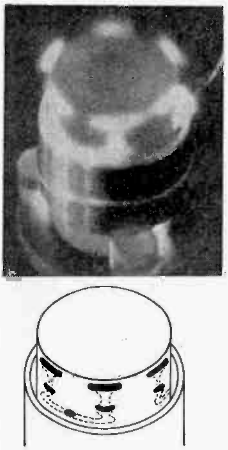


Fig. 15—174 kc, mounting *B*, height 36.67 mm, dia. 24.715 mm.

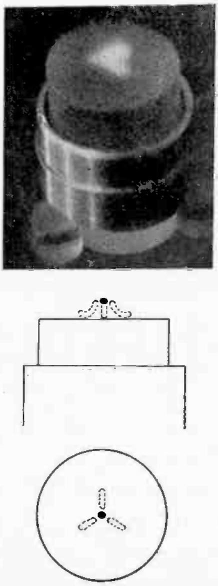


Fig. 16—186 kc, mounting *B*, height 36.67 mm, dia. 24.715 mm.

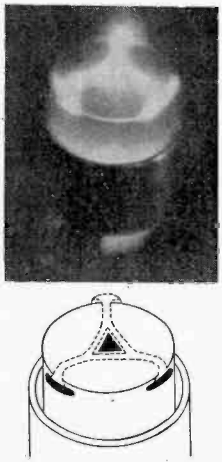


Fig. 17—174 and 179 kc, mounting *B*, height 36.67 mm, dia. 24.715 mm.

For the 520-kc oscillation, the pattern of Fig. 19 was obtained. Here four of the seven spots appeared to lie on a parabola.

B. Experiments with Mountings *A*, *E*, and *G*. It seemed of particular interest to find out whether oscillations could be produced using mounting *A*, with its four quadrant electrodes, considering the peculiar relation of the electrode system to the three piezo-electric axes. Oscillations were nevertheless obtained, as is shown in Fig. 20. The electrode system in this case consisted of thin aluminum strips pasted inside of a glass cylinder whose inside diameter exceeded the diameter of the quartz cylinder by about 2 mm.

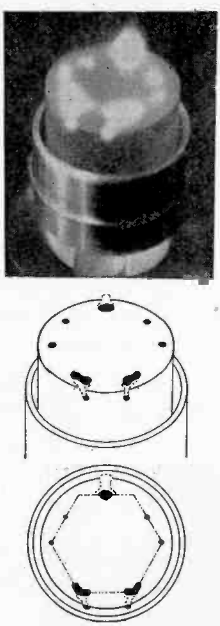


Fig. 18—440 kc, mounting *B*, height 36.67 mm, dia. 24.715 mm.

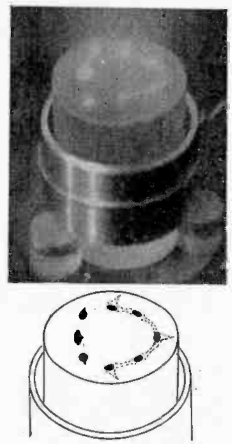


Fig. 19—520 kc, mounting *B*, height 36.67 mm, dia. 24.715 mm.

The 168-kc oscillation, obtained with mounting *A*, consisted of a glow discharge in the upper left corner, coexistent with a similar one, diagonally opposite, that is, on that portion of the lower edge which cannot be seen in the photograph. The diagonal effect for the 410-kc oscillation of Fig. 20*c*, however, can be recognized at least by the general glow to be seen through the lower portion of the cylinder. The 371-kc oscillation produced four surface discharges on top of the crystal, and the 790-kc oscillation the pattern of Fig. 20*d*.

With mounting *E*, which would appear to be a most natural one, embodying six electrodes placed around the cylinder, oscillations shown in Figs. 21 and 22 were produced. Such a mounting may be placed in two distinctly different positions. It may be so placed that the electrodes either cover the points of maximum or the points of minimum piezo-electric polarization, that is, so placed that they fall either on or midway between the three piezo-electric axes. The former position

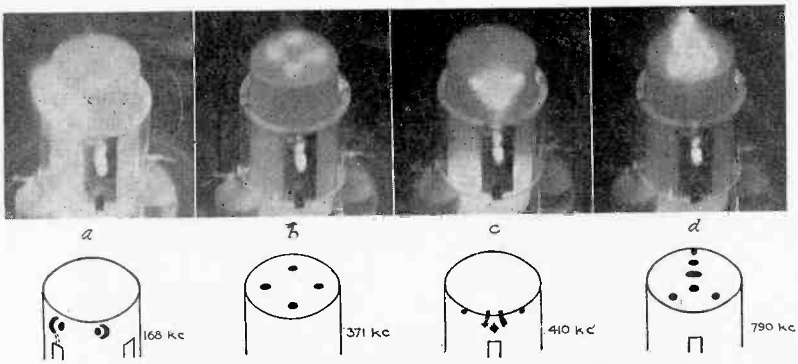


Fig. 20—168, 371, 410, and 799 kc, mounting *A*, height 36.67 mm, dia. 17.6 mm.

may well be called the "Curie" or 0-deg. mounting, and the latter the 30-deg. mounting. Both mountings were tried, and oscillations were produced in each case. Whenever the same pattern, that is, the same oscillation, was obtained in each case, it was found that the pattern occurred at the same positionon the crystal irrespective of the mounting

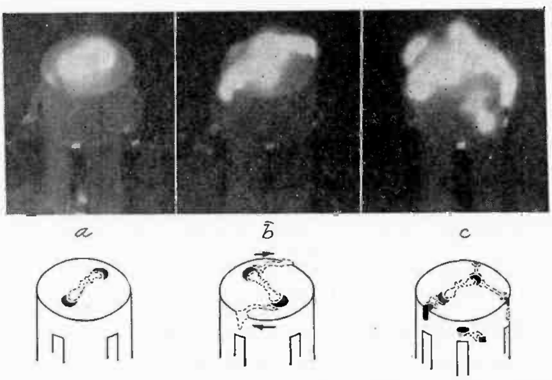


Fig. 21—299 kc, mounting *E*, height 36.67 mm, dia. 17.6 mm.

position. Thus, in the six glow discharge pattern of the 433-kc oscillation shown in Fig. 22*c*, the six surface discharges occurred halfway between the actual piezo-electric axes for both the 0- and 30-deg. mounting. At this point it may be of interest to recall the pattern of Fig. 13

where, also, six circular discharges were obtained on the top face, but this with the cylinder drive *B*. In that case the discharges were also halfway between the piezo-electric axes. Moreover, referring again to mounting *E*, it seems that with the 30-deg. location of the electrodes, oscillations may be brought in somewhat more easily, just as in ordinary piezo-electric work somewhat better response is obtained with 30-deg. cuts than with "Curie cuts."

The 299-kc oscillation shown in Fig. 21 can give patterns as indicated, depending upon gas pressure and feed back. The pattern in Fig. 21*b* consisted of two surface discharges interlinked by a discharge which was raised above the surface of the crystal. The position of these surface discharges, with respect to the piezo-electric axes depends,

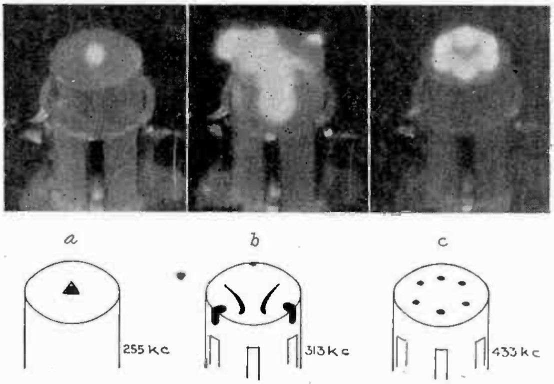


Fig. 22—255, 313, and 433 kc, mounting *E*, height 36.67 mm, dia. 17.6 mm.

apparently, upon phase relationship. When the small condenser C_1, or the regeneration control C_0, of circuit, Fig. 2*a*, was changed by a small amount, this "doublet" turned around either by 60 or by 30 deg. For the former case, the "doublet" swung into the adjacent piezo-electric axis, and for the latter, into a 30-deg. location. Since this took place without a frequency change it must have been caused by a change in phase.

The mounting *G* shown in Fig. 23 was designed with the purpose in mind of producing torsional effects. All shaded electrodes lead to one terminal, and the remaining electrodes to the other terminal. From the discharge patterns and frequencies of oscillations obtained with this drive we must infer that the oscillations, in many cases at least, are the same as obtained with drives *B*, *C*, *D*, *E*, and *F*. An interesting point about this drive is that the orders of the modes of oscillation it produces are generally found to lie in a higher range than those produced with the other mountings.

Comparison of the Experimental Results

Most of the patterns shown herein, and most of those observed by the authors but not shown, strongly indicate that the vibrations of the quartz cylinder are dependent upon piezo-electricity, since the patterns indicate either directly or, at least, suggest in a partial way, the piezo-electric structure. Tawil's "strepho-electricity" must be, therefore, a case of true piezo-electricity. This dependency of vibrations upon piezo-electricity may be better understood from a study of the electric lines of force involved. Consider, for instance, mounting *B*, which suggested itself from Tawil's experiments. The lines of force leave the end face electrodes parallel to the optic (Z-axis, according to Voigt's notation) axis at first, then bend around, and finally enter the cylindrical electrode perpendicularly. Hence there must be components along the three piezo-electric axes, which lie in the equatorial plane. These components must produce "Curie effects." In Table I are compiled some of the frequencies obtained either with the cylinder under a low pressure of helium gas, or in air, at atmospheric pressure. With the exception of those for mounting *A*, the discharge figures and the fre-

TABLE I

Oscillation Frequencies in kc per sec.

Mounting *A* 4 electrodes	Mounting *B* Cylinder Mounting	Mounting *E* 6 electrodes	Mounting *F* 3 rings	Mounting *G* 12 electrodes	Remarks
	118				With mounting *F*, crystal was driven in air. With all others, crystal was driven in a low pressure of helium.
125					
			150		
168				168	
			192		
203					Height of cylinder 36.67 mm.; Dia. 17.6 mm.
215					
				227	
	231				
		240			
	251		251	251	
	255	255			
257					
267			267	267	
	289	289	289	289	
		299	299		
				306	
		313			
371					
	373				
		380		380	
383					
	395	395		395	
410					
	417	417	417	417	
433	433	433		433	
	446			446	
470					
475					
	489				
		545	545		
				520	
	600			600	
790					
830				830	

quencies check each other more or less closely. The only frequency for mounting *A* which agreed with that for any of the other mountings was 433 kc. The pattern for mountings *B*, *E*, *F*, and *G* at this frequency was that shown in Fig. 22*c*, six surface charges located halfway between the piezo-electric axes. But the pattern found at this frequency, using mounting *A*, was somewhat different. It resembled a "doublet," very similar to the one shown in Fig. 21*b*, but smaller and eccentrically located, on the top face of the cylinder.

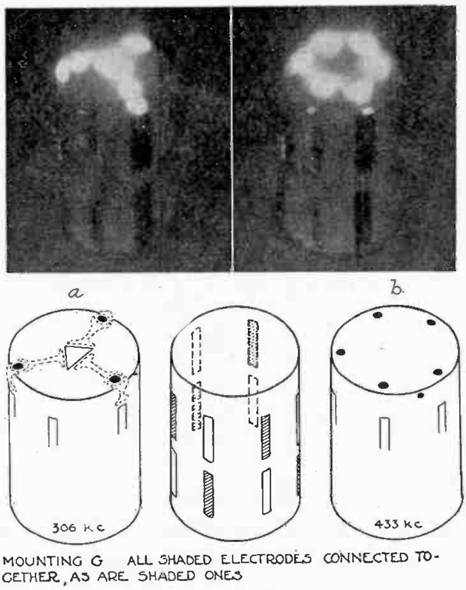


Fig. 23—306 and 433 kc, mounting *G*, height 36.67 mm, dia. 17.6 mm.

With some mountings the phenomenon of recurring patterns was observed. With both mountings *B* and *G*, both the 433- and 446-kc oscillations produced the *same* six-spot pattern (Fig. 22*c*) mentioned above. Similarly, with mounting *B* both the 251- and 255-kc oscillations produced the same triangular spot (shown in Fig. 22*a*) at the center of the top face.

Theoretical Considerations

In general there are three fundamental modes of possible natural oscillation, each of a different nature, as well as the modes of higher order for each of the three, which must be considered. Even in the relatively simple case of an isotropic substance we find that the formulas for vibrations of a body may involve three velocities of propagation, v_1, v_2, and v_3. The first two of these are due to the fact that we have a linear modulus of elasticity, E_1, and a torsional modulus, E_2, to deal with in case of longitudinal and torsional vibrations, respectively. The third velocity is due to what we may consider as a corresponding E_3 effective in the case of transverse vibrations. Thus if D denotes the density, which is 2.65 g/cc for crystal quartz

$$\begin{aligned} v_1^2 &= E_1 D^{-1} \\ v_2^2 &= E_2 D^{-1} \\ v_3^2 &= E_3 D^{-1}. \end{aligned} \tag{1}$$

However, E_3 should not be considered as independent: a simple relation is found to exist between E_1 and E_3 such that we may conveniently write for the corresponding frequencies, f_1 of vibration in the case of a cylindrical body

$$\begin{aligned} &\text{(longitudinal)} && f_{\text{long}} = \frac{p}{2l}\sqrt{\frac{E_1}{D}} \\ &\text{(torsional)} && f_{\text{tors}} = \frac{D}{2l}\sqrt{\frac{E_2}{D}} \\ &\text{(transverse)} && f_{\text{trans}} = \frac{d\psi_p^2}{8\pi l^2}\sqrt{\frac{E_1}{D}} \end{aligned} \tag{2}$$

where p stands for the order of the mode ($p=1$ for the fundamental), and d and l denote the diameter and height of the cylinder, respectively. The values of ψ_p for the fundamental, and some of its higher modes, are

$$\begin{aligned} \psi_1 &= 4.71 \\ \psi_2 &= 7.85 \\ \psi_3 &= 11.0 \\ \psi_4 &= 14.1 \\ \psi_5 &= 17.3 \end{aligned}$$

From this it can be seen that for a cylinder, only the transverse modes of oscillation are affected by the size of its cross section, that is, by its diameter. This is true, however, only when the cylinder height is large compared with the diameter.

The above formulas are all well-known. Moreover, it is evident that those for torsional and transverse vibrations may be rather conveniently expressed in terms of that for longitudinal vibrations.

Thus we may write

$$f_{\text{tors}} = \frac{f_{\text{long}}}{\sqrt{2(1+\mu)}} \tag{3}$$

where μ may have values between 0.2 and 0.5 depending upon the values of E_1 and E_2. And for the transverse frequency we obtain

$$f_{\text{trans}} = \frac{\pi(2p+1)^2}{16p} \cdot \frac{d}{l} f_{\text{long}} \tag{4}$$

from which, for the fundamental mode

$$f_{\text{trans }p=1} = 1.767 \cdot \frac{d}{l} f_{\text{long}} \tag{5}$$

These formulas will give, of course, no very reliable values for crystalline quartz since the modulus of elasticity, although constant in the equatorial plane (perpendicular to the optical axis) is different for all other directions. Fortunately, however, earlier experimenters in the field[8] have determined the longitudinal modulus E_1, as well as the torsional modulus E_2, along the optical axis. They are

$$E_1 = 10.304 \times 10^{11}$$
$$E_2 = 5.085 \times 10^{11}.$$

The values under the radicals in (2) represent velocities, as may be seen by referring to (1), and become, with the above values of elasticity, and the density given previously

$$v_1 = 6.24 \times 10^5 \text{ cm per sec.}$$
$$v_2 = 4.38 \times 10^5 \text{ cm per sec.}$$

For the longitudinal and torsional modes of oscillation of a cylinder of crystalline quartz cut along the optical axis, therefore, we have

$$\left.\begin{aligned} f_{\text{long}} &= \frac{312p}{l} \\ f_{\text{tors}} &= \frac{219p}{l} \end{aligned}\right\} \text{kc per sec.} \tag{6}$$

where the length, l, of the cylinder is expressed in cm and p stands for 1, 2, 3, 4, etc., according to the order of the mode.

For the transverse modes the expression in (2), together with the above value of v_1, gives

[8] Voigt, Riecke, Pockels, and others.

$$f_{\text{trans}} = 24.8\frac{d\psi_p^2}{l^2}\text{kc per sec}. \tag{7}$$

where both the length, l, and the diameter, d, of the cylinder are expressed in cm. As far as the fundamental of this transverse mode is concerned, (5) and (6) check (7) for the value of $\psi_p = 4.71$, and lead to

$$f_{\text{trans } p=1} = 550\frac{d}{l^2}. \tag{8}$$

Of course formula (7) must be considered as an approximation because of the lateral effect. But it should give values sufficiently close to warrant the speculation undertaken in Table II. In this table are compiled for comparison, calculated and experimental values of frequency (for the larger diameter crystal, $d = 2.4715$ cm). It appears that most of the torsional oscillations were obtained, including the fundamental which has hitherto not been mentioned. No description of the pattern for this fundamental mode is given, because the oscillation could be produced only in air, at atmospheric pressure, the reason for which would no doubt be found in a study of the characteristics of the particular drive used.

TABLE II
THEORETICAL AND EXPERIMENTAL FREQUENCIES FOR CYLINDER, IN KC PER SEC.

	Order of Mode	$p=1$	$p=2$	$p=3$	$p=4$	$p=5$	$p=6$
$f_{\text{longitudinal}}$	Calculated (Eq. 6)	85.2	170.4	255.6	340.8	426.0	511.2
	Measured		174	257			520
$f_{\text{torsional}}$	Calculated (Eq. 6)	59.8	119.6	179.4	239.2	299.0	358.8
	Measured	63	118	179		296	331
$f_{\text{transverse}}$	Calculated (Eq. 7)	101	281	552	906		
	Measured		288				
	length $l=3.667$ cm.; diameter $d=2.4715$ cm.; $d/l^2=0.184$						

It is interesting to note that for the cylinder of smaller diameter ($d = 1.76$ cm) but of the same length, there was found a frequency corresponding exactly to one appearing in Table II, namely, 118 kc. This indicates that for this particular mode and order at least, the frequency is independent of cross-section.

CONCLUSION

Although there are reasons why the comparison in Table II is of a speculative nature, nevertheless, after examining it, one finds it very difficult to believe that all the oscillations are of the same mode, even if they were all obtained using the same mounting *B* and drive *A*.

The table seems to indicate, however, that torsional oscillations predominate with this combination of mounting and drive.

As was pointed out in the description of the patterns shown, in most cases the hexagonal formation was indicated, and in many cases the actual piezo-electric axes were either marked out by discharge points or indicated by points midway between. A pertinent point in this respect, and also in its relation to Tawil's work, is that the frequencies of two of the most striking examples of this indication of piezo-electric axes appear to correspond, as shown in Table II, with torsional vibrations. In Table I is to be found a second interesting fact in this respect. It is that most of the frequencies produced using the ring mounting (mounting *B*) can also be produced using the six- and twelve-electrode drives (mountings *E* and *G*, respectively).

In general, the observed facts of these oscillations seem to be in perfect harmony with the previously known phenomona of piezo-electricity; no need for other explanations appears.

Proceedings of the Institute of Radio Engineers
Volume 18, Number 5 *May, 1930*

THE HAGUE CONFERENCE*

By
S. C. Hooper

(Captain, U. S. Navy; Director of Naval Communications, Navy Dept., Washington, D. C.; Member of the delegation of the United States of America to the meeting of the C.C.I.R. at The Hague, September, 1929.)

IN ORDER that the action taken at The Hague Conference may be better understood, it will be advantageous first to quote pertinent parts of the International Radiotelegraph Convention, Washington, 1927, and Regulations annexed thereto.

Article 3 of the General Regulations annexed to the International Radiotelegraph Convention, Washington 1927, is as follows:

Choice and Calibration of Apparatus

1. The choice of radio apparatus and devices to be used by a station shall be unrestricted, provided the waves emitted comply with the provisions of these Regulations.

2. (1) The Administrations must take the necessary measures to assure themselves that the frequency meters (wavemeters) employed in the adjustment of the transmitting apparatus are as accurately calibrated as possible by comparison with their national standard instruments.

(2) In case of international disagreement, the comparisons shall be made by an absolute method of measuring frequencies.

Article 4 of these Regulations is in part as follows:

Classification and Use of Radio Emissions

2. Waves emitted by a station must be maintained upon the authorized frequency, as exactly as the state of the art permits, and their radiation must also be as free as practicable from all emissions not essential to the type of communication carried on.

3. The interested Administrations shall fix the tolerance allowed between the mean frequency of emissions and the recorded frequency; they shall endeavor to take advantage of technical improvements progressively to reduce this tolerance.

4. The width of a frequency band occupied by the emission of a station must be reasonably consistent with good current engineering practice for the type of communication involved.

Article 5 of these Regulations is in part as follows:

Allocation and Use of Frequencies (Wave-lengths) and Types of Emission

1. The Administrations of the contracting countries may assign any frequency and any type of wave to any radio station within their jurisdic-

* Dewey decimal classification: R007.9. Presented at a meeting of the Institute in New York City, February 5, 1930. Edited with the assistance of Lieutenant E. E. Stone, U. S. Navy.

tion upon the sole condition that no interference with any service of another country will result therefrom.

The following note is appended to the table appearing in Article 5:

It is recognized that short waves (frequencies from 6000 to 23000 kilocycles approximately—wavelengths from 50 to 13 meters approximately) are very efficient for long distance communications. It is recommended that as a general rule this band of waves be reserved for this purpose, in services between fixed points.

Article 17 of the International Radiotelegraph Convention, Washington, 1927, and Article 33 of the annexed General Regulations are as follows:

INTERNATIONAL TECHNICAL CONSULTING COMMITTEE ON RADIO COMMUNICATION

1. An International Technical Consulting Committee on Radio Communication shall be established for the purpose of studying technical and related questions pertaining to these communications.

2. Its composition, activities, and operations shall be defined in the General Regulations annexed to the present Convention.

INTERNATIONAL TECHNICAL CONSULTING COMMITTEE ON RADIO COMMUNICATION

1. The International Technical Consulting Committee on Radio Communication, established by Article 17 of the Convention, shall be charged with the study of technical and allied questions which relate to international radio communication and which shall have been submitted to it by the participating Administrations or private enterprises. Its functions shall be limited to giving advice on questions which it will have studied. It shall transmit this advice to the International Bureau, with a view to its being communicated to the Administrations and private enterprises concerned.

2. (1) This committee shall be formed, for each meeting, of experts of the Administrations and authorized private radio operating companies, who wish to participate in its work and who undertake to contribute, in equal parts, to the common expenses of the contemplated meeting. The personal expenses of the experts shall be borne by the Administration or private enterprise which has appointed them.

(2) The experts of such authorized private enterprises shall participate in the work with the right to deliberate but not to vote. When, however, a country is not represented by an Administration, the experts of the authorized private enterprises of that country shall have a right, as a whole and regardless of their number, to a single vote.

3. The Administration of the Netherlands shall be charged with organizing the first meeting of the International Technical Consulting Committee on Radio Communication and with drawing up the program of work for this meeting.

4. The Administrations which shall have been represented at a meeting of the committee shall agree on the designation of the Administration which shall call the following meeting. Questions to be studied by the

Committee shall be sent to the Administration organizing the next meeting and that Administration shall determine the date and program of the meeting.

5. In principle, the meetings of the International Technical Consulting Committee on Radio Communication shall take place every two years.

In May, 1928, the Federal Radio Commission allocated alternate channels in the high-frequency band for radiotelegraph stations on a basis of 0.1 per cent of mean frequency as a channeling system, this being considered good engineering practice.

In July, 1928, foreign governments were addressed by the United States, inviting attention to the channeling system adopted by the United States, and pointing out the advisability of giving consideration to a uniform channeling system for world-wide adoption, along the lines of the United States system, or possibly a better system.

In the early summer of 1929, the Netherlands government submitted a list of topics for consideration, as agenda for the first meeting of the International Technical Consulting Committee on Radio Communication (C.C.I.R.)—invitations for the Conference having previously been issued by the Netherlands government—the date of convening being September 18, 1929. The following subjects were presented for consideration and discussion:

(a) Organization of the Committee, particularly with regard to its future work.
(b) Definitions of several general radio conceptions, including power of a transmitter and division of wavelengths.
(c) Studies resulting from the Washington General Regulations on suppression of interference, including frequency maintenance and band widths.
(d) Special studies to achieve international understanding on various phenomena, including fading, directive effect, skip-distance, etc.
(e) Licenses for amateurs.
(f) Subjects recommended by the Prague Conference, including study of allocation of waves to aviation and to the criminal police, and recommendations for the limitations of the range of broadcast stations.
(g) Radiotelephonic communication between mobile stations and land stations and joining these connections to the telephone system.

Through the machinery of the Interdepartment Radio Advisory Committee, and with the voluntary assistance of several of the leading radio engineers of the United States, the agenda were carefully studied for three months prior to the Conference, and United States proposals were prepared covering all subjects.

The following attended The Hague Conference from the United States:

U. S. Delegates:

Major General Chas. McK. Saltzman, U. S. A. (retired), *chairman*; Major General G. S. Gibbs, Chief Signal Officer, U. S. A.; and Captain S. C. Hooper, U. S. N., Director of Naval Communications.

U. S. Technical Advisors:

Lieutenant Commander T. A. M. Craven, U. S. N. (Bureau of Engineering, Navy Department); Dr. J. H. Dellinger, Bureau of Standards (Department of Commerce); Dr. C. B. Jolliffe, Bureau of Standards (Department of Commerce); Mr. G. C. Gross, Federal Radio Commission; Mr. R. H. Norweb, State Department (who acted as liaison officer between United States delegates and the Netherlands Government); and Captain K. B. Warner, American Radio Relay League.

In addition, the delegates had the invaluable assistance and advice of several United States company representatives, including the following:

American Telephone and Telegraph Company:

Mr. Lloyd Espenschied, Mr. William Wilson (who also represented the Institute of Radio Engineers, informally), and Mr. G. C. De Coutouly.

International Telephone and Telegraph Corporation:

Mr. H. H. Buttner.

Mackay Radio and Telegraph Company:

Mr. T. E. Nivison.

Press Wireless, Incorporated:

Mr. Louis G. Caldwell.

Radio Corporation of America:

Colonel Samuel Reber and Mr. L. A. Briggs.

Radio Marine Corporation of America:

Mr. Charles J. Pannill.

Robert Dollar Company:

Mr. Ralph M. Heintz and Mr. Edgar M. Wilson.

Southern Radio Corporation:

Mr. J. W. Swanson.

Tropical Radio Telegraph Company:

Mr. W. E. Beakes.

Universal Wireless Communication Company:

Dr. John Nathansohn.

Pan American Airways, Inc.

Mr. H. C. Leuteritz.

A disbursing clerk and two stenographers accompanied the delegates.

The official delegation sailed from New York on the *SS Leviathan* on September 7, 1929. Daily meetings were held on board en route. The delegation arrived in The Hague on September 14th, having previously spent two days in London. While at London, there was opportunity to become acquainted with the British delegates, which proved helpful.

At The Hague, the United States delegates were quartered at the Hotel Des Indes. Through the action of our State Department, suitable offices were provided nearby.

The Conference met in plenary session on September 18th with Dr. H. J. Boetje, Chief of the Netherlands delegation, presiding over the Conference.

The following were represented:

French African and other French Colonies
Alaska
Great Britain
Germany
Argentine
Austria
Belgium
Bolivia
Brazil
Bulgaria
Canada
Chile
China
Czechoslovakia
C. C. I. Telegraphiques
C. C. I. Telephoniques à grande distance
Belgian Congo
Costa Rica
Denmark
Dominican Republic
Ecuador
Spain
United States of America
Finland
France
Hawaii
Honduras
Hungary
Dutch East Indies
French Indo China
Ireland
Italy
Japan
Madagascar
Morocco
Mexico
Monaco
Nicaragua
Norway
Palestine
Netherlands
Philippines
Poland
Portugal
Roumania
Siam
Sweden
Switzerland
Union of Soviet Socialist Republics
Union Internationale de Radiodiffusion
Union Radiotelegraphique Scientifique Internationale
International Bureau of the Telegraphic Union

After addresses of welcome by officials of the Netherlands, necessary organization ensued—the following committees being appointed:

Committees	Chairmen	Vice-Chairmen
Organization	Prof. Dr. Breisig (Germany)	Lt. Col. Amoroso Engineer (Italy)
Definitions and Standardization	General Ferrie (France)	Dr. Hirschfeld (U.S.S.R.)
Collaboration	Maj. Gen. Saltzman (United States of America)	M. Nakagami Engineer (Japan)
Operations	Lt. Col. Lee (Great Britain)	M. Strnad Engineer-in-Chief (Czechoslovakia)

The committees were composed of such additional members as the heads of the various delegations proposed. The Collaboration Committee was divided into two subcommittees for one of which I had the pleasure of acting as chairman, while Mr. Corteil, representing Belgium, was chairman of the other.

Upon recommendation of the Netherlands Delegation, the United States proposals were followed as the basis for discussion. This was indeed a compliment to those who prepared the United States proposals.

The work of the various committees, plus informal conferences of groups meeting in an endeavor to bring accord where different points of view existed, was carried on day and night throughout the conference. The work was most difficult owing to the extent of ground to be covered in a short time, and the frequent need for interpretation into the languages of the various nations concerned.

On the ninth day of the conference, the work of the various committees was concluded and at the second and last plenary session, the various committee reports were received and adopted unanimously with slight modifications.

The following is a summary of the principal agreements:

1. It is considered neither necessary nor desirable, under the General Regulations, to set up permanent bodies for the study of questions on the program of the C.C.I.R. Inasmuch as there may be questions still unsettled after meetings of the C.C.I.R., it is considered that at the end of the session of the C.C.I.R., the President should read a list of important questions to be studied, and that he should ask which Administrations are desirous of undertaking the preparation of proposals relating to the said questions, and ready to collaborate with the interested Administrations and with private enterprises, with a view to forwarding these proposals to the Administration organizing the next meeting of the C.C.I.R.

2. It is considered neither necessary nor possible in accordance with the present provisions to now set up a permanent secretariat for the C.C.I.R. It is sufficient to establish a close liaison between the C.C.I.R. and the International Bureau of the Telegraphic Union, it being understood that the role of the Bureau shall be to follow the various activities of the C.C.I.R. with a view to the centralization and the publication of general documents for the use of Administrations.

3. Organization regulations of the International Technical Consulting Committee on Radio Communication are contained in ten detailed articles.

(It is not practicable to insert the detailed articles herein.)

4. Concerning the power of a transmitter—it is considered that the power of a radio transmitter means the power in the antenna. By antenna is meant the conductor or the whole of the radiating conductors. The power in the antenna may be obtained by direct measurement in the antenna itself or by measurements carried out on an equivalent imaginary antenna or on other parts of the transmitter (that is, at the input of the transmitter of a mobile station, if desired); in the case of indirect measurement, the power in the antenna will be calculated in taking account of the output of the intermediary stages.

In the case of a radiotelegraph transmitter, by the power in the antenna is meant the power measured in a continuous dash.

In the case of a modulated wave transmitter, by power in the antenna is meant the product of the total resistance of the antenna multiplied by the square of the effective value of the antenna current, the rate of modulation having the greatest value compatible with the recommendations of the C.C.I. Telephone (Berlin, 1929); that is, being such that the level of the modulation harmonics is at least 2.3 nepers or 20 decibels less than that of the fundamental wave, for the maximum power and for any frequency within the frequency band to be transmitted.

5. As to defining very short, short, medium, and long waves—the following classification should be adopted:

Low frequency—up to and including 100 kilocycles (3000 meters).

Medium frequency—up to and including 1500 kilocycles (200 meters).

Medium high frequency—up to and including 6000 kilocycles (50 meters).

High frequency—up to and including 30,000 kilocycles (10 meters).

Very high frequency—above 30,000 kilocycles.

6. It is considered that the radiation power of a transmitter should be indicated in accordance with the following:

(a) Power of the transmitter (as previously stated above).

(b) Directive properties indicated, if need be, by the letter *D*, followed by the letter *R* when the radiating system is furnished with a reflector.

(c) Azimuth of the maximum direction or directions of radiation, expressed in degrees beginning from the north in a clock-wise direction (zero to 360 degrees).

Example: D R 25 deg. (a single direction)
D R 25 deg. to 45 deg. (variable between limits)

(There follows a discussion concerning antenna characteristics which it is not practicable to insert here.)

7. It is considered that it might perhaps be possible to establish an absolute international frequency standard, which from a scientific standpoint would be interesting. However, in view of the state of the art, and of practical necessities, it is considered undesirable to establish at the present time such an absolute standard for world use. It should be sufficient to let each country establish its national standard—every effort being made to compare the standard of different countries with one another and to improve them constantly.

In this connection, the following definitions have been accepted to avoid any error in interpretation.

Primary frequency standard: Measuring apparatus which permits the evaluation of a frequency as a function of the second of mean solar time.

Frequency meter: Commercial apparatus for measuring frequency, permitting measurements within a certain band.

Secondary standard of frequency: Apparatus capable of producing a frequency with such a consistency that the absolute standard of frequency can discover no variation in it.

Frequency meters used in transmitting stations must be accurate, precise, and constant. With apparatus not provided with special arrangements (such as thermostats, crystals, etc.) an accuracy of standardization of one-ten-thousandth (1/10,000) may be reached. With special arrangements and precautions, it is possible for an accuracy of from two- to five-one-hundred-thousandths (2/100,000 to 5/100,000) to be reached.

For apparatus to be used in coast stations, and mobile stations (including ships and aircraft) and for those to be used in distant countries and under unfavorable local and climatic conditions, accuracy of standardization is at the present time hardly more than three- to four-one-thousandths (3/1,000 to 4/1,000), but the hope is expressed that manufacturers will be able to supply simple and practical measuring instruments suitable for tropical climates and of greater accuracy.

As regards absolute frequency standards and secondary standards, the accuracy of standardization to be attained is at least one-one-hundred-thousandth (1/100,000). Efforts should be made to increase the above-mentioned accuracies.

8. Tolerance is defined as the maximum variation admissible between the nominal frequency reported to the International Bureau of the Telegraphic Union and the average frequency actually transmitted which is the farthest removed from it.

The accuracy of frequency meters used must in any case be such as to permit the station concerned to remain within the limits of the tolerance indicated in the table following:

TABLE OF TOLERANCES OF FREQUENCY OF THE AVERAGE WAVE ACTUALLY TRANSMITTED, AS COMPARED WITH THE FREQUENCY OF THE NOMINAL WAVE

Nature of Transmission	Tolerances	
	immediately applicable	to be applied as soon as possible
A—10 kc to 550 kc (30,000 − 545 m)	±	±
(a) Fixed stations	0.1 per cent	0.1 per cent
(b) Land stations	0.1 per cent	0.1 per cent
(c) Mobile stations using any wave within the band during a transmission	0.5 per cent	0.5 per cent
B—550 kc to 1,500 kc (545 − 200 m)		
Broadcast stations	0.3 kc	0.05 kc
C—1,500 kc to 6,000 kc (200 − 50 m)		
(a) Fixed stations	0.05 per cent	0.02 per cent
(b) Land stations	0.10 per cent	0.02 per cent
(c) Mobile stations using any wave within the band during a transmission	5 kc	5 kc
(d) Fixed and land stations of low power (up to 250 antenna watts) working on bands common to fixed and mobile services, during a transmission	5 kc	5 kc
D—6,000 kc to 23,000 kc (50 − 13 m)		
(a) Fixed stations	0.05 per cent	0.01 per cent
(b) Land stations	0.10 per cent	0.02 per cent
(c) Mobile stations using any wave within the band during a transmission	10 kc	5 kc
(d) Fixed and land stations of low power (up to 250 antenna watts) working on bands common to fixed and mobile services, during a transmission	10 kc	5 kc

The frequency of transmission of a station with tubes may be kept constant by various methods, belonging in the main to the three following groups:

(a) Specially constructed master oscillator.

(b) Master oscillator stabilized by a mechanical oscillator (quartz crystal, tuning fork, etc.).

(c) Master oscillator with frequency regulator.

Constancy of temperature, which is essential in most cases, is maintained by thermostat working continuously or non-continuously.

In stations with an alternator, stabilization of frequency is maintained by mechanical or electrical regulators.

9. It is desirable that each nation should set up a national laboratory equipped with a frequency standard to serve as a basis of frequency measurements for the stations of that nation.

It is recommended that Administrations should inform one another of their different methods of constructing and comparing standards so as to permit standards to be perfected.

10. Owing to the serious interference caused by damped waves, it is recommended that as far as possible Administrations hasten the abolition of stations transmitting damped waves (type B) of more than 300 watts, before the time limit fixed by the General Regulations annexed to the Washington Convention.

11. The C.C.I.R. with a view to the development of world communications on frequencies above 6000 kilocycles, recommends to facilitate the

methodical use of these in the future as fast as progress in the technique is made, that in the bands in this part of the spectrum exclusively reserved for fixed services, only frequencies expressed in numbers multiples of five be allocated by the Administrations.

It is understood that the present state of the art, especially in the higher frequencies, does not always permit two stations to work simultaneously on two frequencies differing only by five kilocycles and that present practice shows that a difference of frequencies of about 0.1 per cent between two telegraph stations is generally desirable in order to secure sufficient protection against interference. However, when the various conditions permit it, telegraph stations may work with a frequency interval less than five kilocycles. It is further recommended that in any band exclusively reserved for fixed services, the frequencies used by a single Administration or a single private enterprise should, if practicable, be grouped together.

12. In order that the maximum possible use may be made of all frequencies, full advantage must be taken of directional effects, skip distances, and time differences. It is therefore recommended that the Administrations supply the International Berne Bureau, in addition to the notification that a radio station has been established, with complete data concerning the service which will be performed by the station, width of channel, speed of transmission, directional properties, countries to be communicated with, and other pertinent data. The Berne Bureau is to publish this information for the use of all nations.

13. The C.C.I.R., having considered the following different systems of transmissions, considers that in the present state of the art the total frequency band which their transmission generally covers is as follows:

For International Morse Code, 100 words per minute, in telegraphy on continuous non-modulated wave—the total frequency band (plus or minus) in cycles—from 160 to 240.

For International Morse Code, in telegraphy on continuous modulated wave—the total frequency band (plus or minus) in cycles—from 160 to 240 plus twice the frequency of modulation.

For transmission of facsimile and pictures—the total frequency band (plus or minus) in cycles—from 2000 to 10000.

For television—the total frequency band (plus or minus) in cycles—from 10,000 to 100,000.

For commercial telephony—the total frequency band (plus or minus) in cycles—6000.

For broadcast telephony—the total frequency band (plus or minus) in cycles—from 10,000 to 20,000.

The C.C.I.R. desires to draw attention to the fundamental importance of the selectivity of receiving apparatus. It considers that as regards the separation necessary between the frequencies utilized by two stations working on neighboring frequencies, account should be taken of that selectivity as much as of the tolerance and of the width of the transmission band.

14. The C.C.I.R. considering that the optimum use of the frequency band between 1500 and 23,000 kilocycles must take account of the different properties of these waves as regards their propagation, recommends to the

Administrations to allocate to fixed services the frequencies contained in these bands as follows:

(a) Frequencies between 6000 and 23,000 kilocycles are in principle reserved for long-distance communication. However, during daylight at the transmitting station transmissions may be made on frequencies between 6000 and about 9000 kilocycles (medium distance communications).

(b) Frequencies between 6000 and 3500 kilocycles are in principle reserved for medium distance communications.

(c) Frequencies between 3500 and 1500 kilocycles are in principle used for shorter distance communications.

In order to facilitate the application of these principles, it is recommended as regards short and medium distance communications, that regional agreements should be entered into between the Administrations of neighboring countries.

Foreseeing that a large number of stations will probably be placed in the shared bands (fixed and mobile services) above 6000 kilocycles, it is important that these stations be equipped with modern apparatus as regards both transmission and reception unless traffic handling in these bands is to become very difficult.

15. The International Technical Consulting Committee on Radio Communication expressed the opinion that it is not as yet fully competent to decide the question as to whether or not the waves designated for aviation are suitable for such service.

16. Concerning amateurs—it is considered that each country should take effective measures to insure that amateurs remain well within the frequency band allotted to them, in particular, by obliging amateurs, if necessary, to use a frequency meter or other equivalent apparatus.

At the present time, it is considered impracticable to lay down rules applicable in all countries of the world relative to amateur licenses, and this question must form the subject either of regional agreements or of national decisions.

17. The following questions remain for future consideration, no definite action having been taken on them at The Hague meeting. The nation to which the study of each subject is assigned is mentioned following each question.

(a) "What are the most suitable methods from a technical standpoint to insure the good organization of a commercial radiotelephone service, especially long distance, connecting mobile stations—and particularly passenger-carrying vessels—to the public telephone networks?" (Germany)

(b) "Coordination of radiotelephony between fixed stations with telephony on the land networks, particularly as concerns the following questions:

(1) What is the most suitable method for measuring noise levels under the special conditions of a radiotelephone circuit?

(2) What should be the maximum tolerable limit of the noise level measured by this method?

(3) What instrument would be suitable to permit the special operator who is situated at the junction point between the radiotelephone connection and the metallic circuit to measure the voice level?" (France)

(c) "The study and perfecting of methods technically available for maintaining constant the stability of a transmitter." (United States of America)

(d) "The study and perfecting of methods for the comparison of frequency standards." (France)

(e) "Calibration of wave meters." (Italy)

(f) "The study of the methods to be adopted to reduce interference in the bands shared by fixed and mobile services above 6000 kilocycles." (United States of America)

(g) "The study of technical possibilities of reducing the frequency band occupied by a transmitter, by the partial suppression of the frequency band transmitted (that is, the emission of a single side band only, or of a side band and the carrier wave) for various types of transmission and types of service." (Austria)

18. Before the conference disbanded, it was brought to the attention of all delegates that it is desirable for each Administration to begin the study, in view of the Madrid Conference, of a new arrangement for the allocation of frequency bands among the various radio services, endeavoring to find for each class of transmission:

(a) The frequency bands most suitable for the service to be carried on, taking into account the most recent progress in the art.

(b) The financial and economic effects which important changes would involve, as compared with the present allocation.

(c) The possibility of insuring a legitimate place in the allocation of frequencies for new applications of radio principles.

This concludes the general summary of official activities at The Hague.

I find it impossible to express in words the gracious hospitality of the Netherlands Government. In fact, there were so many functions and tours that it was most difficult to accomplish the required work, but we visitors enjoyed the entertainments and appreciated the opportunities to see Holland and especially its radio facilities. During our stay we visited Amsterdam, Rotterdam, Eindhoven, Kootwijk, and Noorwijk.

There was a beautiful reception on the first day of the conference, and many formal and informal entertainments during the time of the conference. Two nights prior to departure the Netherlands Government gave a delightful banquet in honor of the visiting delegations and this favor was returned the following night by a dinner and dance sponsored by the visitors.

The conference adjourned on October 2, after which the United

States delegates spent two days in The Hague preparing the report. Duty being completed, the United States delegates disbanded.

In conclusion, as one of the delegates representing the United States, I wish to state that the conference was entirely worth while and successful, not only because of the accord reached on the points of the agenda but particularly because of the friendships made and renewed, as well as the opportunity for obtaining the points of view of all the nations represented on all sorts of communication subjects. Radio, more than any other business, depends for its efficiency on cooperation between peoples separated at great distances, and such cooperation can best be accomplished by understanding, confidence, and friendships such as are only possible by frequent international gatherings of this character.

The second meeting of the International Technical Consulting Committee is scheduled for Copenhagen in 1931 and will be similar to The Hague Conference. These conferences will both affect the manner in which the nations handle and allocate radio channels, the allowed tolerances, and the inspection of operation, and will stimulate progress tremendously and in a proper manner. With the experience resulting from these conferences, the nations will meet in Madrid in 1932 in an International Conference with treaty-making powers, to consider such revision of the Washington International Radiotelegraph Convention as may be desirable.

Proceedings of the Institute of Radio Engineers
Volume 18, Number 5 *May, 1930*

RECOMMENDATIONS OF THE INTERNATIONAL TECHNICAL CONSULTING COMMITTEE ON RADIO COMMUNICATION*

The Hague, Sept. 18-Oct. 2, 1929

(Translation from the French Text of the MINUTES OF THE CLOSING PLENARY SESSION)

Question No. 1 of the Program

ORGANIZATION of the International Technical Consulting Committee on Radio Communication (C.C.I.R.), especially with regard to its work in the future.

FIRST RECOMMENDATION

The C.C.I.R. considering

1. that it is neither necessary nor possible, under the General Regulations,[1] to set up permanent bodies for the study of questions on the program of sessions of the C.C.I.R.,
2. that there may be questions still unsettled after meetings of the C.C.I.R.,

unanimously expresses the opinion

1. that at the end of the session of the C.C.I.R., the Chairman should read a list of important questions to be studied, and
2. that he should ask which Administrations are desirous of undertaking the preparation of proposals relating to the said questions, and ready to collaborate with the interested Administrations and with private enterprises, with a view to forwarding these proposals to the Administration organizing the next meeting of the C.C.I.R.

SECOND RECOMMENDATION

The C.C.I.R., after a discussion on the question of the future organization of the C.C.I.R., in which the representatives of the following countries took part, Belgium, Spain, the United States of America, France, Great Britain, Italy, Netherlands, Portugal, Switzerland, Czechoslovakia, and the Union of Soviet Socialist Republics; after the declarations of the Director of the International Bureau of the Telegraph Union concerning the steps which he proposes to take to

* Dewey decimal classification: R007.9. See also "The Hague Conference," by S. C. Hooper, PROC. I. R. E., this issue, page 762.

[1] This refers to the General Regulations annexed to the International Radio Convention signed at Washington in 1927. See PROC. I.R.E., 16, 409; April, 1928.

secure the assistance of technical experts without any increase in the sums allotted to the Bureau by the Administrations; and after the declaration of the United States of America with regard to the Articles of the Washington Convention and General Regulations referring to the relation of the International Bureau to the C.C.I.R., unanimously expresses the opinion

1. that is neither necessary nor possible, in accordance with present provisions, to now set up a permanent Secretariat for the C.C.I.R.
2. that it is sufficient to establish a close liaison between the C.C.I.R. and the International Bureau of the Telegraph Union, it being understood that the role of the Bureau shall be to follow the various activities of the C.C.I.R., with a view to the collection and the publication of general documents for the use of Administrations.

Third Recommendation

The C.C.I.R. proposes that the following organization regulations should be adopted:

Organization Regulations of the International Technical Consulting Committee on Radio Communication

Article 1

At the end of a meeting of the Committee, the Administration which organized the said meeting shall conclude current business, in collaboration with the International Bureau of the Telegraph Union.

It shall, as soon as possible, forward the documents to the Administration organizing the next session.

Article 2

Before the end of each meeting the Committee shall name the Administration that is to call the next meeting; it shall indicate any new questions and also those which have not yet been settled; the sum total of these questions shall be placed on the program for the next meeting.

Article 3

At the end of a meeting all new questions, not provided by the Assembly, for submission to the Committee, shall be addressed to the Administration entrusted with the task of organizing the next meeting. This Administration shall enter these questions on the program for the next session.

Article 4

At the last plenary session of a meeting of the Committee, the Chairman shall announce the list of important questions to be settled. He shall then ask which Administrations are desirous of undertaking the preparation of proposals relating to the said questions, and are ready to collaborate with the interested Administrations and with private enterprises, with a view to the transmission of these proposals to the Administration organizing the next meeting.

ARTICLE 5

The Administration in charge of the Organization of the Committee may correspond directly with the Administrations, Companies, and Organizations capable of collaborating in the work of the Committee. It shall forward at least one copy of documents to the International Bureau of the Telegraph Union.

ARTICLE 6

During the first meeting, the plenary session shall designate its Chairman and, on the proposal of the latter, the Vice-Chairmen, and other members of the Bureau.

ARTICLE 7

The Director of the International Bureau of the Telegraph Union or his representative shall be present at meetings and take part in the discussions in an advisory capacity.

ARTICLE 8

The International Bureau of the Telegraph Union shall take part in the various activities of the Committee with a view to the collection and the publication of general documents for the use of the Administrations.

ARTICLE 9

The Secretariat of the meeting shall be carried on by the organizing Administration, with the collaboration of the International Bureau.

ARTICLE 10

Plenary Sessions shall undertake as far as possible to approve or reject the reports submitted by the Committees, or to order them, if necessary, to be returned to the Committees sitting during the meeting of the C.C.I.R.; in the case of the final plenary session questions not settled shall be entered on the list referred to in Article 4.

Question No. 2 of the Program

What is meant by the power of a transmitter?

RECOMMENDATION

The C.C.I.R. expresses the opinion

that the power of a radio transmitter means the power in the antenna.

By antenna is meant the conductor or the whole of the radiating conductors.

The power in the antenna may be obtained either by direct measurement in the antenna itself, or by measurements carried out on an equivalent dummy antenna or on other parts of the transmitter (e.g. at the input of the transmitter of a mobile station, if desired); in the case of indirect measurement, the power in the antenna will be calculated, taking account of the output of the intermediary stages.

In the case of a radiotelegraph transmitter, by the power in the antenna is meant the power measured in a continuous dash.

In the case of a modulated wave transmitter, by power in the antenna is meant the product of the total resistance of the antenna multiplied by the square of the effective value of the antenna current, the rate of modulation having the greatest value compatible with the recommendations of the C.C.I. Telephone (Berlin, 1929) i.e., being such that the level of the modulation harmonics is at least 2.3 nepers or 20 decibels less than that of the fundamental wave, for the maximum power and for any frequency within the frequency band to be transmitted.

Question No. 3 of the Program

What is meant by very short, short, medium, and long waves?

Recommendation

The C.C.I.R. expresses the opinion that the following classification should be adopted:

Frequencies

Kilocycles per second		Meters
	Low	
100		3000
	Medium	
1500		200
	Medium High	
6000		50
	High	
30000		10
	Very High	

ANNEX TO RECOMMENDATION ON QUESTION NO. 3 OF PROGRAM

Language	Low Frequency	Medium Frequency	Medium High Frequency	High Frequency	Very High Frequency
German	Lange Wellen	mittlere Wellen	Grenzwellen	Kurze Wellen	sehr kurze Wellen
Spanish	baja frecuencia ondas largas	frecuencia media ondas medias	frecuencia intermedia ondas intermedias	alta frecuencia ondas cortas	muy alta frecuencia ondas extracortas
Finnish	pitkät aallot	Keskipitkät aallot	raja-aallot	lyhyet aallot	erittäin lyhyet aallot
French	ondes longues	ondes moyennes	ondes intermediaires	ondes courtes	ondes très courtes
Hungarian	hosszu hullamok	kozep hullamok	hatar hullamok	rovid hullamok	igen rovid hullamok
Italian	onde lunghe	onde medie	onde mediocorte	onde corte	onde ultra-corte
Dutch	lange golven	middengolven	grensgolven	korte golven	zeer korte golven
Norwegian	lange bólger	midlere bólger	Grensebólger	korte bólger	ultrakorte bólger
Polish	fale długie	fale średnie	fale pośrednie	fale krótkie	fale bardzo krótkie
Portuguese	ondas longas ondas largas ondas grandas	ondas medias	ondas intermedias	ondas curtas	ondas muito curtas
Rumanian	unde lungi	undi mijlocii	unde intermediare	unde scurte	unde foarte scurte
Russian	niskaya tchastota dlinnié volni	sredniaya tchastota srednié volni	promé joutotchnaya tchastota promé joutotchnié volni	vissokaya tchstota korotkié volni	otchenne vissokaya tchastota otchenne korotkie volni
Swedish	lánga vagor	medellanga vagor	gränsvagor	korta vagor	ultrakorta vagor
Czech	dlouhé vlny	strédni vlny	mezilehlé vlny	krátké vlny	velmi krátké vlny

Question No. 4 of the Program

Recommendation for the practical application of Article 13 of the Washington General Regulations with regard to information as to the normal radiation power of transmitters on very high frequencies.[2]

Recommendation

The C.C.I.R. expresses the opinion that the radiation power of a transmitter should be indicated by the following data:

1. power of the transmitter, defined in accordance with the recommendation concerning question No. 2 of program;
2. directive properties indicated, if need be, by the letter *D*, followed by the letter *R* when the radiating system is furnished with a reflector;
3. azimuth of the maximum direction or directions of radiation, expressed in degrees beginning from the north from 0 to 360, in a clockwise direction.

Examples:

case of one single special direction: D R 25 deg.
case of two special directions: D R 25 deg.
D R 45 deg.

In the case of an azimuth capable of varying continuously between two limits, these limits will be given.

Example: D R 25 deg. to 45 deg.

Where an azimuth may be of any value, this will be indicated by the letter *T*.

Any other technical data that it might be useful to give might be sent in a notice to the International Bureau of the Telegraph Union.

The attached annex gives as an indication a method of notation enabling a radiating system to be defined in a large number of cases.

Annex to Recommendation Concerning Question No. 4 of the Program

It is possible to define accurately a fairly large number of types of antennas by giving the following information:

1. length *L* of the useful part of the antenna wire, expressing *L* in wavelength and putting it in the form

[2] Waves described as very high frequency in the text of question 4 are those which, by virtue of the reply given by the Committee to question 3, are at present called "high frequences" (i.e., 6000–30,000 kilocycles).

$$L = \frac{a+b+c+\cdots}{2}$$

in which a, b, c, etc., represent the number of half wavelengths of distribution of current, measured successively along the wire, using a new number at each point where the phase changes;

2. number of wires n;
3. height h_1 of the lowest point of the antenna above the ground, expressed in wavelengths;
4. azimuth of the maximum direction or directions of radiation, in accordance with the indications given in the preceding advice;
5. width b of the directional antenna expressed in wavelengths;
6. angle θ made by the wires with the horizon;
7. form of the wire, if it is not a single straight wire, e.g. if it is an antenna in the form of T or L;
8. height h_2 of the horizontal part of the wire above the ground expressed in wavelengths.

Examples: 12 kw; DR 160 deg., DR 160 deg. $\pm$180 deg.; $n=24$; (a) $L=(3)/2$; $b=11\ 1/2$; $h_1=1/2$; $\theta=90$ deg.

This represents a transmitter of a power of 12 kw in the antenna, provided with a directional antenna capable of transmitting at will either in the direction 160 deg. or in the direction 160 deg. +180 deg. the effective wires of which, 24 in number, are of a length of one and a half wavelengths with a distribution of current as shown in Fig. 1.

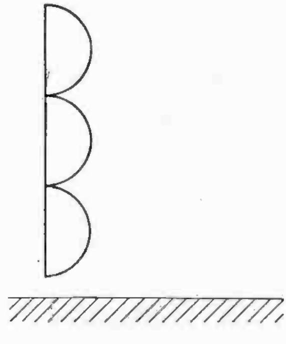


Fig. 1

The width of the directional antenna is 11 1/2 wavelengths, the height of the lowest point of the wire above the ground is a half wavelength, and the wires vertical.

(b) $1 \text{ kw}; n=1; L=\frac{2}{(2)}; \theta=0; h_1=\frac{1}{2}$.

This represents a transmitter of a power of 1 kw in the antenna, provided with a horizontal single wire antenna, a half wavelength above the ground, of a length of one wavelength, with a current distribution as shown in Fig. 2.

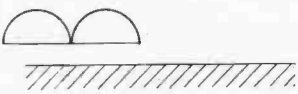


Fig. 2

(c) $1 \text{ kw}; n=1; L=\left(\frac{\frac{1}{2}+1}{2}\right); \theta=90 \text{ deg.}; h_1=0$.

This represents a transmitter of a power of 1 kw in the antenna, provided with a vertical single wire antenna of 3/4 of a wavelength long with its lower extremity grounded and with a current distribution as shown in Fig. 3.

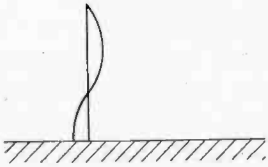


Fig. 3

Question No. 5 of the Program

A study of the measures to be taken towards standardizing as precisely as possible the frequency meters that are used for the adjustment of transmitting sets by comparison with their national standard instruments. (Article 3, paragraph 2 of the General Regulations.) *Study of the organization of a permanent international service for frequency checking.*

and

Question No. 6 of the Program

Study of the methods now technically available for the maintenance of the waves emitted by a station as accurately as possible on the authorized frequency, and recommendations for the fixing of the tolerance *permissible for the difference between the mean frequency of emissions and the notified frequency.* (Article 4, paragraphs 2 and 3 of the General Regulations.)

The C.C.I.R. makes the following recommendations:

First Recommendation

It might perhaps be possible to establish an absolute international frequency standard which from a scientific standpoint would be interesting.

But in view of the state of the art, and of practical necessities, it is considered undesirable to establish at the present time such an absolute standard for world use; it should be sufficient to let each country establish its national standard; however, every effort should be made to compare the standards of different countries with one another and to perfect them constantly.

Second Recommendation

1. The following definitions have been accepted to avoid any error in interpretation:

primary frequency standard: measuring apparatus which permits the evaluation of a frequency as a function of the second of mean solar time.

frequency meter: commercial apparatus for measuring frequency, permitting measurements within a certain band.

secondary standard of frequency: apparatus capable of producing a frequency with such a consistency that the absolute standard of frequency can discover no variation in it.

2. For comparing secondary standards, i.e., national frequency standards, various methods are technically available, for instance the following:

(a) Methods involving transportation of the apparatus:

(1) direct comparison between two frequency meters,

(2) comparison of several frequency meters with a portable apparatus, i.e., with an apparatus that would be transported from one country to another.

(b) Methods not involving the transportation of apparatus:

(1) transmission of standard frequencies, standardized either in high or in low frequency (modulated waves).

(2) simultaneous measurements of the same transmitted wave, not standardized, but being sufficiently stable to permit of simultaneous measurements.

It has been considered that all these methods have their advantages and their disadvantages; that they are all now sufficiently accurate for practice; none of them should therefore be rejected, but they should be concurrently used, endeavors being constantly made to improve them.

Third Recommendation

1. Frequency meters used in transmitting stations must be accurate, precise, and constant.

With apparatus not provided with special arrangements (thermostats, crystals, etc.), an accuracy of standardization of one ten thousandth (1/10,000) may be reached.

With special arrangements and precautions it is possible for an accuracy of from two to five one-hundred-thousandths (2/100,000 to 5/100,000), to be reached.

For apparatus to be used in coast stations and mobile stations (ships and aircraft) and for those to be used in distant countries and under unfavorable local and climatic conditions, as in the Colonies, accuracy of standardization is at the present time hardly more than three- to four-thousandths (3/1,000 to 4/1,000), but the hope is expressed that manufacturers will be able to supply simple and practical measuring instruments suitable for tropical climates and capable of greater accuracy.

2. As regards absolute frequency standards and secondary standards, the accuracy of standardization to be attained is at least one one-hundred-thousandth (1/100,000).

3. Effort should be made to increase the above accuracies.

4. The accuracy of frequency meters used must in any case be such as to permit the station concerned to remain within the limits of the tolerance indicated in the table to be found in the fourth recommendation below.

Fourth Recommendation

Tolerance is the maximum variation admissable between the nominal frequency reported to the International Bureau of the Telegraph Union and the average frequency actually transmitted which is the farthest removed from it. This variation arises from a combination of three errors:

(a) Error of standardization of the frequency meter used for measuring the wave transmitted.
(b) Error made during the adjustment of the station.
(c) Slow variations in the frequency of the transmitter (instability). No account is taken of modulation.

The tolerances admissible for different values of frequency and for different services are shown in the table below:

TABLE OF FREQUENCY TOLERANCES OF THE AVERAGE WAVE ACTUALLY TRANSMITTED, AS COMPARED WITH THE FREQUENCY OF THE NOMINAL WAVE

Nature of Transmission	Tolerances	
	Immediately applicable	To be applied as soon as possible
A—10 kc per sec. to 550 kc per sec. (30,000—545 m)	±	±
(a) Fixed stations	0.1 per cent	0.1 per cent
(b) Land stations	0.1 per cent	0.1 per cent
(c) Mobile stations using any wave within the band during a transmission	0.5 per cent	0.5 per cent
B—550 kc per sec. to 1,500 kc per sec. (545—200 m) Broadcast stations	0.3 kc per sec.	0.05 kc per sec.
C—1,500 kc per sec. to 6,000 kc per sec. (200—50 m)		
(a) Fixed stations	0.05 per cent	0.02 per cent
(b) Land stations	0.10 per cent	0.02 per cent
(c) Mobile stations using any wave within the band during a transmission	5 kc per sec.	5 kc per sec.
(d) Fixed and land stations of low power (up to 250 antenna watts) working on bands common to fixed and mobile services, during a transmission	5 kc per sec.	5 kc per sec.
D—6,000 to 23,000 kc per sec. (50—13 m)		
(a) Fixed stations	0.05 per cent	0.01 per cent
(b) Land stations	0.10 per cent	0.02 per cent
(c) Mobile stations using any wave within the band during a transmission	10 kc per sec.	5 kc per sec.
(d) Fixed and land stations of low power (up to 250 antenna watts) working on bands common to fixed and mobile services, during a transmission	10 kc per sec.	5 kc per sec.

The interference caused by a transmitting station depends not only on the slow variation of its mean frequency but also on the rapid variation of the latter; an endeavor should be made to reduce these variations to a minimum.

FIFTH RECOMMENDATION

1. The frequency of transmission of a station using vacuum tubes may be kept constant by various methods, belonging in the main to the three following groups:

(a) Specially constructed master oscillator.

(b) Master oscillator stabilized by a mechanical oscillator (quartz, tuning-fork, or magnetostriction).

(c) Master oscillator with frequency regulator.

Constancy of temperature, which is essential in most cases, is maintained by thermostat working continuously or non-continuously.

In stations with an alternator, stabilization of frequency is maintained by mechanical or electrical regulators.

2. Certain documents[3] submitted to the C.C.I.R. give interesting information as to arrangements of this nature.

[3] See in particular Documents No. 54 (Germany) and No. 55 (United States of America.) A translation of these documents is included in the Report of the American Delegation to the C.C.I.R., printed by the Government Printing Office, Washington, D. C.

3. Among frequency stabilizing arrangements known at present for vacuum-tube stations, there are relatively simple and practical devices which, when working under good conditions, maintain a constancy of frequency of one to two ten-thousandths (1/10,000 to 2/10,000).

With more complicated and costly apparatus, a constancy of one to two one-hundred-thousandths (1/100,000 to 2/100,000) may be expected, and still greater constancies are hoped for in the future.

Regarding long-wave stations with alternators equipped with regulators, the constancy obtained is of the order of plus or minus one-thousandth (1/1,000).

Sixth Recommendation

The C.C.I.R. recommends:

1. That any fixed or land station, and any special service station should be equipped with a frequency meter having at least the accuracy indicated in the Third Recommendation, under No. 4, or an equivalent apparatus, with the understanding that by the term *equivalent apparatus* is meant stabilization apparatus of at least the same effectiveness, or a system permitting very frequently the measurement of frequency at a distance. It is recommended, however, that any station of which the frequency is liable to vary owing to local conditions should be equipped with a frequency meter.

2. That each country should take effective measures to insure that amateurs remain well within the frequency band allotted to them, in particular by obliging amateurs, if need be, to use a frequency meter, or some equivalent apparatus.

3. That, for ship stations, the frequency of transmission should be verified as often as possible by the inspection services to which they are subject; it is, however, recommended that stations transmitting on frequencies above 6,000 kc per sec. (waves below 50 meters) should be equipped with a frequency meter.

4. That, for aircraft stations, it is desirable that administrations should take the necessary steps to maintain the frequency of the transmitters of their respective aircraft within the limits laid down by the C.C.I.R.

Seventh Recommendation

1. It is desirable that each nation should set up a national laboratory equipped with a frequency standard to serve as a basis of frequency measurements for the stations of that nation.

2. The International Bureau of Weights and Measures shall be asked to consider the possibility of organizing international comparisons of national frequency standards.

3. Each country shall be free to organize as it sees best the measurement of frequencies of stations set up in that country, using as a basis its national standard.

4. This organization shall not prevent countries, operating organizations or groups of operating organizations, from concluding agreements among each other for setting up laboratories and measurement stations charged with carrying on the checking of one or several more or less extended frequency bands; it is desirable, on the contrary, that such laboratories and measurement stations should continue to function or should be created.

Eighth Recommendation

Owing to the serious interference caused by damped waves, the Committee recommends that the various administrations shall, as far as possible, hasten the abolition of stations transmitting damped waves (type B) of more than 300 watts, before the time limit fixed in Article 5, paragraph 8, of the General Regulations of Washington.

Supplementary Recommendation

The C.C.I.R. recommends that Administrations should inform one another, through the International Bureau of the Telegraph Union, of their different methods of constructing and comparing standards, so as to permit national standards to be perfected.

Question No. 7 of the Program

Study of the width of a frequency band occupied by the emission of a station for each type of communication and wave and recommendation for fixing the maximum allowable widths. (Article 4, paragraph 4, of the General Regulations.)

and

Question No. 8 of the Program

Recommendation for fixing, in accordance with the possibilities that have been found to be available by the studies referred to under Nos. 6 and 7 of the program:

(a) The necessary separation in cycles or kilocycles between two successive frequencies of the same service, so that the stations to which these frequencies are assigned do not cause interference with one another.

(b) The separation, also in cycles or kilocycles, to be observed between the frequency of one station belonging to a given service and the edge of the band which is assigned to that service so as not to cause any injurious interference in the operation of the stations belonging to the services to which the next immediately neighboring frequencies are assigned. (Article 4, paragraph 5 of the General Regulations.)

and

Question No. 14 of the Program

Study of the allocation of ultra short waves to national services. (Article 5 of the General Regulations.)

First Recommendation

The C.C.I.R., with a view to the development of world communications on frequencies above 6000 kc and to facilitate the methodical use of these in the future as fast as progress in the technique is made, recommends that in the bands in this part of the spectrum reserved exclusively for fixed services, only frequencies expressed as far as possible in numbers multiples of 5 be allocated by the Administrations.

It is understood that the present state of the art, especially in the higher frequencies, does not always permit two stations to work simultaneously on two frequencies differing only by 5 kc and that present practice shows that a difference of frequencies of about 0.1 per cent between two telegraph stations is generally desirable in order to secure sufficient protection against interference.

However, when the various conditions permit it, telegraph stations may work with a frequency interval less than 5 kc.

It is further recommended that, in any band exclusively reserved for fixed services, the frequencies used by a single Administration or a single private enterprise should, as far as possible, be grouped together.

Second Recommendation

With this object, the C.C.I.R. recommends that when necessary the Administrations send the following information to the International Bureau of the Telegraph Union, along with the notifications of frequencies provided for in Article 5, paragraph 17, of the General Regulations of Washington:

1. geographical position of the transmitter;
2. frequency (wavelength);
3. proposed call signal;

4. power provided for in the antenna;
5. type of emission (A1, A2, A3);
6. frequency (or frequencies) of modulation, where necessary;
7. normal speed of transmission;
8. directional properties of the antenna (see Recommendation concerning Question 4 of the program);
9. nature of service and countries with which communication is proposed;
10. proposed date of completion of station;
11. date of initial operation of the station (by a later notification).

The C.C.I.R. also recommends that the Administrations send as soon as possible to the International Bureau of the Telegraph Union the same information concerning stations in service or stations of which the frequencies have already been reported.

Lastly, the C.C.I.R. recommends that the International Bureau of the Telegraph Union should collect this information in a publication easy to consult.

Third Recommendation

The C.C.I.R., having considered the following different systems of transmissions, considers that in the present state of the art the total frequency band which their transmission generally covers is the following:

System	Total Frequency Band (plus or minus) in cycles
International Morse Code, 100 words a minute, in telegraphy on continuous *non*-modulated wave.	From 160 to 240 cycles per sec.
International Morse Code, in telegraphy, on continuous modulated wave.	The number of cycles given by the preceding line for the speed used, plus twice the frequency of modulation.
Transmission of facsimile and pictures	From 2,000 to 10,000 cycles per sec.
Television	From 10,000 to 100,000 cycles per sec.
Commercial Telephony	6,000 cycles per sec.
Broadcast Telephony	From 10,000 to 20,000 cycles per sec.

Fourth Recommendation

The C.C.I.R., taking into account the provisions of Article 11, paragraph 4, of the General Regulations of Washington, again draws attention to the fundamental importance of the selectivity of receiving apparatus. It considers that as regards the separation necessary between the frequencies utilized by two stations working on neighboring frequencies, account should be taken of that selectivity as much as of the tolerance and the width of the transmission band.

The C.C.I.R. recognizes that any good modern receiver should be arranged to receive not only the single frequency allotted, but the frequency band corresponding to the transmission desired. The examination of methods of reception at present available shows that it is possible to make a receiver which, while admitting a frequency band equal to that of the transmission in question, presents a high attenuation for all frequencies which are found outside a band, the center of which coincides with the frequency of the transmission to be received, and whose width is equal to twice the communication band in question.

However, it is recognized that the great majority of receivers at present in use, especially for the reception of short waves, are far from achieving such a selectivity. Owing to the great number of stations at present proposed, it will no doubt soon be necessary to use receivers of a selectivity comparable to that defined above.

Fifth Recommendation

The C.C.I.R., considering that the optimum use of the frequency band between 1500 and 23,000 kc per sec. must take account of the different properties of these waves as regards their propagation, recommends to the Administrations to allocate to fixed services the frequencies contained in these bands in accordance with the following principles:

(a) Frequencies between 6,000 and 23,000 kc per sec.[3] (waves from 50 to 13 meters) are, in principle, reserved for long-distance communication. (General Regulations of Washington, note at foot of table in Article 5.) However, during daylight at the transmitting station (i.e., from about two hours after sunrise to about two hours before sunset), transmissions may be made on frequencies between 6,000 kc per sec., and about 9,000 kc per sec.[3] (waves from 50 to 33 meters) for medium-distance communications.

(b) Frequencies between 6,000 and 3,500 kc per sec.[3] (waves from 50 to 85 meters) are, in principle, reserved for medium-distance communications.

(c) Frequencies between 3,500 and 1,500 kc per sec.[3] (waves from 85 to 200 meters) are, in principle, used for shorter distance communications.

[3] The frequencies given here are, of course, only approximate.

In order to facilitate the application of these principles, it is recommended, as regards short- and medium-distance communications, that regional agreements should be entered into between the Administrations of neighboring countries.

SIXTH RECOMMENDATION

The C.C.I.R., foreseeing that a large number of stations will probably be placed in the shared bands (fixed and mobile services) above 6,000 kc per sec., draws attention to the importance of these stations being equipped with modern apparatus as regards both transmission and reception; otherwise traffic may become very difficult in these bands.

Question No. 9 of the Program

Study of the methods now technically available for preventing, as far as possible, emissions which are not essential to the type of communication carried on by a station. (Article 4, paragraph 2, of the General Regulations.)

RECOMMENDATION

The C.C.I.R. recommends that Document No. 12* be accepted as a sufficiently detailed statement concerning the question. It considers that it is not necessary to establish a rule on this subject at the present time.

Question No. 10 of the Program

Organization of studies to be made, by international agreement on various phenomena closely connected with the development of radio communication (for example, fading, directional effects, "skip-distance," atmospheric interferences, etc.)

RECOMMENDATION

The Committee on Organization is of the opinion that the studies in question enter within the scope of those which were the object of a resolution passed by the Committee at its meeting on September 27, 1929, and that consequently they should be carried on in conformity with the provisions of Article 4, of the Organization Regulations of the C.C.I.R.

* Document 12 contains proposals submitted by Great Britain. A translation of this document is included in the Report of the American Delegation to the C.C.I.R., printed by the Government Printing Office, Washington, D. C.

Question No. 11 of the Program

Standardization as far as possible of the technical conditions to be required of holders of amateur licenses.

Recommendation

The Committee on Definitions and Standardization recognizes that it is not at present possible to lay down rules applicable in all countries of the world, relative to amateur licenses, and that this question must form the subject either of regional agreements or of national decisions.

Question No. 12 of the Program

Study of the allocation or waves to aviation. (Article 5, paragraph 14, of the General Regulations).

Recommendation

The C.C.I.R. expresses the opinion that it is not competent to decide the question as to whether or not the waves for aviation are suitable for this service.

It merely observes that the waves in question were selected in the bands reserved for different services. It expresses the view that the Washington Conference set up no body for the allotment of waves, but that, in the present case, Article 5, paragraph 1, of the Washington General Regulations is applicable.

Question No. 13 of the Program

Study of the allocation of waves for the criminal police. (Article 5, paragraph 15, of General Regulations.)

Recommendation

The Operations Committee proposes the following recommendation:

The C.C.I.R. is of the opinion that the Washington Conference set up no body authorized to allocate wavelengths for special purposes.

The C.C.I.R. must, therefore, confine itself to recommending that the provisions of Article 5, paragraph 1, of the General Regulations be applied.

Question No. 14 of the Program

Refer to statements under Questions Nos. 7, 8, and 14.

Question No. 15 of the Program

Recommendations for the limitation of the effectiveness of broadcast stations, and for a possible regulatory formula for such a limitation.

Recommendation

With regard to the limitation of the power of broadcast stations using frequencies below 300 kc per sec., (wavelengths above 1000 meters), the International Technical Consulting Committee on Radio Communication, having considered the needs of aviation services, recommends that all broadcast stations should strictly observe the provisions of Article 5, paragraph 6, of the General Regulations of Washington, by which an increase of their power is forbidden if any disturbance to existing radio services shall thereby result.

For broadcast services using frequencies between 550 and 1500 kc per sec. (545 and 200 meters) the Committee makes the following recommendation *which applies only to European stations excepting those of the U. S. S. R.*[4]

Broadcast stations using frequencies between 550 and 1500 kc per sec. (545 and 200 meters) should provisionally limit their power to about 100 kw.

Question No. 16 of the Program

Radiotelephone communications between mobile stations and land stations, and the joining of these connections to the telephone networks.

Recommendation

The International Technical Consulting Committee on Radio Communication is of the opinion that experience gained in the matter is not yet sufficient to enable it to fix rules on this subject.

Allied Question

Communications by wire and radiotelephone.

Recommendation

The International Technical Consulting Committee on Radio Communication agrees to use Document No. 16,[5] as a basis of its work for

[4] Union of Soviet Socialist Republics.

[5] A translation of this document is included in the Report of the American Delegation to the C.C.I.R., printed by the Government Printing Office, Washington, D. C.

the complete study of the question of coordination between wire and radiotelephony.[6]

Questions for Further Consideration[7]

First Question

What are the most suitable methods from a technical standpoint to insure a satisfactory organization of a commercial radiotelephone service, especially long-distance, connecting mobile stations—and particularly passenger carrying vessels—to the public telephone networks?

Centralizing Administration: Germany.

Collaborating Administrations: Spain, United States of America, France, Great Britain, Japan, and Netherlands.

Second Question

Coordination of radiotelephony between fixed stations with the telephony on the land networks, particularly as concerns the following questions:

(a) What is the most suitable method for measuring noise levels under the special conditions of a radiotelephone circuit?
What should be the maximum tolerable limit of the noise level measured by this method?

(b) What instrument would be suitable to permit the special operator who is situated at the junction point between the radiophone connection and the metallic circuit to measure the voice level?

Centralizing Administration: France.

Collaborating Administrations: Germany, United States of America, Great Britain, Dutch East Indes, and Netherlands.

Third Question

The study and perfecting of methods technically available for maintaining constant the stability of a transmitter.

Centralizing Adminstration: United States of America.

[6] It is well understood that these questions form part of the program of studies undertaken by the 5th Committee of the C.C.I. Telephone, concerning the coordination of radiotelephone connections with the public telephone network.

[7] It is understood that other Administrations may collaborate and that the cooperation of private enterprises may be enlisted in the preparation of proposals relating to these questions.

Collaborating Administrations: Germany, Great Britain, Italy, Japan, and U. S. S. R.
Additional Collaborating agency: International Broadcasting Union.

Fourth Question

The study and perfecting of methods for the comparison of frequency standards.
Centralizing Administration: France.
Collaborating Administrations: Germany, United States of America, Great Britain, Italy, Japan, and U. S. S. R.
Additional Collaborating Agencies: International Union of Scientific Radiotelegraphy and International Broadcasting Union.

Fifth Question

Calibration of wavemeters.
Centralizing Administration: Italy.
Collaborating Administrations: Germany, United States of America, France, Switzerland, and the U. S. S. R.
Additional Collaborating Agency: International Broadcasting Union.

Sixth Question

The study of the methods to be adopted to reduce interference in the bands shared by fixed and mobile services above 6000 kc (wavelengths below 50 meters).
Centralizing Administration: United States of America.
Collaborating Administrations: Germany, France, Italy, and Japan.

Seventh Question

The study of technical possibilities of reducing the frequency band occupied by a transmitter, by the partial suppression of the frequency band transmitted (that is, the emission of a single side band only or of a side band and the carrier wave) for various types of transmission and types of service.
Centralizing Administration: Austria.
Collaborating Administrations: Germany, United States of America, France, and Dutch East Indies.

Proceedings of the Institute of Radio Engineers
Volume 18, Number 5 *May, 1930*

DEVELOPMENT OF THE VISUAL-TYPE AIRWAY RADIOBEACON SYSTEM*

By

J. H. Dellinger, H. Diamond, F. W. Dunmore

(Bureau of Standards, Washington, D. C.)

Summary—*Research work on a visual-type radiobeacon system for use on the airways of the United States has been under way at the Bureau of Standards during 1926–1929. As a result of this work a system has been developed which fulfills the requirements for course navigation on the civil airways. A directional transmitter is employed on the ground making possible the use of simple apparatus on board the airplane. A single radio receiver is sufficient to make use of all the radio aids provided. Visual indication is provided by means of a tuned-reed course indicator. The pilot observes the vibration amplitudes of two reeds. On the course the amplitudes are equal. Off the course they are unequal, the reed vibrating with the greater amplitude being on the side to which the airplane has deviated.*

Two types of beacon transmitters are described, the double-modulation and the triple-modulation. The former is capable of serving either two courses at 180 deg. with each other or four courses at arbitrary angles. The latter serves twelve courses at arbitrary angles and is better adapted for use at airports located at the junction of a large number of airways. Reed indicators for use with the double-modulation and triple-modulation beacons are described.

A discussion of the radio receiver and receiving antenna system employed is included. Airplane engine ignition shielding is also discussed.

A marker-beacon system has been developed whereby the pilot is given visual indication of his exact position at definite intervals along the route.

Special adaptations of the beacon system are described for facilitating landing in fog.

I. Introduction

THIS PAPER gives a general description of the research on radiobeacon systems for the airways of the United States during 1926 to 1929.†

The object of the research was to provide a system of navigational aids by which aircraft could be flown on a course in fog or any condition of visibility or no visibility. This system was to be specifically adapted to the requirements of navigation on the airways of the United States. Therefore, the navigational aids developed have had in view primarily the rendering of maximum service to fixed airways, the needs of aircraft on independent courses being secondary. Fortunately, as

* Dewey decimal classification: R526.1.

† More specific descriptions of various features of the development are given in Bureau of Standards Research Papers Nos. 19, 28, and 35. Titles of these papers are given in bibliography references numbered, respectively, 15 9, 22, 13, 10, 12, 14, 15, and 21.

will be shown, the system evolved gives aid to the independent flyer as well as to the navigator of the regular airways.

The system furnishes a pilot the desired guidance without special maneuvers of the aircraft or more than ordinary attention on his part. All the complicated and expensive parts of the system are at ground stations maintained by the Government. The pilot is required to do nothing at all to obtain a reading but glance at an indicating instrument on his instrument board whenever he wishes.

1. The Need for this Development

With the transportation of air mail, express, and passengers constituting its basic source of revenue, the success of air transportation in the United States depends in large measure upon the rigorous maintenance of scheduled flying by day and night. Present-day business requires the gathering of the mail at the close of a business day and its transportation to remote destination for early delivery on the next or next following morning. The transportation of passengers by air can become a genuine service, and really popular, only when the traveler can count on a scheduled service as dependable as the railway trains and independent of weather or other contingencies.

The present limitation on this most essential feature of air passenger service arises entirely from the hazards of the weather. Means are at hand to cope with every other limitation on flight. Multiple engines and improved controllability assure safety, landing fields are being provided in great numbers, aircraft of adequate strength and stability are available, and every comfort and convenience are offered the air traveler. And yet air traffic is still halted when meteorological conditions make the pilot uncertain that he can see landmarks, lights, or landing field.

It is impossible to exaggerate the difficulties of a pilot flying in dense fog. Deprived of all landmarks, under incessant strain at the controls to maintain equilibrium and direction, the aviator must frankly abandon dependence upon his senses and navigate according to the information conveyed by his instruments.

By means of the familiar instruments such as the altimeter, bank-and-turn indicator, rate-of-climb indicator, and compass, a pilot can continue flying in fog, but it is only by radio means that he can be certain to keep on a given course and find his landing field when the ground is invisible. Accurate as a compass may be, it cannot tell the pilot how much he is drifting sidewise on account of cross winds, nor what actual progress he is making forward because of the unknown effects of head or tail winds. Unless radio aids are used, fog always brings the

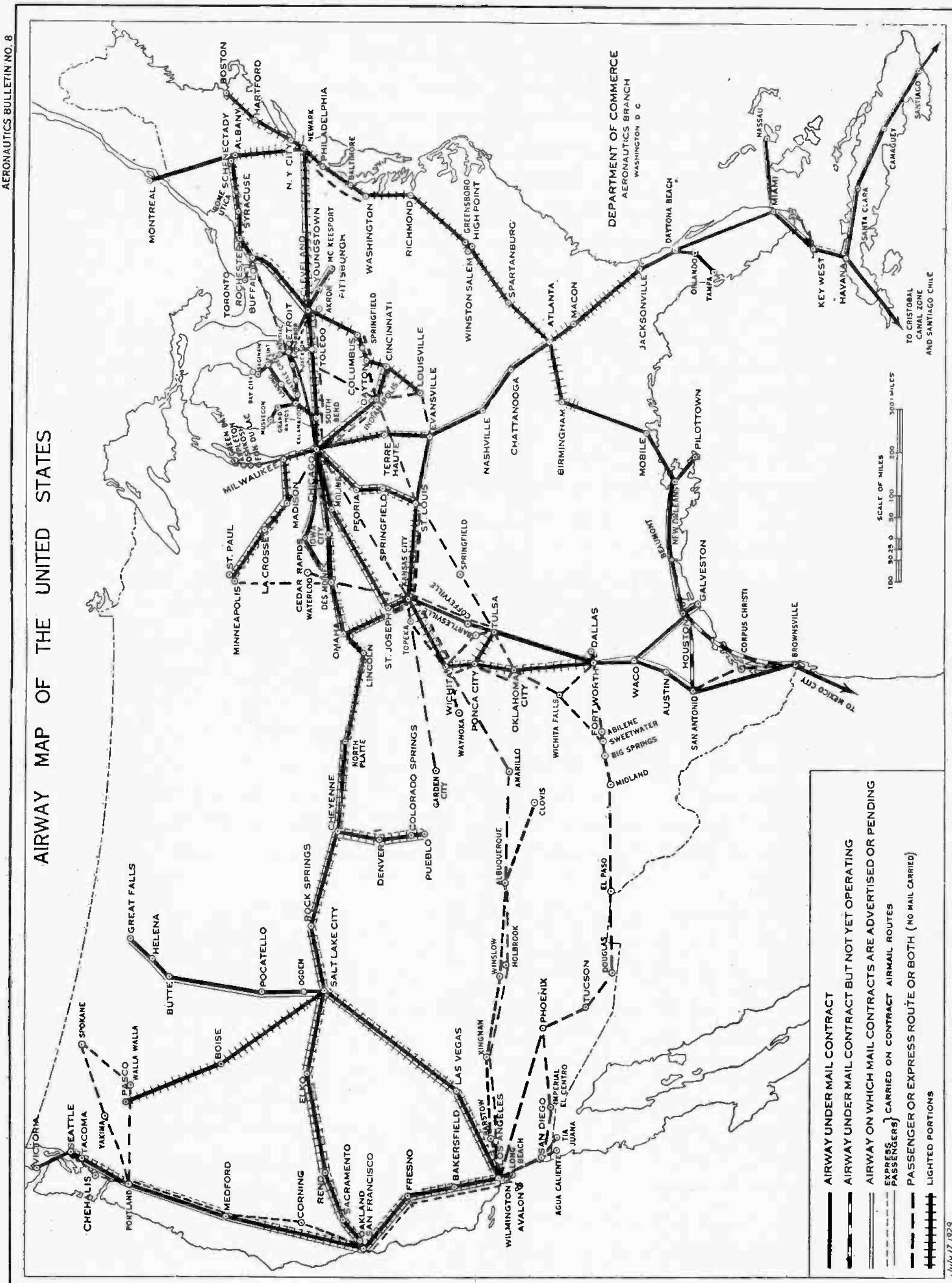


Fig. 1—Map of the civil airways of the United States.

hazard of getting off the desired course into unfamiliar or dangerous areas, and also makes even the possibility of a safe landing small.

By means of the radiobeacon system in its present form the pilot can keep accurately on his course, know the points he is flying over and proceed unerringly to the landing field. Adaptations of the radiobeacon to the landing problem are now in progress which it is believed will also make possible landings in densest fog. With the system fully established, a great obstacle to safe flight will have been conquered, and additional dependability added to scheduled flying.

2. Previous Work

The present development differs from much of the earlier work on radio navigational aids in its emphasis upon the requirements of fixed airways. The first work in this field was for military purposes during the World War. Military aircraft inherently require direction-determination service on independent courses. They do not generally fly fixed airways. The natural means chosen accordingly was the direction finder. The use of loop antennas, with sensitive radio receivers, aboard [(1)*] airplanes, gave a homing device well adapted to military needs. This method has not been extensively used for non-military aviation, because of the great difficulties experienced with receiving apparatus of this type. It has the inherent limitation that it does not prevent wind-drift from shifting the airplane off its course; the method does eventually bring the airplane to its destination although by a circuitous route if there is a side wind.

The next chief development was also a direction-finder method, but with the direction finder located on the ground. This is the system[(2)] now used throughout Europe for aircraft navigation by radio. Every airplane in the commercial transport service carries a radiotelephone (or -telegraph) transmitter and receiver, used with a trailing-wire antenna. There are permanent direction-finding stations located at certain of the principal airports. When an airplane desires to learn its position, it transmits a telephonic request to the airport, whereupon two or more of the ground direction-finding stations each determine the direction by observations upon the radio waves transmitted by the airplane. Triangulation then gives the airplane's position, which information is transmitted to the airplane. The system requires the airplane to carry both transmitting and receiving apparatus. It is not effective when a large number of airplanes desire the position service simultaneously, as the ground station can serve only one airplane at a time.

* See Bibliography at end of paper.

A third method of furnishing navigational aid to the flyer is the rotating radiobeacon recently developed in England[3]. This is a radio transmitting station, located at an airport, which has a directive antenna rotating at a constant speed of one revolution per minute. A figure-of-eight pattern is thus rotated in space. A special signal indicates when the figure-of-eight minimum passes through north and also when it passes through east. A pilot listening for the beacon signal with his radio receiver can start a stop watch when the north signal is received and stop it when the figure-of-eight minimum reaches him. The number of seconds multiplied by 6 gives him his true direction in degrees from north. The stop watch may be calibrated directly in degrees, so that the position of the second hand when the minimum signal is received gives the bearing directly. This system thus serves any course within its range. It has, however, the disadvantages of slowness of operation and also of being difficult to use during conditions of severe atmospheric disturbances or interference from outside services.

The radiobeacon system described herein is an outgrowth of a development undertaken by the Bureau of Standards for the Army Air Service in 1920. The Air Service requested the Bureau to devise a method whereby a directional transmission would serve as a guide to airplanes along a chosen course. Such a method was developed[4], having the advantages that direction service could be given simultaneously to any number of airplanes flying the course, and that each airplane only had to carry a radio receiver, with no other special equipment whatever. A description of this method, the subsequent contributions of the Army Air Corps engineers, and the more recent work by the Bureau of Standards, follow. A discussion of the relative merits and features of the various types of radio navigational systems is given in Section IX.

II. The Aural Radiobeacon System

The radiobeacon system employs two directive antennas placed at an angle with each other. Along the line bisecting the angle between the two antennas, the intensities of the radio waves from the two are equal. Elsewhere, one of the two waves is stronger than the other. An airplane could, therefore, follow a course along the bisector referred to if the two sets of radio waves could be distinguished from one another. A different signal is impressed on each set of waves for this purpose.

In the original apparatus transmission took place alternately from the two antennas, a switch being used to throw the radio-frequency power from one antenna to the other. Tests made at Washington on the ground and on ships showed that a course was effectively marked out, and could be followed. The apparatus was next set up by the Bureau of Standards with the cooperation of Army Air Corps engineers, at Dayton, Ohio, and tests made in the air. The method was successful in airplane flights and had the advantage that no error was introduced by wind drift, which is an important limitation on the use of direction finders aboard aircraft.*

In the following four years the Army Air corps engineers at Dayton, Ohio, developed this radio range† further(5); in particular, they devised a signal-switching arrangement such that the signals from the two antennas merged into a steady dash when on the course, giving an added criterion besides that of equal signal intensity to enable the observer to tell whether he was on or off the course. They also introduced a goniometer, or mutual inductance device, to permit orienting the course in any desired direction without moving the antenna. The idea of interlocking the two signals to be compared was founded on an early German patent(6). The theory underlying the operation of the goniometer was also known(7). The contribution made by the Army engineers was to combine the two in a practical operating system.

The subject received renewed study by the Bureau of Standards early in 1926. There was pending in Congress a proposal to create an Aeronautics Branch in the Department of Commerce with jurisdiction over commercial flying and with the duty of providing aids to air navigation. The Department officers requested the Bureau of Standards to recommend ways in which radio could be used for aids to navigation on the airways. In the recommendations submitted, the Bureau proposed the providing of telephone broadcasts of weather information to aircraft from ground stations maintained by the goverment, and a radiobeacon service of the type here described. It was pointed out that this would put all the expensive and heavy radio equipment on the ground, to be maintained by the Government, requiring the airplanes to carry nothing but a very simple radio receiver.

Accordingly, when the Aeronautics Branch was organized, in July 1926, it assigned the necessary experimentation and development in this field to its research division, which was organized in the Bureau of Standards. In the work on the radiobeacon which began immediately, several improvements over the existing form of the beacon were sought. These included some matters of design detail (involving the goniometer, interlocking switch, etc.), an automatic device for serving several courses simultaneously (for use at airports where several courses in-

* For a discussion of this, see page 294 of (4).

† A name which is coming into use for any directive radiobeacon transmitter.

tersect), and especially means of replacing the telephone receivers by a visual indicator. The work, which still continues, has been done in the Bureau laboratory at Washington and at two field stations, one at College Park, Md., a suburb of Washington, and the other at Bellefonte, Pa., chosen because of its location on the New York-Cleveland airway in particularly hazardous mountain terrain. These two stations were equipped with radiobeacon and also radiotelephone and radiotelegraph transmitting apparatus. The Bellefonte, Pa., station was transferred in 1928 to the Airways Division of the Department of Commerce, and is now used for giving regular radio service to that portion of the transcontinental air route on which it is situated. The

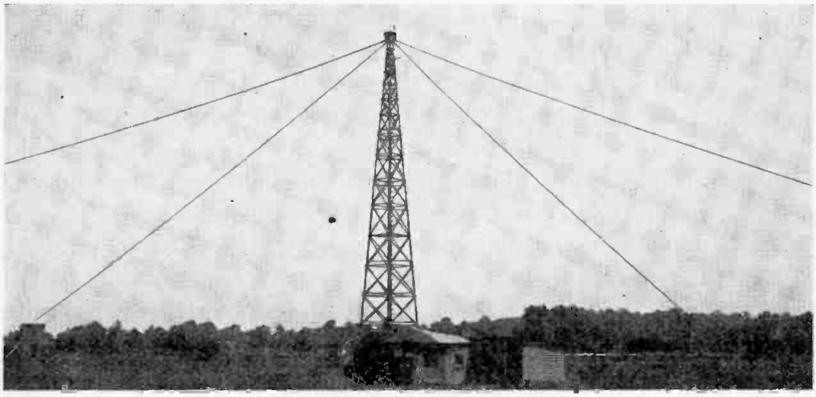


Fig. 2—Experimental radiobeacon station at College Park, Md., showing directive-antenna system.

College Park station continues to serve as a development laboratory and as a model and demonstration station, and is, in addition, available to give radio service to the air routes passing through Washington,† A photograph of this station showing the directive antenna system is reproduced in Fig. 2.

III. The Double-Modulation Beacon System

1. First Experiments

A number of disadvantages are inherent in the aural interlocking radio range. Of these, the constant strain on the part of the pilot in listening to the guiding signals and distinguishing between their magnitudes is the most important. Another disadvantage is the masking of the guiding signals by atmospheric disturbances or interference from

† The experimental work on the aural beacon carried on during 1926–1927 has already been described in the Proceedings. See reference (8).

other services, with a consequent reduction in the effective distance of reception. A third is the skill required on the part of the pilot in interpreting the received signal.

The Bureau, therefore, undertook the development of a visual means for receiving the guiding signals. Several arrangements were tried using both single and double modulation. These early methods are also described in a reference(8). Difficulties owing to errors introduced by the presence of interfering signals, complexity of apparatus at the receiving end, and lack of positive indication when on course were experienced.

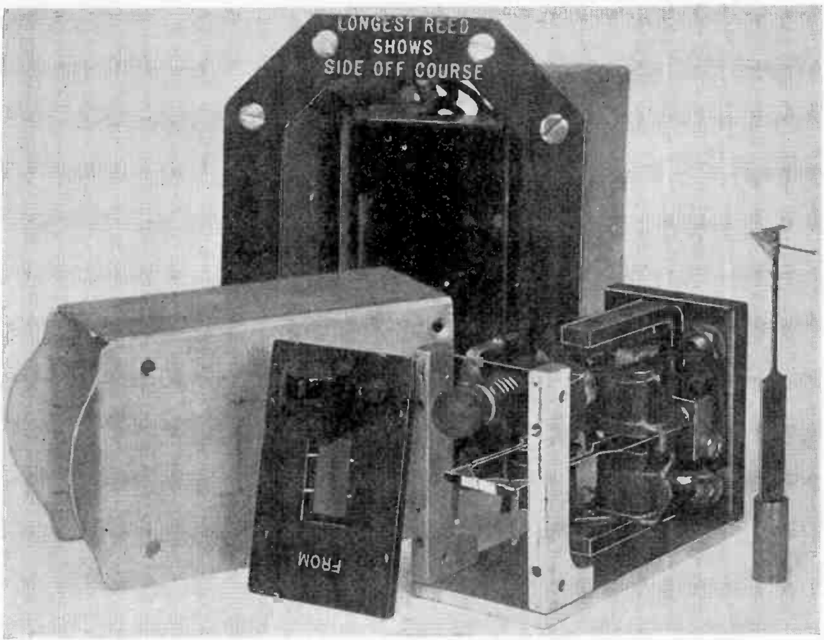


Fig. 3—Visual beacon course indicator with shockproof mounting, two-course type.

2. Use of Tuned-Reed Indicators

A method was then worked out which overcame these difficulties. Two low-modulation frequencies were employed, 65 and 86.7 cycles per second. The visual-indicating instrument(9) for use on the airplane consists of two vibrating reeds, mechanically tuned to the two beacon modulation frequencies, actuated by small electromagnets connected to the output circuit of the receiving set. When the beacon signals are received, the two reeds vibrate, and, since they are tuned to the two modulation frequencies used at the beacon, serve as a device for indicating equality of received signals from the two antennas. The tips of the reeds are white against a dark background, so that when vibrating they appear as vertical white lines. When the two lines are equal

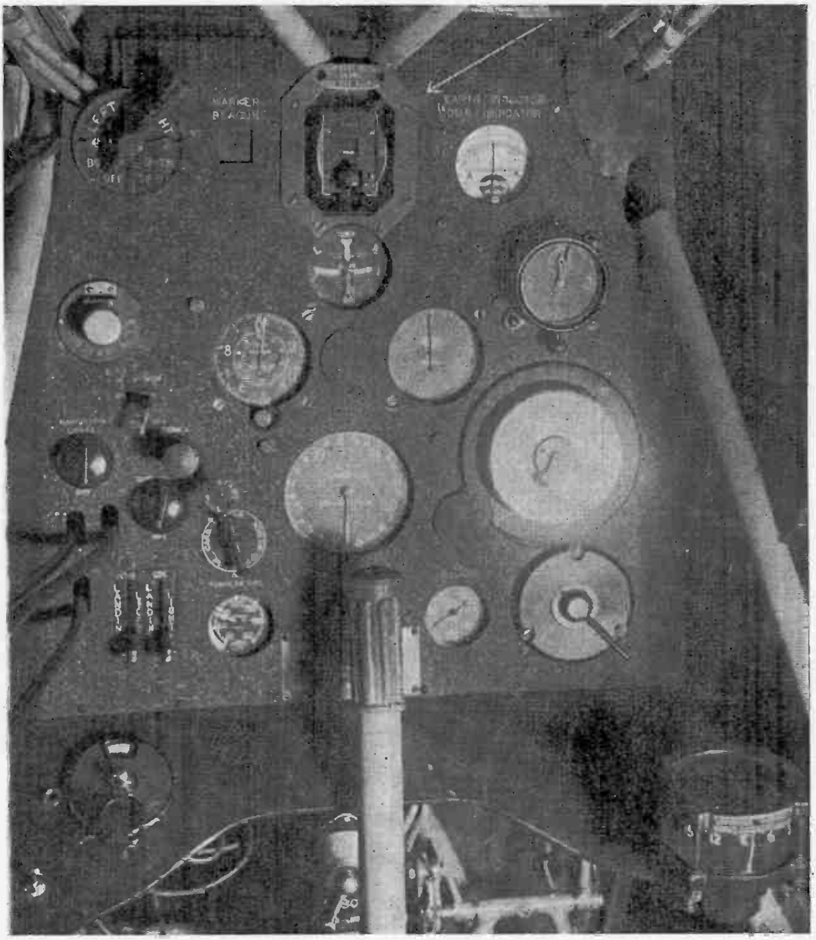


Fig. 4—Airplane instrument board with course indicator mounted above the other instruments.

in length the airplane is on its course. In the interest of simplicity the adjustment is aways such that a deviation from the course to the left serves to increase the relative deflection of the left reed, and the reverse is true if the airplane deviates to the right. To return to the course the pilot turns in the direction of the shorter reed deflection. A photograph of the reed indicator with shockproof mounting is given in Fig. 3. Fig. 4 shows this indicator installed on the instrument board of the Bureau's experimental airplane.

Simplicity of operation has resulted from the use of this system. An ordinary radio receiver with a smal reed unit weighing less than an ordinary pair of headphones, constitutes the airplane equipment. A

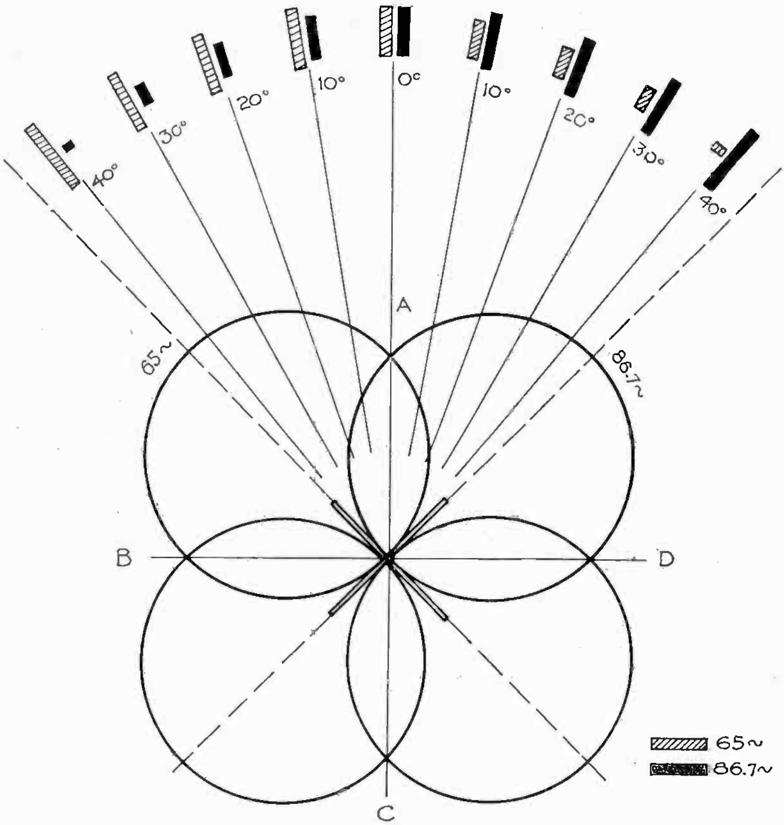


Fig. 5—Space characteristic of double-modulation type radio range showing relative deflections of the two reeds comprising the course indicator for different deviations in degrees from the beacon course.

signal is received whether on or off the course, a glance at the relative reed amplitudes being sufficient to tell the pilot whether or not he is on the course, and if not, approximately how far off he is and to which side. Finally, the sharp mechanical tuning of the reeds adds the very desirable feature of freedom from interfering signals, as the reeds operate effectively through interference sufficient to ruin aural reception.

A diagrammatic representation showing the relative deflections of the two reeds comprising the visual-course indicator for different deviations in degrees from a given beacon course is shown in Fig. 5. As may be observed, a deviation of ±2 degrees may be readily detected.

To make the use of the course indicator as simple as possible, a plug-in arrangement is provided so that the relative position of the two tuned reeds of the indicator may be reversed (by turning the indicator upside down). Reference to Fig. 5 will indicate the purpose of this reversal. Suppose that a pilot is flying away from the beacon on either course A or C. If he deviates to the left of his course, the amplitude of the 65-cycle reed will increase and that of the 86.7-cycle reed will decrease. A deviation to the right of the course results in an op-

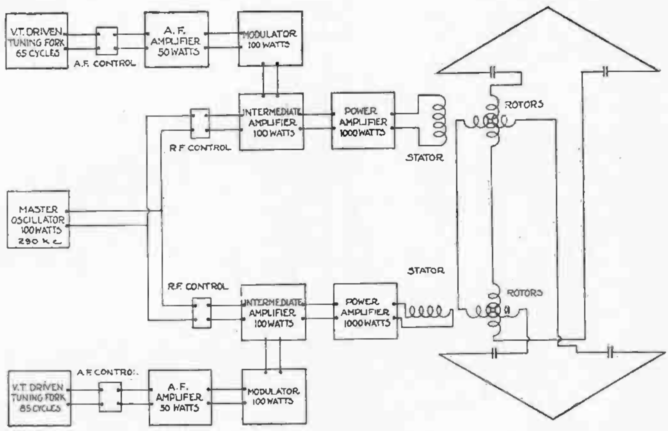


Fig. 6—Schematic diagram of double-modulation beacon using electron-tube-driven tuning forks as sources of the modulation frequencies.

posite effect. It is desirable, therefore, to place the 65-cycle reed on the left of the 86.7-cycle reed in order that the pilot may observe the simple and instinctive rule (longest reed shows side off course—turn to the shorter reed). When flying to the beacon, however, this rule holds true only if the relative position of the reeds is reversed, the 65-cycle reed being now on the right of the 86.7-cycle reed. Consider, now, the two 90-deg. courses, B and D. On these courses the relative position of the two reeds (in order that the rule stated above may apply) is exactly the reverse of that for courses A and C, whether flying from or to the beacon. To distinguish between the two sets of courses (A, C and B, D) a color system may be adopted on the airway maps, A, C being in one color and B, D in another. A shutter is mounted on the course-indicator front which exposes either one color or the other.

When set to the first color the words [TO / FROM] are exposed, while when the shutter is set to expose the second color, the words [FROM / TO] are exposed. The pilot then sets the shutter to the color of the course to be flown and plugs in the course indicator in order that the direction (with respect to the beacon) which he is to fly is right side up. The simple rule stated above then obtains. A complete description of the shutter arrangement is given in a separate paper[10].

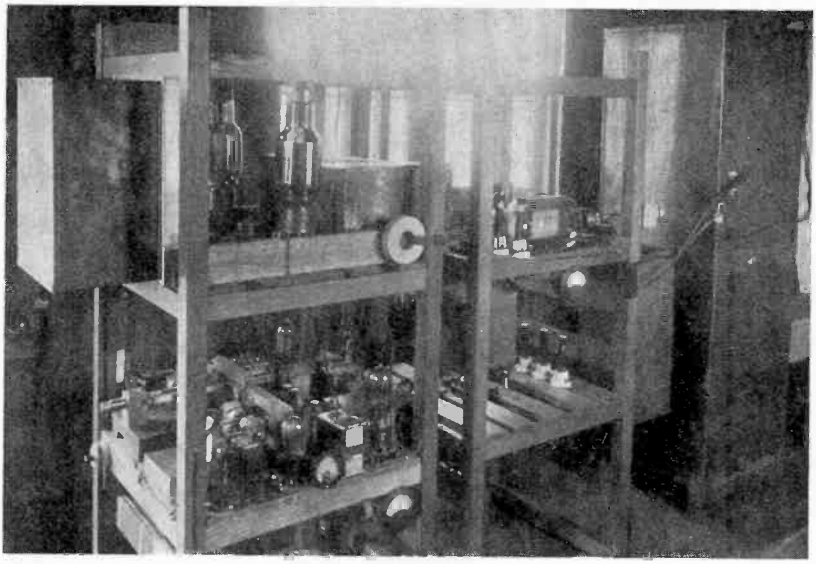


Fig. 7—Transmitting set for double-modulation beacon using tuning-fork modulation.

3. General Details of Transmitting Arrangement

Since the vibrating reeds are sharply tuned to their particular frequencies, it is necessary that the modulation frequencies of the transmitter be kept constant within certain limits. In the earlier beacon transmitting arrangements (see Fig. 6) this requirement was met by the use of electron-tube-driven tuning forks mechanically tuned to the desired frequencies. The outputs from these tuning forks, after sufficient amplification, were made to modulate the 290-kc carrier in the two amplifier branches of the beacon set. Heising plate modulation was employed. A photograph of the transmitting set using this method of modulation is shown in Fig. 7. The goniometer used for orienting the beacon causes in any desired direction is shown in Fig. 8.

The practical application of this modulation arrangement resulted in a beacon set somewhat more complex than was considered desirable. Since the maintenance of a "beacon course" or "equisignal zone" in space depends upon a balance of the modulated output of one amplifier branch and its associated loop antenna with the modulated output of the second-amplifier train and its loop antenna, it became neces-

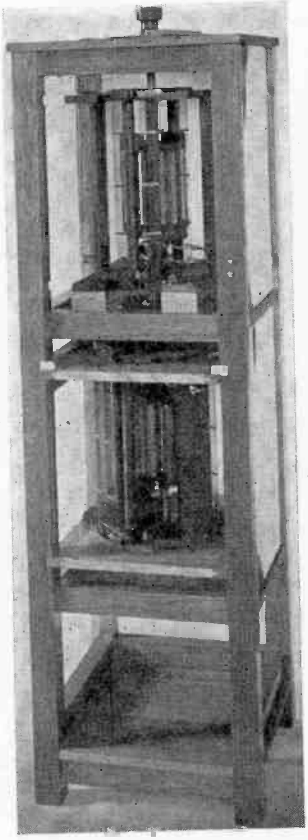


Fig. 8—Double rotor-type goniometer used with double-modulation beacon.

sary to insure a balance between; (1) the r.m.s. values of current in the two antennas, (2) the percentages of modulation in the two amplifier branches, and (3) the wave forms of the two modulation frequencies when applied through the Heising chokes. To accomplish this it was necessary to provide controls for varying the radio-frequency voltages supplied from the master oscillator to each amplifier branch, and also for varying the degree of modulation on each amplifier branch. The wave forms of the two modulation frequencies were kept as nearly sinusoidal as possible.

It was also important that no coupling exist between the two amplifiers, either by direct induction or by virtue of an impedance common to the two amplifiers. This necessitated the use of a considerable number of expensive condensers and chokes or the adoption of separate generators for supplying the plate and grid voltages to each amplifier branch. The use of the commercial 60-cycle alternating current for heating the tube filaments was also found not possible. Owing to the amount of audio amplification involved, any stray 60-cycle voltages introduced in the early stages were amplified sufficiently to cause a 5-cycle beat on the 65-cycle reed.†

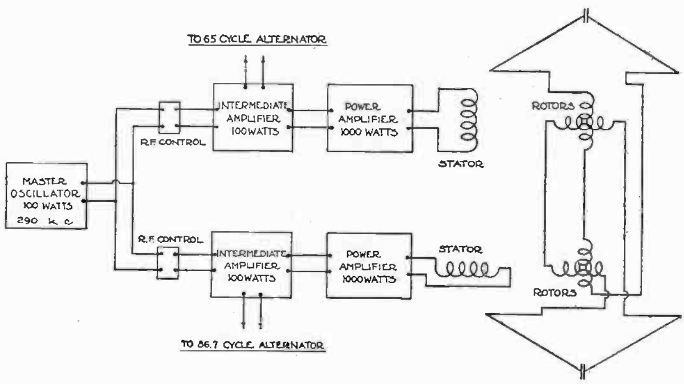


Fig. 9—Schematic diagram of double-modulation beacon using simplified modulation.

Early in the development of the double-modulation beacon the use of low-frequency generators for supplying the modulation frequencies was attempted. The modulation arrangement was essentially that indicated in Fig. 9, where the plates of the intermediate amplifier tubes are supplied through suitable transformers with high a-c voltages of the proper frequencies. Synchronous motor drive of these alternators was employed. Owing to the variation of the commercial supply frequency, however, it was found impossible to obtain the desired constancy of speed for driving the low-frequency alternators. However, the considerable simplification of the beacon transmitting circuit network that could be effected by the use of this system of modulation, coupled with the fact that both amplifier branches would then be positively modulated to the same degree, thus eliminating the need

† A further description of this method of modulation is given in (8).

for modulation controls, led to further efforts to make its application feasible.

An obvious method of attack was to broaden the resonance curve of the vibrating reeds comprising the course indicator to the point where small variations in the modulation frequencies became unimportant. This could not be carried too far, however, since the reed sensitivity materially decreases as the resonance curve is broadened.

A further change in the design of the vibrating reeds made possible a still further reduction in the requirements for speed constancy in the driving motor. The two alternators supplying the modulation frequencies, one having 6 poles and the other 8 poles, were rigidly coupled and driven at 1300 r.p.m. by the same motor. Variations in the speed of the motor, therefore, resulted in the *same percentage change* in the two modulation frequencies. The two reeds could then be designed to have, as nearly as possible, equal reductions in deflection for equal percentage frequency change[10]. In many installations this makes possible the use of a synchronous motor as the driving motor. Since the nearest synchronous speed is 1800 r.p.m., a chain drive is necessary for driving the alternators at 1300 r.p.m.

By the method described above, variations of the order of 0.3 per cent in the supply frequency can be permitted. Many of the larger power supply companies maintain their line frequency to this accuracy. Where the frequency variations of the supply mains are greater than this value, a motor other than of the synchronous type must be employed, with provisions for controlling its speed within the desired limit of accuracy. The securing of a suitable constant speed motor has been difficult. While the advent of television has given considerable impetus to the development of constant speed motors, most of these are not of sufficient power. A constant speed unit having the desired characteristics was finally obtained through the cooperation of the Leeds and Northrup Company, and has been in satisfactory operation at College Park for several months. This motor is essentially a rotary converter operated inverted, a portion of the a-c output being impressed upon a frequency bridge. This bridge operates a galvanometer which controls, through suitable relays, a motor-driven field rheostat connected in the shunt field circuit of the rotary converter. Any change in output frequency of the converter thus results in a change of the speed of the converter in such direction as to correct for the frequency change. A constancy of speed to within 0.1 per cent is thus maintained. A photograph of the control panel showing the frequency controller, *A*, the motor-driven field rheostat, *B*, and the automatic starting box, *C*, is shown in Fig. 10. A frequency recorder, *D*, used for checking the degree of speed constancy is also shown. Fig. 11 is a photograph of the beacon transmitter using the simplified modulation arrangement. The

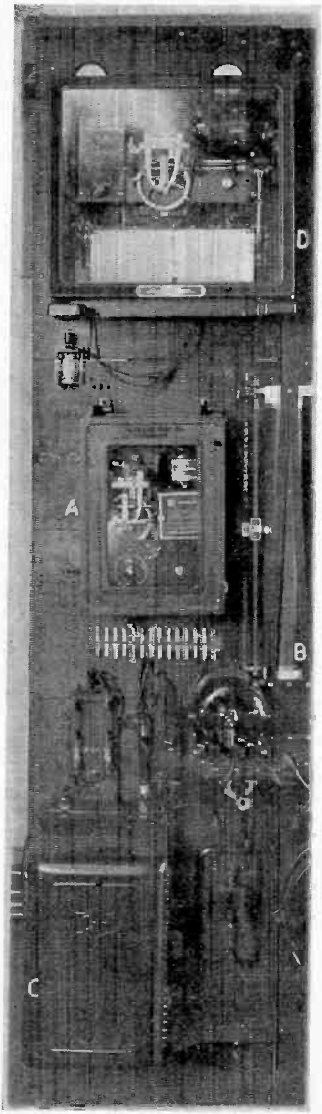


Fig. 10—Control panel for constant-frequency unit.

rotating machinery made necessary when using this modulation is more than compensated for by the great simplification in the transmitting

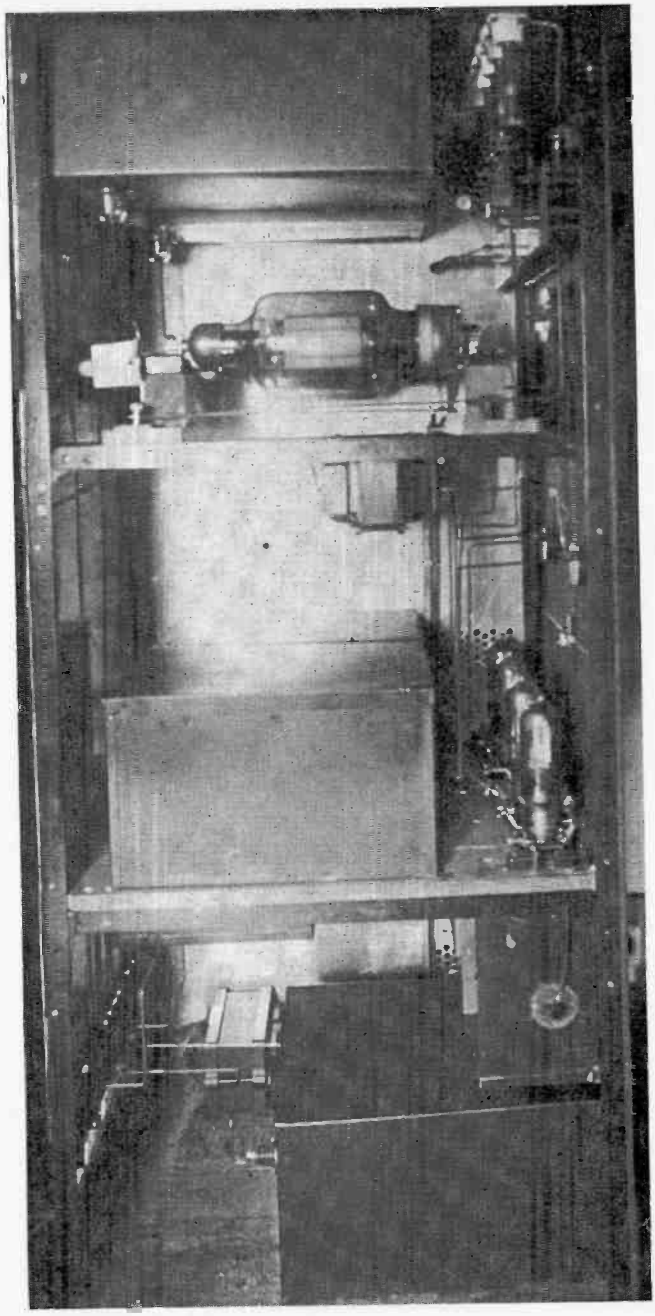


Fig. 11—Transmitting set for double-modulation beacon using simplified modulation.

circuit and the attendant improvement in performance and stability. The number of transmitting tubes employed is reduced from 18 to 8.

An improvement in the operation of the beacon was obtained by a change in the location of the loop-antenna tuning condensers. Previously, the tuning condensers were inserted in the base of the triangular loop antennas, as shown in Fig. 6. The distribution of voltage along the antenna is then as indicated in Fig. 12 (at 1) the portion of

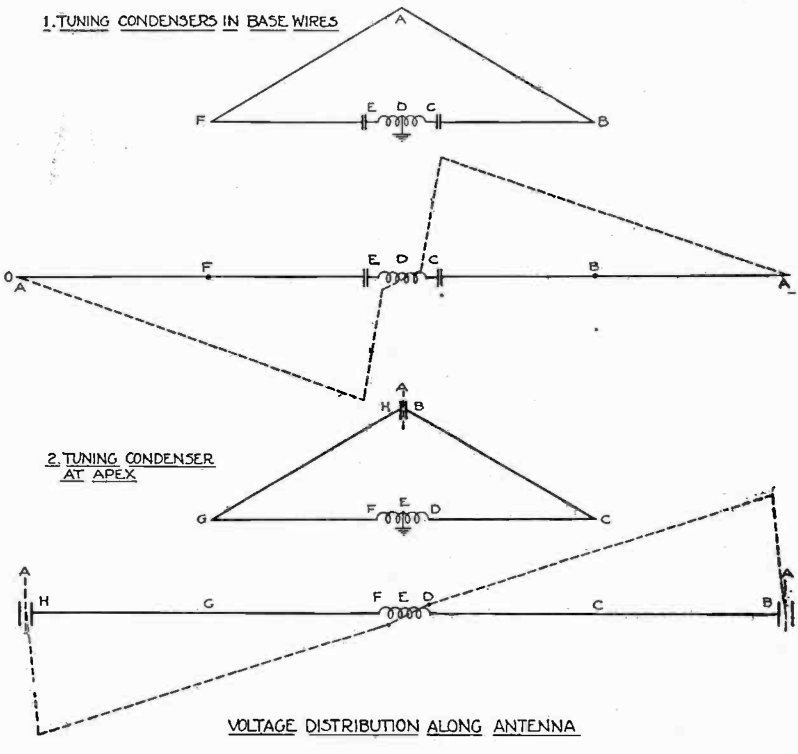


Fig. 12—Voltage distribution along loop antennas for two different locations of the tuning condensers.

the antenna nearest the group being at the highest potential. With this connection it was found that the tuning of the antennas changed considerably with the weather, often affecting the course settings. The effective capacity to ground constituted the variable factor. By placing the tuning condensers at the apices of the antennas (see Fig. 9), the voltage distribution becomes that shown in Fig. 12 (at 2), the portions of the loop antennas nearest the ground being at the lowest potentials. The effect of the weather on the tuning is then very much reduced. The weatherproof box used for housing the tuning condensers on top of the beacon tower may be seen in Fig. 2.

4. Adaptation of Beacon to Four Independent Courses

In order to use the beacon practically at any airport, it is necessary to adjust the angles between the equisignal zones arbitrarily so as to make them coincide with the airways converging on the airport. To understand how this may be done it is necessary to study the polar pattern of the field radiated by the double-modulation beacon[11]. One loop antenna radiates a 290-kc wave modulated to 65 cycles,

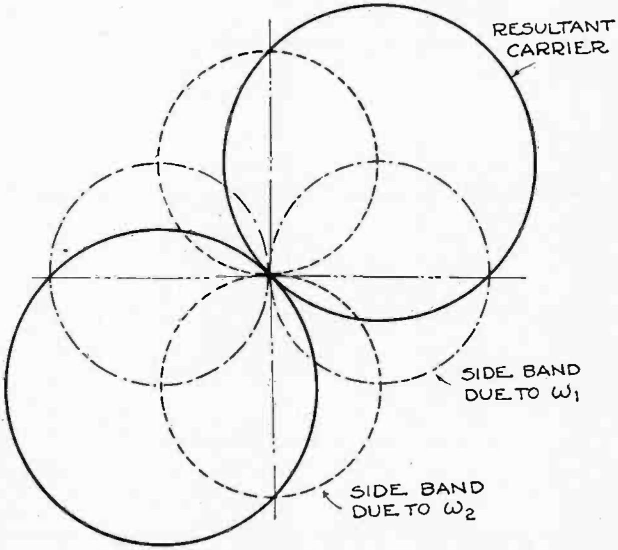


Fig. 13—Space pattern radiated by double-modulation beacon when the carrier currents in the two antennas are in time phase.

while the other loop antenna radiates a 290-kc wave modulated to 86.7 cycles. The wave due to each antenna may be resolved into a carrier and two side bands. The carriers in the two loop antennas being of the same frequency and in time phase, combine into a carrier having its maximum intensity along a plane bisecting the angle between the two antennas. The side bands of the two antennas do not combine since they are of different frequencies. The maximum intensity of each side band is therefore in the plane of the antenna radiating it. The space pattern indicating the field intensities of the combined carrier and the two sets of side bands is shown in Fig. 13. Since the reeds operate as a result of the low frequencies in the radio receiver output produced by the beating of the side-band frequencies with the carrier in the detector, they respond to a space-pattern characteristic as indicated in Fig. 14. This assumes a square-law detector. It will be noted that but two courses are produced, and that practically no signal is radiated in the directions at right angles to these courses.

In many cases, the elimination of the two 90-deg. courses is desirable. In the application of the beacon to course navigation on the

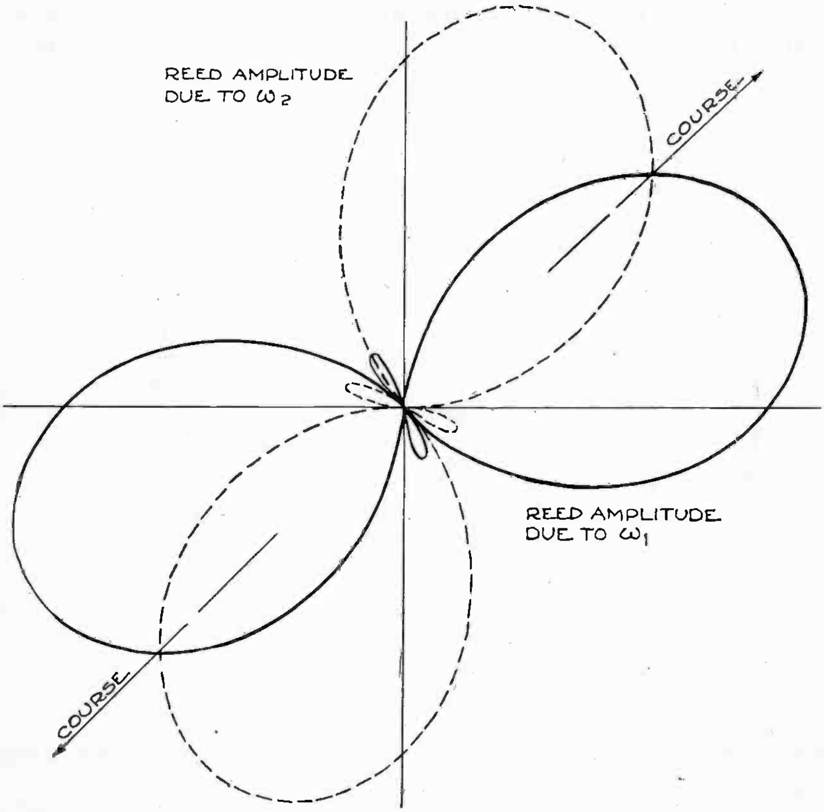


Fig. 14—Received pattern corresponding to space pattern of Fig. 13.

airways, however, airports requiring only two courses 180 deg. from each other are the exception rather than the rule. At those airports where two courses are sufficient, these are usually at an angle other than 180 deg. The beacon may be easily modified to permit the use of four courses at arbitrary angles. By a suitable coupling arrangement to the master oscillator, one of the carrier-frequency currents can be advanced in phase 90 deg. ahead of the other. Since the two loop antennas are in 90-deg. space-phase and their carrier currents in 90-deg. time-phase relationship, a revolving field is set up in space, so that the carrier space pattern becomes circular. See Fig. 15. The polar pattern as received by the reeds is that indicated in Fig. 16, four courses being obtained.

These four courses may be shifted considerably from their 90-deg. relationship in order to make them coincide with the airways converging on a given airport. Several methods are employed for effecting the course shifting. One consists of reducing the magnitude of current in

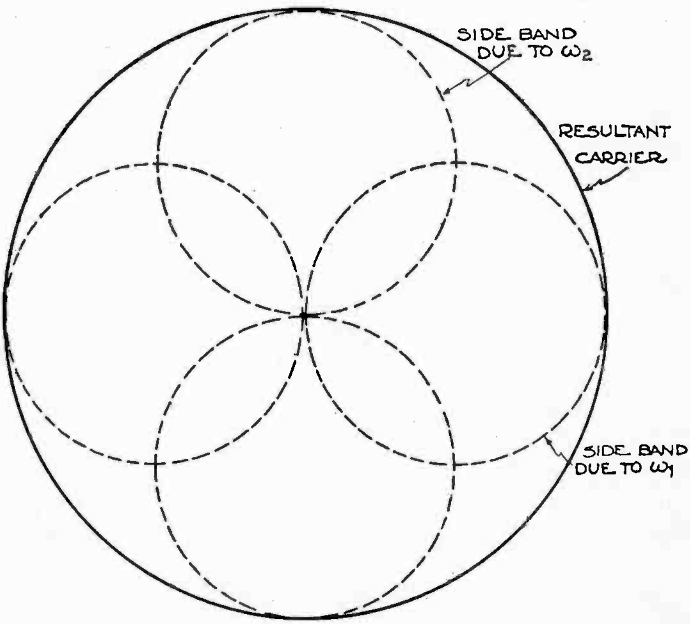


Fig. 15—Space pattern when the carrier currents in the two antennas are 90 deg. out of time phase.

one of the two loop antennas. A second method utilizes the circular radiation from a vertical antenna extending along the beacon tower in addition to the normal figure-of-eight radiation due to each loop antenna. The vertical antenna is coupled to the output circuit of either one or both of the two amplifier branches of the system, the space pattern due to either one or both loop antennas being thus altered. Combinations of the two methods described are also useful. A detailed description of these methods and an analysis of their degrees of usefulness are given in a separate paper[12].

5. Station Course Shift Indicator

In the practical operation of a radiobeacon system it is necessary to make periodic checks of the correctness of the courses it marks out. For this purpose an indicating instrument was developed and put into operation at College Park, Md., which makes possible the checking of the courses of the 2-or 4-course beacon within an accuracy of 0.1 deg.(13). This device indicates at the station whether the courses as laid out in space remain unvarying from day to day. If such variation occurs this instrument shows it, and an adjustment of the trans-

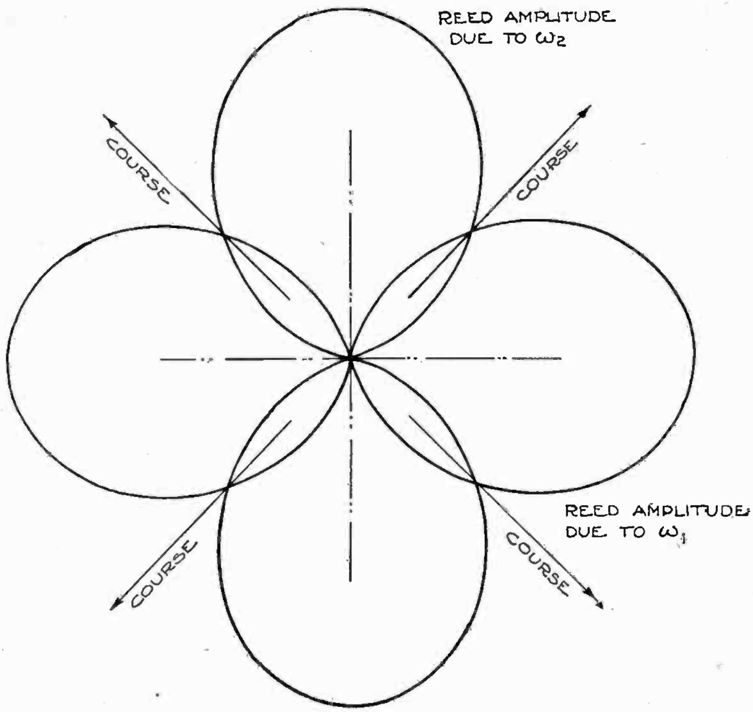


Fig. 16—Received pattern corresponding to space pattern of Fig. 15.

mitting set may then be made to correct this deviation, thus eliminating the necessity of recalibration at a distant point.

The circuit arrangement used in applying this instrument at the beacon station comprises a rotatable pickup coil inductively coupled, preferably with equal coupling, to the two loop antennas of the beacon, a detector-amplifier unit, a suitable filter unit, and a differential ratio instrument. The ratio instrument consists of two fixed field coils and an armature or rotor coil. A pointer attached to the rotor coil moves over a suitable scale. The force actions of the two field coils upon the rotor coil are in opposition, so that with equal currents in the field coils the pointer assumes a mid-scale position. The filter unit is so designed that with equal 65-and 86.7-cycle voltages impressed upon the instrument, equal currents flow through the field coils. If the 65-cycle voltage becomes greater than the 86.7-cycle voltage, one field coil carries a greater current than the other and the net force acting upon the rotor coil becomes greater than zero, the pointer attached to the rotor coil moving to the left of its mid-scale position. The reverse is true if the 86.7-cycle voltage becomes greater than the 65-cycle. The differential action of the two field coils upon the rotor coil, therefore, serves directly as a means for comparing the relative amount of

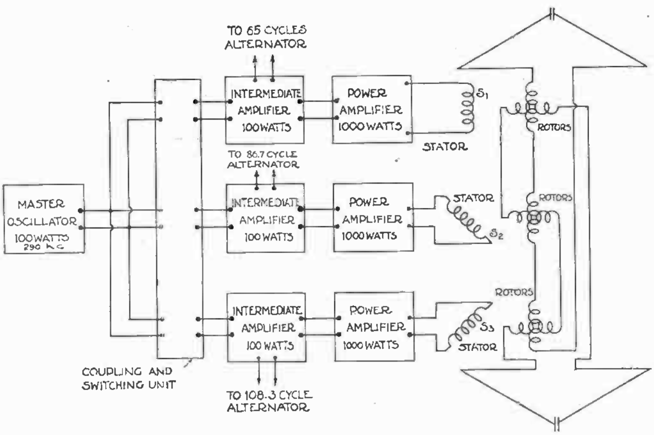


Fig. 17—Schematic diagram of triple-modulation beacon.

65-and 86.7-cycle modulation in the radio-frequency voltages induced in the pickup coil.

Recalling, now, that the pickup coil is inductively coupled to the two antennas of the beacon, rotating this coil about its axis changes the relative coupling to the two antennas both in magnitude and in sign. Rotating this coil is therefore equivalent to circling the beacon with a non-directional receiver. There are, then, as many positions of this coil at which the ratio instrument reads zero (i.e., equal 65-and 86.7-cycle voltage are induced in the coil) as there are beacon courses. If these coil settings have been determined during the original calibration of the beacon, the correctness of the courses marked out by the beacon may be checked at any later time in very simple fashion. The ordinary course indicator may, of course, be used to replace the differential ratio instrument together with its filter unit. The accuracy of the course settings will then not be so great (1 to 2 deg. rather than 0.1 deg.).

IV. The Triple-Modulation Beacon System

1. Transmitting Arrangement

To render the beacon system still more flexible and thus make it suitable for use at cities located at the junction of a large number of airways, a beacon transmitter was developed, capable of serving twelve courses simultaneously. The increase in apparatus over the beacon described above is not great. The same crossed-coil antenna system and the same circuit arrangements are employed (see Fig. 17), except

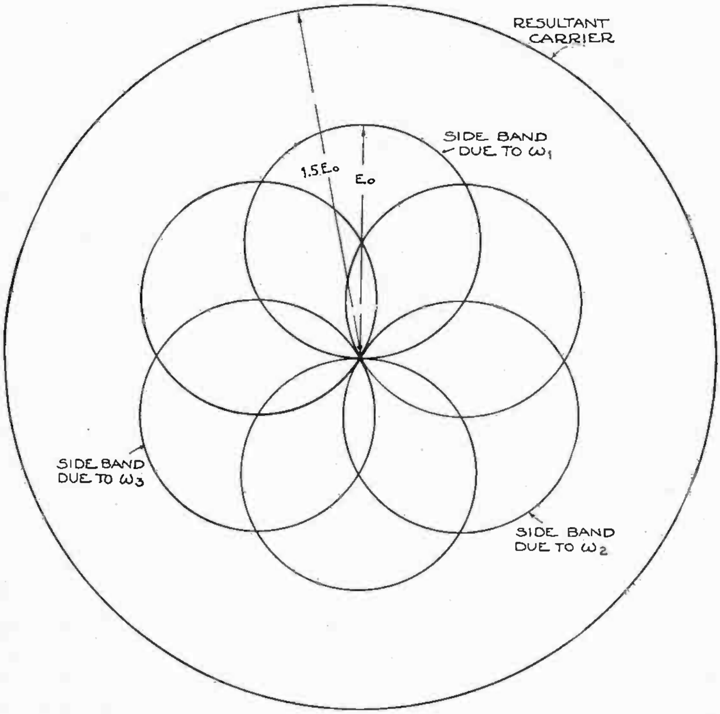


Fig. 18—Space pattern radiated by triple-modulation beacon using radio-frequency switching.

that three amplifier branches, modulated to three different frequencies, are necessary. The modulation frequencies used are 65, 86.7, and 108.3 cycles, respectively. A special goniometer is also required. The rotor system of this goniometer is the same as before; three stator coils are, however, required, one stator coil being connected to each power-amplifier tube. The stator coils are disposed at 120 deg. to each other, although these angles may be deviated from in order to obtain certain desired conditions.

Since the stator coils are not at right angles to each other, it is essential that but one stator be excited at any given time in order that coupling between stators be avoided. This is accomplished by radio-frequency switching, provided in the grid circuits of the intermediate amplifier tubes. By means of a suitable coupling arrangement to the master oscillator the carrier voltages applied to the grid circuits of the three intermediate amplifiers of the transmitter are displaced by

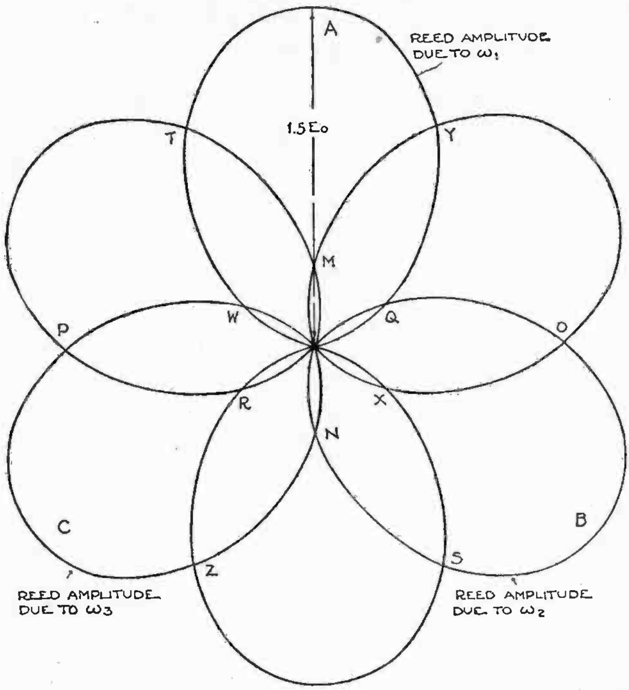


Fig. 19—Received pattern corresponding to space pattern of Fig. 18.

120 deg. in time phase from each other. The modulated voltages applied to the three stator coils are thus similarly displaced. Consequently, neglecting the fractions of a cycle when any two of the three voltages are of like sign,* but one stator is excited at a time. Further information regarding this method of switching is given in a separate paper[14].

Referring to Fig. 17 it will be observed that one stator carries a 290-kc current modulated to 65 cycles, the second stator a 290-kc

* This assumption is permissible since the power transmitted during these fractions of a cycle is small.

current modulated to 86.7 cycles, and the third stator a 290-kc current modulated to 108.3 cycles. Each stator, acting in conjunction with the two crossed rotor coils and the two crossed loop antennas, sets up a system which is electrically equivalent to a single loop antenna. For zero rotor setting the plane of the phantom antenna coincides with the plane of the stator coil considered. Since there are three stator windings, normally disposed at 120 deg. to each other, three such phantom antennas (also crossed at 120 deg.) exist, each phantom antenna carrying current of the same radio frequency but modulated to a different low frequency. The space pattern radiated by the beacon is given is Fig. 18. As the carriers in the three phantom antennas are 120 deg. out of phase both in time and in space, a revolving field is set up, and the resultant carrier space pattern is represented as a circle. The three sets of side bands are of different frequencies and do not combine. Assuming square-law detection, the polar pattern as received on the reeds is given in Fig. 19. This pattern is obtained by the beating of each side band with the *in-phase* components of the three carriers making up the resultant revolving field[(14)].

As will be observed from Fig. 19 twelve useful courses exist, any two adjacent courses being separated by 30 deg. Of the twelve courses, four courses (M,N,O, and P) can be received by a reed box tuned to 65 and 86.7 cycles, four courses (Q, R, S, and T) by a reed indicator tuned to 86.7 and 108.3 cycles, and four courses (W, X, Y, and Z) by an indicator tuned to 65 and 108.3 cycles. The equisignal zone of two of each set of four courses (e.g., M and N) is from 1 to 1.5 deg. wide, while the equisignal zone for the other two courses (viz., O and P) is from 3 to 4 deg. wide.

A 12-course radio range of the type described has been installed at College Park, Md., and is giving satisfactory results. On the basis of the results obtained, the Airways Division of the Department of Commerce is constructing seven sets of this type with a view to perfecting the design and employing these sets on an air mail route.

2. Special Three-Reed Course Indicator

To obviate the necessity of using three separate indicators in order to receive all twelve beacon courses, a special course indicator containing three reeds tuned to the three modulation frequencies of the beacon has been developed. Using this indicator, any one of the twelve beacon courses may be followed. Two shutters are employed on the indicator front. One shutter serves to expose any one of the three sets of reed combinations which go to make up the twelve course indications, each reed combination (for example, the two reeds tuned to 65 and 86.7

cycles, respectively) serving two sets of two courses (viz., M. N and O, P of Fig. 19). Two different colors are exposed corresponding to each setting of this shutter in order to facilitate the choice of the proper two reeds for a given course. Thus, if on the airways map courses M and N are shown in black and courses O and P in red, the shutter setting which exposes the two reeds tuned to 65 and 86.7 cycles, respectively, also exposes the two colors, black and red. The second shutter provided on the indicator front serves the same purpose as the shutter used with the 4-course indicator (see Sec. III, part 2); i.e., to simplify the choice of the proper relative position of the two reeds in use in order that the rule (longest reed shows side off course, turn to the shorter reed) may apply. This shutter has two settings, one exposing the words [TO / FROM] and the three colors corresponding to the three sets of courses (M, N), (Q, R) and (W, X), (See Fig. 19), while the other setting exposes the words [FROM / TO] and the colors corresponding to the three sets of courses (O, P), (S, T) and (Y, Z). The pilot uses the 12-course indicator exactly as he would the 4-course indicator, except that he must set two shutters instead of one in order to expose the color (according to the airways map) of the course to be flown.

A photograph of this special 3-reed indicator mounted on the instrument board of an airplane is shown in Fig. 20. The indicator is of cylindrical shape in order to conform to the other airplane instruments. The operating characteristics of this indicator are the same as for the 2-reed type, with the exception that since three pairs of actuating coils are employed, 50 per cent greater voltage is required for equivalent reed deflection. The sensitivity may be made equal to that of the two-reed type by means of a suitable arrangement for switching out the pair of coils controlling the reed not in use.†

3. Adjusting the Courses to Airways at Arbitrary Angles

With the 12-course radio range, as with the 4-course type, the problem of adjusting the angles between the beacon courses arbitrarily so as to make them coincide with the airways converging on a given airport, must be solved. The methods previously described (see Section III in Part 4) for effecting the arbitrary shifting of the courses of the 4-course beacon from their normal positions, are all applicable to the 12-course system. The first method described is the simplest and may well be employed. The other methods, although entirely prac-

† This special indicator is further described in (10).

ticable are not quite as simple and need not be used, particularly since an additional, and very simple, method, applicable only to the 12-course beacon is available.

This method consists in displacing the stator windings from the 120-deg. space relationship, thereby modifying the space pattern radiated by the beacon. It will be recalled that for zero rotor setting the plane of each phantom antenna coincides with the plane of the stator winding which produces it. A displacement of a given stator

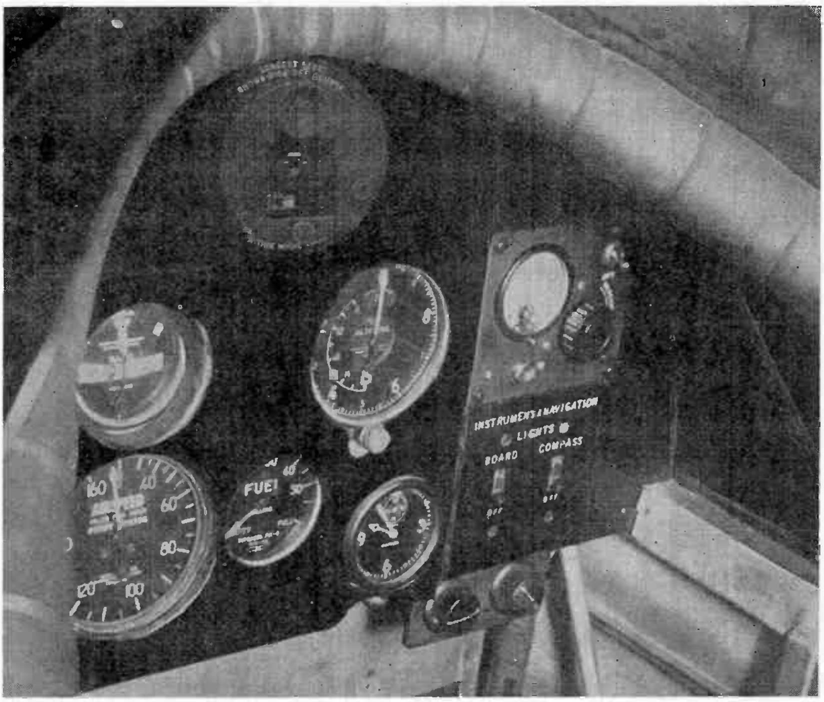


Fig. 20—Special three-reed course indicator mounted on airplane instrument board.

winding therefore results in a displacement of the space characteristic due to the phantom antenna associated with that stator winding. The space characteristics of the three phantom antennas may therefore be crossed at any angles found desirable. This does not mean, however, that in the received polar diagram (see Fig. 19) the three component characteristics (A, B and C) are necessarily crossed at the same angles. As stated previously, each set of side bands beats with the *in-phase* component of the carrier due to *each* phantom antenna, yielding the received polar pattern corresponding to that side band. When the three sets of side bands (and consequently the three carriers) are symmetrically disposed in space, there is reason to expect a symmetrical received pattern. With an unsymmetrical radiated space pattern, however, the received pattern is not necessarily similar to the radiated pattern. Nevertheless, the three component characteristics of the received pattern *are* displaced from their 120-deg. relationship, the angles between adjacent beacon courses being therefore adjustable.

Using the two simple methods outlined it becomes possible to adjust the angles beween the beacon courses over a wide range of values[14]. Obviously, each installation will require a different adjustment, which may be more or less difficult. The statement that these methods will prove successful in all possible cases cannot therefore be made.

4. Indication of Correctness of Courses

The course shift indicator described for use in checking the correctness of the courses marked out by the 4-course beacon is not applicable for use with the 12-course system. If the circuits of the filter unit could be made sufficiently sharp to exclude the third modulation frequency (108.3 cycles), this device could be used for checking four of the twelve courses. It is difficult to obtain the necessary sharpness of tuning. The special 12-course indicator is, therefore, used to replace the differential ratio instrument and filter unit, thus making possible the checking of all twelve courses to within 1 to 2 deg.

V. Airplane Receiving Equipment

1. Airplane Radio Receivers

The beacon system can be used with any radio receiver which operates at the frequencies employed, merely replacing the telephone receivers by the simple reed-indicator unit. There are, however, a number of special conditions involved in receiving on an airplane, and the Bureau has developed special radio receivers[15] in order to use the beacon system under the most advantageous conditions.

The radio receiver designed employs six tubes and weighs less than 15 pounds, the auxiliary batteries weighing an additional 10 pounds. The radio receiver operates in the frequency range from 285 to 350 kc and is used to receive either the beacon signals or radiotelephone weather messages at will. It is highly selective and sensitive. The audio-frequency amplifier is specially designed to be efficient at the low-modulation frequencies used in the beacon. The selectivity of the set is supplemented by the selectivity of the vibrating reeds, which help greatly in reducing interference. Nevertheless, it is important that a good degree of selectivity be provided in order to make the most efficient use of the frequency channels provided for this service and also make the radio receiver suitable for the reception of weather telephone messages. The set has remote-control arrangements for tuning and volume, so that it may be mounted in any location on the airplane.

The Bureau interested several manufacturing companies in building radio receivers of suitable characteristics. Three companies are now ready to furnish radio receivers, all of which have proved satisfactory.

The result of more than two years of flying on the visual-type radio range has proved that a radio receiver designed for beacon reception should have as high an undistorted power output as possible. Since the reeds are practically immune to interference, atmospheric and other disturbances will not affect their operation unless they are of sufficient strength to overload the radio receiver. The greater the overload point of the radio receiver, the greater will be the range of the beacon during severe interference.

The incorporation of an automatic volume control is highly desirable, since such a device would still further reduce the effort expended by a pilot in making use of the radio navigational aids. The 2-course, the 4-course, and the 12-course visual radio ranges as now employed will each function properly with or without automatic volume control. Automatic volume control is, however, not possible with the aural radio range since its effect would be to reduce to equal signal strength the two coded signals, the relative magnitudes of which it is desired to compare. The chief value of automatic volume control with the visual radio range would be within 10 to 15 miles of the beacon, in the region where the beacon signal strength changes most rapidly. At great distances from the beacon an auxiliary manual control would be essential, since the effect of large interfering signals (when using automatic control) would be to reduce the amplitude of vibration of both reeds. This may well prove troublesome, particularly since interference is normally intermittent in nature.

2. Airplane Antenna

The development of radio receivers having the necessary sensitivity made possible the use of an antenna system on the airplane, consisting of a metal pole extending vertically from the fuselage, the total length of this pole being but 6 to 8 feet. (See Fig. 21.)

The antenna system in common use on airplanes previous to this development was the weighted trailing wire. This system had numerous disadvantages. It was heavy, difficult to handle, and dangerous. It had marked directive properties, resulting in erroneous indications of the beacon course unless it lay in the vertical plane containing the transmitting station;[16] in additional errors when near the beacon (where the angle between transmission path and ground is appreciable); and in marked apparent variations of the beacon courses at night.

The existence of errors at night in the apparent direction of radio stations has long been known.[17,18] Investigations as to the causes of direction shifts have been under way for some time[19] and experimental proof has been secured that these shifts are largely due to the horizontal component of the downcoming reflected or refracted wave. The existence of these apparent shifts in the directive radiobeacon courses was first observed in August, 1927.[20] The tests were made on the aural-type beacon using a trailing-wire antenna for receiving on the airplane. The results of these tests are summarized below.

Fig. 21—Airplane showing vertical-pole antenna.

1. Within 25 miles of the beacon the shifting was not of a very serious nature.
2. At 50 miles the shifting became pronounced but due to the zone appearing to be stationary in its proper position for possibly 75 per cent of the time, the beacon could still be depended upon when used with judgment.
3. At a distance of 100 miles the shifting became very pronounced and persisted for more than 50 per cent of the time, giving the beacon a questionable value.

4. At 125 miles the beacon was of no further use as a guide.

Later tests made on the ground,[20] indicated that the use of a vertical antenna reduced the amount of variation of the course to a considerable degree. This was one of the contributing reasons which led to the adoption of the vertical-pole antenna. Since this type of antenna is not affected by horizontal electric fields, the results obtained were in accordance with what was expected.

More recent tests carried on periodically during the past two years using the visual-type beacon, tend to corroborate these results. With tuned reed indication it became possible to estimate more closely the variation of the courses in degrees. The test were made in the air and on the ground, the results obtained in each case being very nearly the same. These results are summarized below.

1. Within 75 miles of the beacon the shifting was not serious.

2. At a distance of 125 miles the shifting was readily detectable, maximum variations ranging from 10 to 20 deg. being observed. The period of the variations appeared regular, the reed indicator showing "off course" first to one side and then to the other. However, the true course could still be estimated with a fair degree of accuracy, visual indication having the psychological effect of averaging out the variations.

3. At a distance of 200 miles the course shifting appeared not very much worse than at 125 miles, an estimation of the true course still being possible. Not enough data were taken at this distance to permit of definite conclusions.

The improvement due to the use of the vertical antenna is evident. The normal range expected from the beacons is about 125 miles. For this range, the apparent night variations of the course should not prove serious.

An added advantage for the use of the vertical-pole antenna is that it becomes possible to guide an airplane directly over the beacon tower. (With the trailing wire this was a difficult feat, becoming impossible when a side wind produced a side slant to the antenna). Furthermore, since the vertical antenna is affected only by vertical electric fields, a region of zero signal is met with directly above the beacon tower, where no vertical field exists. The beacon can thus be located to within 100 to 200 ft. when the airplane is not over 1000 ft. above it, a most valuable aid in fog.

3. Engine Ignition Shielding

The use of a sensitive radio receiver together with a short vertical antenna located near the airplane-engine ignition system, makes necessary a considerably more rigorous shielding of the ignition system than was previously required to prevent ignition interference. The entire electrical system of the ignition must be encased in a high conductivity metallic shield. This requires that the magnetos be provided with such metal covers as will completely enclose the distributing heads. The booster magneto outlet must also be covered. All distributing wires must be enclosed in a metal tube or braid, the spark plugs must be completely shielded, and the booster leads and leads to the ignition switch, including the ignition switch itself, similarly treated.

The Bureau has been in active cooperation with airplane engine, magneto, spark plug and cable manufacturers in an effort to develop a safe method for effecting this shielding and to make the necessary equipment commercially available. As a result of this cooperation, suitable shielding assemblies may now be purchased for use on all Wright and Pratt-Whitney airplane engines. A metallic ignition manifold is employed with high-tension cable drawn through it in the usual way. The leads from the manifold to the spark plugs and the groups of leads from the manifold to the magneto outlets are enclosed in liquid-proof flexible aluminum tubing with copper braid on the outside to insure effective shielding. Each flexible tube is suitably fitted to the ignition manifold and to the magnetos or spark plugs, as the case may be. The magnetos are provided with covers which completely enclose the distributor blocks. A single outlet permits the use of an elbow fitting for connection to the large flexible metal tubing. This elbow fitting differs for different types of engines. Outlets are provided in the elbows for the booster and ground leads. The spark plugs are of a type in which the shield is an integral part and are provided with elbows for connection to the smaller flexible metal tubing. The ignition switch is totally enclosed in a metal cover, the booster magneto is also covered, and the leads from the magnetos to the ignition switch and booster magneto are enclosed in flexible metal tubing. The complete assembly insures electrical safety, mechanical sturdiness, liquid proofing of magnetos, spark plugs and ignition cable, and ease of installation and of servicing.

At a conference held at the Bureau of Standards on June 11, 1929, in response to a number of requests from representatives of the aircraft and radio industries, the present status of shielding was discussed. In addition, a beginning toward the standardization of shielding assembly practice was made and a series of standard tests whereby the mechanical, electrical, and radio efficiency of a given shielding installation may be determined, were adopted.

Further details regarding the Bureau's work in this field are given in a separate paper[21].

VI. Marker Beacons

The directive radiobeacon will successfully guide a pilot along a given course but does not directly indicate his exact location along that course. Where it is desirable that this indication be given, for example at the intersection of two beacon courses or at a dangerous portion of the airway, it can be obtained by the installation of a small marker-beacon transmitter of very low power (a few watts). The marker beacons operate on the same radio frequency as the main beacon. This signal operates a 40-cycle reed indicator mounted at a suitable location on the airplane instrument board and connected in series with the main course indicator, and is received for two or three minutes as the airplane passes over the marker. The pilot can thus locate his exact position on the airway.

The first experimental work with the marker beacon involved the use of a reed indicator tuned to 60 cycles. Modulation of the marker beacon was accomplished by supplying the oscillator with a plate voltage secured from the commercial 60-cycle supply. This resulted in an inexpensive marker-beacon transmitter. The use of 60 cycles was not practicable, however, since a 5-cycle flutter was observed on the 65-cycle reed of the main course indicator during the entire period that the receiver was within the range of the marker-beacon transmitter. This destroyed the usefulness of the main beacon course during that period. A self-rectifying circuit, still using the 60-cycle supply, but giving a 120-cycle modulation frequency, was then tried, the marker-beacon reed being tuned to 120 cycles. The 5-cycle flutter on the 65-cycle reed still occurred. The frequency of 40 cycles was then chosen. The beat frequency (25 cycles) is then sufficiently high so that neither reed has opportunity to follow this beat frequency owing to mechanical inertia. A 4-pole alternator driven by a 6-pole synchronous motor operated from the commercial supply is used as the 40-cycle source.

In the earlier experiments, it was decided to use an open antenna with the marker beacon, and to code the transmitted signal with a characteristic corresponding to that used on the light beacon at the same location (if there is one there). The use of an open antenna is, however, not entirely satisfactory. A sharp indication of the exact marker-beacon location is obtained only when passing directly over the antenna, a region of zero signal being then observed. The use of a loop antenna, oriented as shown in Fig. 22, removes this objection. As will be observed from the loop characteristic, sharp indication of a line perpendicular to the airway route is obtained, a drop in the marker

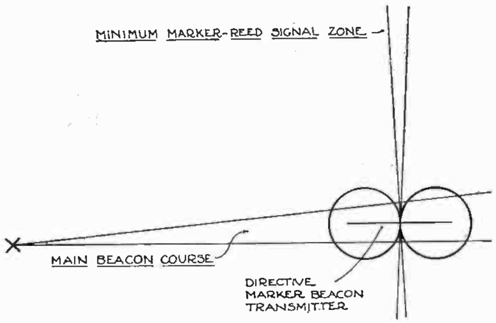


Fig. 22—Diagram illustrating use of directive marker beacon on the airways.

beacon reed-indicator deflection being observed when crossing this line. Coding of the transmitted signal is, however, not practicable when using this antenna arrangement. Actual use on the airways will determine which antenna system is the more desirable.

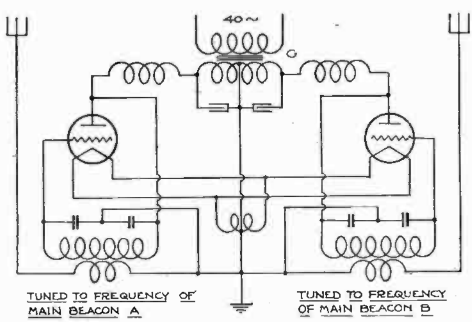


Fig. 23—Circuit diagram of marker beacon located at the intersection of two main beacon courses.

When located at the intersection of two main beacon courses, an arrangement must be provided on the marker beacon to permit the omission of its signal on each of the two radio frequencies used by the main beacons. A satisfactory audio-frequency switching arrangement for accomplishing this purpose has been developed and is included in the circuit diagram of Fig. 23. Either open or loop antennas may be employed. The two antennas shown are tuned to the two different beacon frequencies. These are excited alternately at a 40-cycle rate by means of transformer *G*.

VII. Fog Landing

By the use of the radiobeacon system described, it will become entirely feasible to fly between any two points along a given airway and to arrive within a few thousand feet of the desired destination regardless of weather conditions. The problem of effecting a safe landing during fog and extremely low visibility is not yet, however, completely solved.

Recent tests indicate that fog-penetrating lights are not yet available. The dissipation of fog by mechanical means has been the subject of considerable laboratory experimentation, the general result being that it is not economically possible on a useful scale.

The most feasible method of attack at the present time appears to be in the application of radio. When attacked from this angle, the problem of fog landing resolves itself into two separate problems; namely, field localizing, and the development of a suitable altimeter.

1. Field Localizers

Practically all previous experimentation in this field has been in the use of "leader cables." The principal installations are those of the British Government at Farnborough and of the French Government at Chartres. The British installation uses a complete circuit around the landing field with a visual indicator in the airplane instrument board. The French installation uses straight cables. The Loth Company of Paris, has also conducted experimental work using straight cables.

The ground equipment at Farnborough consists of an oval loop of cable about 5 by 2 miles, buried 2 ft. in the ground. One of the straight sides of this oval loop passes through the airdrome. Near this straight side and surrounding the portion of the airdrome free from obstructions is a second smaller oval loop. A pilot circles around the major loop coming lower and lower. Once each revolution, he receives a signal from the smaller loop indicating that he is directly over the airdrome. When he is at a sufficiently low altitude and over the airdrome a safe landing may be effected. An obvious disadvantage of the leader-cable method of field localizing is its great cost.

The success obtained with the radio range in its application to point-to-point flying, suggests its possibilities as a field localizer. With the main beacon used for guiding an airplane to a given landing field, a low-power beacon with small loop antennas may be employed for marking out the major, or most desirable axis, or runway of the landing field. This can be done quite as effectively as with leader cables. For example, consider a class A field having the required dimensions of 2500 by 2500 ft. with two perpendicular runways at least 300 ft. wide. The equisignal zone of the two-course radiobeacon is at a maximum 5-deg. wide. (The use of the 2-course beacon is here assumed because of the obvious advantages of eliminating the 90-deg. courses.) If, then, a course is oriented along a particular runway, with the beacon at one end of the field, a pilot can locate the axis of this runway at the other end of the field within 100 ft. He is thus certain to land on the runway.

An installation has been made at College Park, Md., and a second installation for the Guggenheim Fund for the Promotion of Aeronautics at Mitchel Field, Long Island, with a view toward obtaining a practicable arrangement. Each installation includes a localizing beacon for guiding an airplane along the major runway of the field and suitably placed marker beacons for defining the beginning of the hazard-free approach to the field and the limits of the field. This arrangement combined with a suitable landing altimeter, gives promise of making fog landing feasible.

3. Landing Altimeters

The method of fog landing demonstrated by Lieut. J. H. Doolittle of the Guggenheim Fund[33] consists of maneuvering the airplane into a glide from a position in space of fixed bearing and altitude with respect to the landing field. The barometric altimeter is adjusted to read altitude above the field based on data communicated from the ground. If the landing is entirely blind the glide continues until a landing is made without the usual "flattening-out," owing to the lack of knowledge of the altitude to the accuracy required.

Experiments are being undertaken by a number of investigators looking toward the development by several means of altimeters indicating the absolute height above ground. One is the development of a sonic altimeter. Another device is the capacity altimeter which measures the distance from the ground by detecting the change in the electrical capacity between two plates on an airplane, as the airplane approaches the ground. A third method is by the use of direct reflection with radio waves. It is doubtful at the present time whether any of these instruments will be sufficiently sensitive for use in "flattening-out" so as to make a normal landing. These instruments when available will, however, be exceedingly valuable in determining the altitude from which the glide shall be started in landing and also in maintaining a safe altitude during point-to-point blind flying.

The Bureau is conducting experiments toward making possible normal three-point landings in dense fog. A special radiobeam at the landing field is so oriented in space as to define the proper gliding path which if followed will permit such landings. Experiments toward the production of such a beam with a suitable visual-indicating device on the airplane show some measure of success. High frequencies are employed (about 70 megacycles), making the necessary equipment on the ground and on the airplane rather simple. This arrangement, if found suitable, will of course merely obviate the need for an altimeter in landing; the localizing and marker beacons will still be necessary.

VIII. Tests of the Beacon System

The practicability of the visual radio-range system described has been demonstrated by a considerable amount of test flying on the College Park station. The useful range of the beacon under summer and winter conditions is, of course, a function of the power used at the beacon station, the length of receiving antenna, sensitivity and overload point of radio receiver, sensitivity of the reed indicator, and degree of airplane-engine ignition shielding.

Using 1-kw tubes in each power-amplifier stage of the beacon transmitter, a current of 12 amperes may be obtained in each loop antenna. The antennas are triangular in shape with a base 300 ft. long and a net height of 70 ft. On the airplane a receiving antenna 6 to 8 ft. long was employed. The radio receiver with which 90 per cent of the tests were made has a sensitivity of about 120 db and begins to overload slightly at an output voltage of 12 v. Serious overloading occurs when the output voltage is 20 v. The 4-course reed indicator has an impedance of about 4000 ohms and requires 4 v across its terminals to give normal reed deflection; the 12-course reed indicator has an impedance of about 6000 ohms and requires 6 v. Perfect ignition shielding is assumed. Under these conditions, the average winter range of the 4-course beacon is 200 miles and the average summer range about 100 miles. With the 12-course beacon the useful distance depends upon the courses used. Referring to Fig. 19, the range on courses M, N, Q, R, W, and X is 150 miles in the winter and 75 to 90 miles in the summer, respectively. The range on courses O, P, S, T, Y, and Z is as great as with the 4-course beacon. The reduction of indicator sensitivity as compared with the 4-course type is compensated for in part by the fact that in the 12-course beacon three power-amplifier tubes rather than two feed power into the antennas. In addition, the greater indicator impedance more nearly matches the plate impedance of the output tube of the radio receiver.

Preliminary tests which have been begun using a radio receiver of approximately the same sensitivity as the radio receiver mentioned above but having an overload voltage of about 30 v, show that the summer range may be increased somewhat over the figures given above. A typical test will be described. Using the first radio receiver on a partially shielded airplane, a range of 40 miles was obtained before the ignition interference began to effect the operation of the reeds. With the second radio receiver, having the greater overload point, mounted on a different airplane (but shielded to approximately the same degree) the College Park beacon signals were received at Hadley Field, N. J., a distance of about 185 miles, the reeds operating properly and with full-scale deflection. Although the conditions under which the tests were taken were not identical, the effect of greater load capacity in the radio receiver is nevertheless positive.

The remarkable selectivity of the reed indicator has been demonstrated in several flights from College Park, Md., to Hadley Field, N. J., with the double-modulation radio range at College Park and the aural-type Hadley beacon both operating on the same radio frequency and approximately the same power. Using the radio receiver having the lower overload voltage rating, the interference due to the Hadley beacon began to affect the reeds at a point about 140 miles from College Park and only 45 miles from Hadley.

The ruggedness of the radio equipment on board the airplane was demonstrated when an airplane crashed in July, 1929. Several pilots remarked that this was the worst wreck that this particular type of airplane had ever experienced. All the instruments on the instrument board, except the reed indicator, were completely demolished. The shock-mounting case for the reed indicator was seriously damaged. The indicator itself, however, was found to be in good condition, and in accurate adjustment. The radio receiver, which was shock-mounted in a compartment behind the pilot's cockpit, also escaped with minor injuries.

The simplicity of operation of this system, and its adaptation to the needs of the pilot, is evidenced by the following typical test. On a day of low visibility, a pilot, unfamiliar with the route, took the air in Philadelphia for Washington with no maps or instructions as to landmarks. He was told to proceed to Washington (a distance of 120 miles) and land at College Park Field solely in accordance with the guidance given by the beacon indicator on his instrument board. He not only flew in a straight line to Washington, but when over

College Park field, the location of which he did not know, the sudden drop in the reed deflections told him he was at his journey's end, whereupon he landed.

IX. Comparison of Various Types of Radio Aids to Air Navigation

It is of interest to compare the advantages of the radiobeacon system described in this paper with the other systems in use for guiding aircraft. A brief description of the various systems employed is given in the introduction to this paper under "Previous Work." The discussion will be limited to the application of these systems to course navigation on fixed airways, which is of primary importance in the United States.

1. Requirements for Course Navigation on Fixed Airways

The fundamental requirement of a radio system for guiding airplanes traveling the fixed airways is that it shall give the pilot information to enable him to continue along a given airway, when no landmarks or sky are visible. If he leaves the course, it should tell him how far off he is, and to which side, should show him the way back to the course, and should inform him when he arrives at his destination. Guidance along the airways means guidance along the route regularly flown, with its emergency field, lights, and other facilities. The guidance system must be entirely free from errors owing to wind drift. The system must provide service to all airplanes flying the course, and must be adaptable to the complex conditions on the busiest airways.

In addition to these requirements, there are a number of additional desiderata which are not strict necessities. The identity of the portion of the airway traversed should be indicated by the radio signals utilized. The service should be continuous rather than intermittent. The pilot should receive the service by a mere glance at an instrument, being free from any necessity of using ear phones, or adjusting anything, or correlating with other instruments, or changing the course of the airplane. The radio frequencies, power, type of emission, and location of transmitting stations should be so chosen as to serve the needs with maximum efficiency and conservation of the limited radio channels. The radio equipment on the airplane should be simple, rugged, and inexpensive. Finally, the transmitting equipment on the ground should be as simple as possible.

2. Direction Finder on Airplane

The use of a direction finder on aircraft makes possible a very simple transmitting station on the ground. Available radio stations may be utilized and guidance obtained in every desired direction. Simultaneous service to any number of airplanes is possible. Complicated equipment must, however, be carried aboard the airplane. This system does not fulfill the major requirements listed above. It does not take care of wind drift, resulting in circuitous courses to the airport. It, therefore, does not as a rule guide aircraft over the lighted or marked airway, and does not give a pilot the advantage of the emergency landing fields and other aids along the airways.

3. Direction Finder on the Ground

This system also has the advantage of giving guidance in every desired direction. The apparatus on the ground is more complicated than with the previous method, two or more radio stations with an intercommunication system being required in order to give the pilot a bearing. Simultaneous service to several airplanes in the air is not possible, individual service to each airplane from two stations being necessary. The apparatus on the airplane is bulky, comprising a transmitter and a receiver. Two-way communications must be maintained. Since but infrequent bearings are available, the pilot must rely on blind flying by means of his other flight instruments during the greater portion of his flight. Consequently, the route traveled is generally not over the regular airways.

4. Rotating Radiobeacon

This system has relatively simple apparatus both on the ground and aboard the airplane. The use of this system, however, burdens the pilot more than is desirable. It is capable of giving simultaneous service to any number of airplanes in any direction. This service is, however, intermittent and slow, requiring at least thirty seconds for each bearing. Drift may be checked by determining positions periodically and correction may be applied. Since the determination of a minimum signal must be made, this system is particularly subject to interference and atmospheric disturbances. The errors in course determination with this system are somewhat greater than with the directive type radiobeacon.

5. Four-Course Aural Radio Range

The use of a directional transmitter places the complicated apparatus on the ground under skilled supervision and makes possible the use of a simple receiver on the airplane for taking advantage of all radio aids. The radio-marked channels coincide with the airways so that the pilot can utilize the other navigational aids provided on these airways. The system can furnish simultaneous service to any number of airplanes. Wind drift is readily detected. An observation is made without any necessity for moving the airplane or correlation with maps or any flight instrument. The safest route is radio-marked, and is over the route flown in good weather. This aids greatly in missing obstructions and safely takes the pilot through mountain passages and canyons. The system acts as a homing device, guiding the pilot to the airport and informing him when he has reached the airport. It has the disadvantages of requiring the pilot to wear headphones and to recognize coded signals. It is at present capable of serving but four courses and cannot therefore furnish guidance in more than four directions.

6. Four-Course Visual Radio Range

This system has all the advantages of the 4-course aural system. In addition, visual indication removes the necessity of wearing headphones. A glance at the reed indicator tells the pilot his exact position with respect to the course. No skill is required on the part of the pilot in the use of this system. Finally, the selectivity of the reed indicator renders the system almost immune to interference from other services or atmospheric disturbances. Course guidance is therefore available when no other radio service is possible. The chief disadvantage of this system is that only four channels are available, thereby making its use difficult at airports located at the junction of a large number of airways.

7. Multicourse Visual Radio Range

This system removes the only objection inherent in the one just described. Twelve radio channels (with the angle between adjacent channels controllable over a considerable range) are sufficient for the busiest airport. Directional guidance is obtained in any desired direction with all the advantages of the previous system.

X. Acknowledgment

The authors desire to acknowledge the parts played by other Government departments and commercial organizations in lending their valuable cooperation toward this development. Special appreciation is due the Airways Division of the Department of Commerce, particularly to Capt. F. C. Hingsburg, H. J. Walls, and W. E.

Jackson, for valuable suggestions and information as to the needs and requirements for radio direction on the airways; to the National Air Transport Co., and the Pitcairn Aviation Co. for their practical testing of the beacon system; to the American Telephone and Telegraph Company for the use of their facilities at their former station WCAP; to the radio manufacturers for the development of suitable receiving equipment aboard the airplane; and to the numerous manufacturers in the aircraft industry for their active part in the development of suitable ignition-shielding equipment.

Bibliography

(1) J. Robinson, "Direction finding for aircraft," *Wireless World*, **7**, p. 475; 1919.

(2) "Wireless bearings from the air," *Wireless World and Radio Review*, **18**, 866–868; June 30, 1926.

(3) R. L. Smith-Rose, "Directional wireless and marine navigation rotating beacons," *Nature* (London), **121**, 745; May 5, 1928. *Experimental Wireless and Wireless Engineer* (London), **5**, 402; July, 1928.

(4) F. H. Engel and F. W. Dunmore, "A directive type of radio-beacon and its application to navigation," Bureau of Standards Scientific Paper No. 480, 1923.

(5) W. H. Murphy and L. M. Wolfe, "Stationary and rotating equi-signal beacons," *Jour. S. A. E.*, **19**, 209; September, 1926.

(6) Patent granted to O. Scheller, 1907.

(7) Patent on Bellini-Tosi system, 1907.

(8) J. H. Dellinger and H. Pratt, "Development of radio aids to air navigation," Proc. I.R.E., **16**, 890–920; July, 1928.

(9) F. W. Dunmore, "Design of tuned-reed course indicators for aircraft radiobeacon," *Bureau of Standards Journal of Research*, 751; November, 1928. RP28 (Research Paper No. 28).

(10) F. W. Dunmore, "Tuned reed indicators for the 4- and 12-course radio ranges," *Bureau of Standards Journal of Research*, 461; April, 1930. R. P. 160.

(11) H. Pratt, "Field-intensity characteristics of double-modulation type of directive radiobeacon," Proc. I.R.E., **17**, 873; May, 1929.

(12) H. Diamond, "Applying the visual double-modulation beacon to the airways," *Bureau of Standards Journal of Research*, 265; February, 1930. R. P. 148.

(13) H. Diamond and F. W. Dunmore, "A course shift indicator for the double-modulation type radiobeacon," *Bureau of Standards Journal of Research*, **3**, 1; July, 1929. RP77.

(14) H. Diamond and F. G. Kear, "A 12-course radio range for guiding aircraft with tuned reed visual indication," *Bureau of Standards Journal of Research*, 351; March, 1930. R. P. 154.

(15) H. Pratt and H. Diamond, "Receiving sets for aircraft beacon and telephony," *Bureau of Standards Journal of Research*, October, 1928. RP19. Also published in Proc. I.R.E., **17**, 283; February, 1929.

(16) W. H. Murphy, "Space characteristics of antennae," *Jour. of the Franklin Institute*, **201**, 411–429; April, 1926. **203**, 289–312, February, 1927.

(17) A. H. Taylor, "Variation in direction of propagation of long electromagnetic waves," Bureau of Standards Scientific Paper No. 353, 1919.

(18) R. L. Smith-Rose, "Some radio direction-finding observations on ship and shore transmitting stations," *Jour. I.E.E.* (London), 62, 7–1–711; August, 1924.

(19) R. L. Smith-Rose and R. H. Barfield, "The cause and elimination of night errors in radio direction-finding," *Jour. I.E.E.* (London), **64**, 831–843; August, 1926.

(20) H. Pratt, "Apparent night variations with crossed-coil radiobeacons," Proc. I.R.E., **16**, 652; May, 1928.

(21) H. Diamond and F. G. Gardner, "Airplane engine-ignition shielding for radio reception," *Bureau of Standards Journal of Research*, 415; March, 1930. R. P. 158.

(22) E. Z. Stowell, "Unidirectional radiobeacon for aircraft," *Bureau of Standards Journal of Research*, December, 1928. RP35.

(23) J. H. Dellinger, "Applications of radio in air navigation," *Engineers and Engineering*, **43**, 301; November, 1926; *Mechanical Engineering*, **49**, 29; January, 1927.

(24) A. Blondel, "Sur les radiophares tournants," *Comptes Rendus*, **184**, 721; March, 1927.

(25) T. H. Gill, R. L. Smith-Rose, and others, "Symposium on rotating radio beacons," *Experimental Wireless* (London), **5**, 85; February, 1928.

(26) C. B. Jolliffe and E. M. Zandonini, "Bibliography on aircraft radio," Proc. I.R.E., **16**, 985; July, 1928.

(27) C. C. Shangraw, "Radiobeacons for transpacific flights," Proc. I.R.E., **16**, 1203; September, 1928.

(28) F. H. Drake, "Radio receiving equipment with rod antenna for reception of beacon and weather service," *Aero Digest*, **13**, 717; October, 1928.

(29) "Directional radio as an aid to safe flying," papers of Seventeenth Annual Safety Congress, National Safety Council, 564; October 4, 1928; also published in *Aeronautical World*, **2**, 20; February, 1929.

(30) J. H. Dellinger, "Uses of radio as an aid to air navigation," *Jour. A.I.E.E.*, **48**, 105; February, 1929.

(31) J. H. Dellinger and H. Diamond, "Radio developments applied to aircraft," *Mechanical Engineering*, **51**, 509; July, 1929.

(32) F. H. Drake, "An aircraft radio receiver for use with rigid antenna," Proc. I.R.E., **17**, 306–319; February, 1929.

(33) "Solving the Problem of fog flying," 52-page pamphlet issued by the Daniel Guggenheim Fund for the Promotion of Aeronautics, 598 Madison Ave., New York, N. Y.

Proceedings of the Institute of Radio Engineers
Volume 18, Number 5 *May, 1930*

ENGINE-IGNITION SHIELDING FOR RADIO RECEPTION IN AIRCRAFT*

BY

H. DIAMOND AND F. G. GARDNER
(Bureau of Standards, Washington, D. C.)

Summary—*The use of highly sensitive receiving equipment on aircraft has made the problem of airplane-engine ignition shielding an important one. Ignition shielding consists of so confining the electrical fields of the ignition system that no interfering signal can be set up in the radio receiving circuits. The problem in ignition shielding is chiefly the electrical and mechanical design of the arrangement for shielding, as it is much more difficult to secure an assembly which will not adversely affect the engine ignition system than to obtain complete freedom from interference for the radio equipment.*

The Bureau has been in active cooperation with airplane engine, magneto, spark plug and cable manufacturers in an effort to develop a safe method for effecting this shielding and to make the necessary equipment commercially available. As a result of this cooperation shielding assemblies may now be purchased for use on all Wright and Pratt-Whitney airplane engines. A metallic ignition manifold is employed with high tension cable drawn through it in the usual way. The leads from the manifold to the spark plugs and the groups of leads from the manifold to the magneto outlets are enclosed in liquid-proof flexible aluminum tubing with copper braid on the outside to insure effective shielding. Each flexible tubing is suitably fitted to the ignition manifold and to the magnetos or spark plugs, as the case may be. The magnetos are provided with covers which completely enclose the distributor blocks. A single outlet permits the use of an elbow fitting for connection to the large flexible metal tubing. This elbow fitting differs for different types of engines. Outlets are provided in the elbows for the booster and ground leads. The spark plugs are of a type in which the shield is an integral part and are provided with elbows for connection to the smaller flexible metal tubing. The ignition switch is enclosed in a metal cover, the booster magneto is also covered, and the leads from the magnetos to the ignition switch and booster magneto are enclosed in flexible metal tubing. The complete assembly insures electrical safety; mechanical sturdiness; liquid-proofing of magnetos, spark plugs and ignition cable; and ease of installation and of servicing.

I. Introduction

THE INCREASING use of radio reception on aircraft for weather and navigation services has made the problem of airplane engine ignition shielding of primary importance. To obtain full operating efficiency of the sensitive aircraft radio receivers now available, it is necessary to eliminate the intense electrical disturbances set up in the radio receiving circuits by the engine ignition system. Ignition shielding consists of so confining the electrical fields of the ignition system that no interfering signal can be induced in the radio circuits.

* Dewey decimal classification: R521.

The care which must be taken in ignition shielding depends entirely upon the ratio of the interfering signal[1] in the receiving antenna to the signal required. This ratio is dependent upon the sensitivity of the radio receiver employed, the type and location of the receiving antenna and the frequency of the signal to be received. The more sensitive the radio receiver, the smaller is the signal voltage required in the antenna for actuating whatever device may be connected in the receiver output. Since the voltage of the ignition interference is fixed for a given antenna the interference-to-signal ratio is thus increased. On the other hand, assuming a fixed receiver sensitivity (hence a fixed minimum useful received signal) the interference-to-signal ratio will depend upon the length of receiving antenna and its position with respect to the interfering source. Finally, since the source of disturbance consists essentially of a group of spark transmitters of varying high frequencies, the higher the frequency to which the receiving system is tuned, the greater will be the interference-to-signal ratio.

Within the past two years it has become common practice to use a vertical pole antenna with a highly sensitive radio receiver for reception on aircraft. The requirements for ignition shielding have therefore become rigorous. To obtain effective shielding it becomes necessary to enclose the entire electrical system of the engine ignition in a high conductivity metallic shield. Therefore, the magnetos must be provided with such metallic covers as will completely enclose the distributing heads. The booster magneto must also be enclosed in metal. All distributing wires must be covered with a metal tube or braid. The spark plugs must be completely shielded. The booster leads, the leads to the ignition switch, and the ignition switch itself, must also be shielded.

II. Requirements for a Practicable Shielding Assembly

The enclosure of the high-voltage electrical system of the ignition in a closely surrounding grounded metallic casing introduces certain problems of electrical and mechanical design. It is much more difficult to secure an arrangement which will not adversely affect the engine ignition system than to obtain freedom from ignition interference for the radio equipment. The factors which enter into the design of a safe and practicable shielding assembly may well be stated at this point.

(1) Reliability of engine performance is the first consideration. The shielding must be such as to prevent insulation breakdown of any of the component parts of the ignition system. Full provision for the protection of the component parts from the effects of oil, gasoline, and

[1] When the engine is unshielded.

water should be made. Mechanical protection of the ignition cable and other parts is necessary.

(2) Shielding of an effective and permanent nature is the second consideration. The effectiveness of the shielding should not decrease with service. This requires a mechanically sturdy assembly.

(3) The shielding assembly must be satisfactory from an operating point of view. Servicing of the spark plugs and magnetos should be

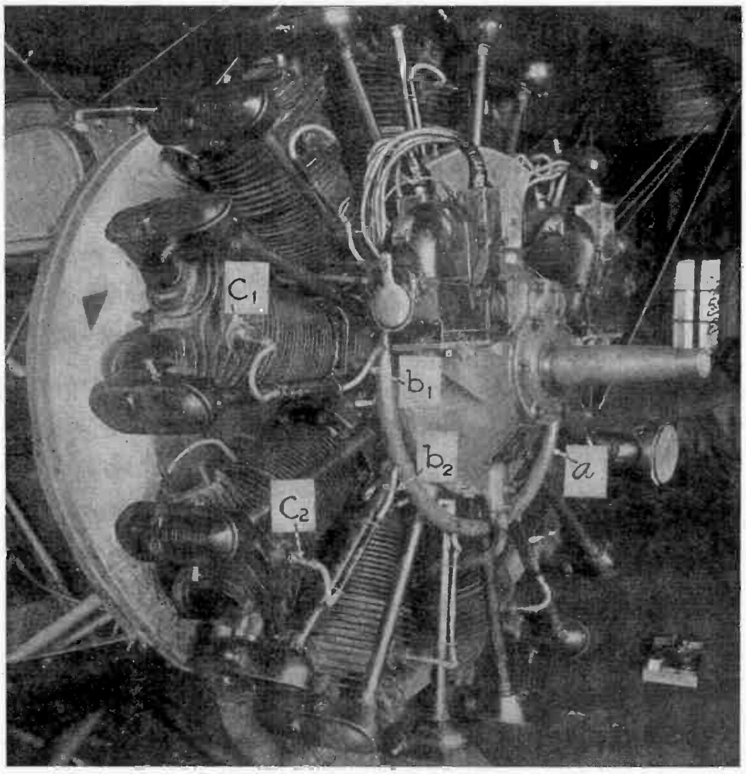


Fig. 1—Early shielding installation on Wright J-5 airplane engine.

possible with a minimum of effort on the part of the operating staff. Replacements of individual leads or groups of leads should also be possible. Ordinary replacements should in no way affect the efficiency and completeness of shielding.

(4) In addition to the above considerations, it is important that the component parts of the shielding be simple in their manufacture in order that the cost of radio shielding shall not be prohibitive.

This paper describes the experimental work carried on at the Bureau of Standards toward the development of a satisfactory and safe shielding assembly. Active cooperation was maintained in this problem with other Government departments, with manufacturing concerns and research organizations in the aircraft and radio industries, and with several air transport companies. The final shielding assembly shown in Figs. 17 to 21 inclusive, which gives promise of fulfilling all the requirements for safe shielding, is a result of this cooperation.

III. Descriptions of Bureau's Work

The Bureau first became interested in the problem of ignition shielding in the winter of 1926–27, during the course of experiments on two-way radiotelephony between aircraft and ground. However, the airplanes used in these experiments were equipped with water-cooled Liberty engines and little difficulty was had in shielding these engines, a satisfactory shielding arrangement having already been developed by Army Air Corps engineers. Owing to the shape of this type of engine and of the cowling employed, shielding of the spark plugs was not required. A few months later when it became necessary to provide shielding for transport airplanes equipped with radial type air-cooled engines, the situation was found to be entirely different. It became apparent that the price which would have to be paid for the use of radio receivers having the necessary sensitivity to make a vertical pole antenna feasible, was the screening of the spark plugs. Such work as had previously been done on the shielding of radial type engines had resulted in shielding installations hardly practicable for use on commercial transport airplanes. The Bureau undertook to develop a suitable shielding assembly.

1. Early Shielding Assemblies

Several experimental installations were made in order to determine specifically the amount of shielding necessary and the nature of the technical difficulties encountered. The installation shown in Fig. 1 on a Wright J-5 engine represents the first one considered at the time sufficiently practicable for transport use. For the purpose of mechanical protection of the high-tension distributing leads, the original ignition manifold (a) supplied with the engine was retained. Each distributing lead (b_1, b_2, etc.) was separately shielded with closely woven copper braid and threaded through the manifold. The method of connecting the distributing leads to the shielded spark plugs (c_1, c_2, etc.) may be seen in Fig. 1 and in somewhat better detail in Fig. 2. Fig. 1 also shows the method employed for shielding the magnetos. The distributor blocks were individually covered with metal cans accurately fitted to the magneto castings to within 0.005 inch. Hand-made covers using thin copper sheeting were employed to obtain a closer fit to the

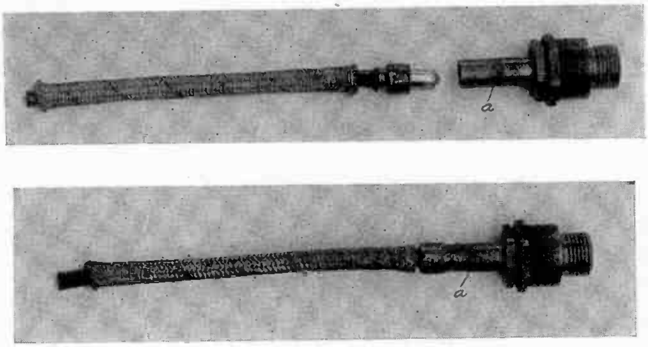


Fig. 2—Early type shielded spark plug.

irregular magneto surfaces than was possible with the cast aluminum covers commercially available at the time (see Fig. 3). The shielded

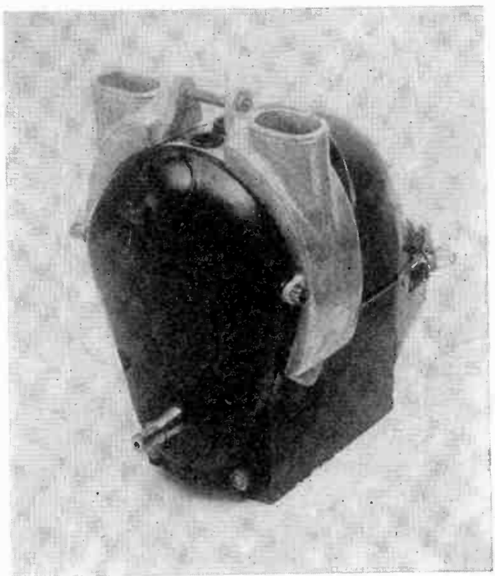
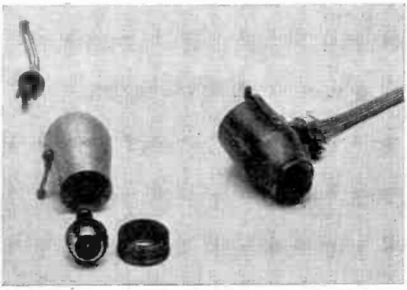


Fig. 3—Early type shielded magneto.

spark plugs used were of a type developed jointly by the Navy Department and the B. G. Spark Plug Corporation, with the shield incorporated as an integral part of the spark plug. These were adopted after considerable experimental work with metal covers for screening the plugs. Two types of shielding covers, Figs. 4a and 4b were employed in the preliminary experimental installations with successful results insofar as radio shielding was concerned. However, totally enclosing the



Figs. 4a and 4b—Metal covers for shielding spark plugs.

spark plugs had resulted in their operation at temperatures in excess of normal.

To obtain effective shielding it was found necessary to enclose the ignition switch in a shielding can, as shown in Fig. 5. Covering the

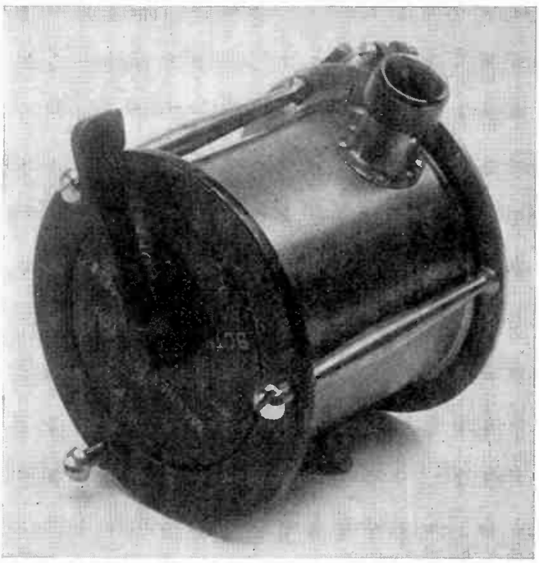


Fig. 5—Completely shielded ignition switch.

terminal block of the booster magneto and shielding the switch and booster leads by means of closely woven copper braid completed the installation.

From a radio point of view, the shielding installation as described above was satisfactory. Not the slightest trace of ignition interference could be heard in the head telephones when using a radio receiver having an overall voltage amplification of about 1,000,000 to 3,000,000. Practical difficulty was, however, experienced with this assembly. The magneto and spark plugs were not sufficiently protected from water. Short circuiting of the spark plugs and of the magneto distributors during rain occurred, and the overall assembly was too frail mechanically. The method of connecting the distributing leads to the spark plugs introduced sharp bends in the leads exactly at their points of greatest exposure. Oil and dirt collecting on the metal braid at these points rendered the braid brittle. Whipping of the leads in the propeller slip-stream resulted in breaks in the braid and in consequent decreasing effectiveness of shielding as well as in potential points of insulation breakdown.

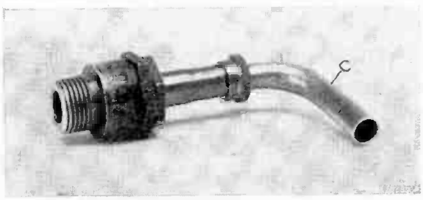


Fig. 6—Shielded spark plug provided with elbow fitting to insure liquid-proofing.

Finally, the shielding assembly was faulty from the point of view of electrical design. As each lead was individually shielded, the capacitance per lead was from 400 to 500 $\mu\mu$f as compared with 80 to 100 $\mu\mu$f for the lead unshielded. While a capacitance of 400 to 500 $\mu\mu$f will not normally affect the magneto voltage sufficiently to interfere with the engine ignition, this is not necessarily true under certain abnormal conditions. Breaking of the small wires of the shielding braid, either in manufacture or in use, served to destroy the lacquered finish on the surface of the high-tension cable and produced points of brush discharge due to the interior current of the cable. The abrasive action of the metal braid on the cable also tended to injure the lacquered finish. This finish is necessary to protect the rubber of the cable against corona ozone that otherwise tends to destroy the rubber rapidly. The same film of lacquer protects the rubber against the effects of oil and moisture. With the lacquered film injured, faulty ignition occurred. The method of insulating the lead-in wires to the shielded spark plugs was also found to be unsatisfactory. Thin mica sheeting rolled in the form of cigarette tubes served as an insulating wall within the metal stem (*a*) of the spark plug, Fig. 2. Flaking of the mica when taking the plugs apart for installation or inspection resulted in short circuits to the metal wall of the stem.

To provide better protection against rain for the spark plugs and magnetos the arrangements indicated in Figs. 6 and 7 were adopted. The aluminum elbow (*c*), Fig. 6, was flanged so that with the knurled nut screwed tight, sealing of the spark plug against moisture was

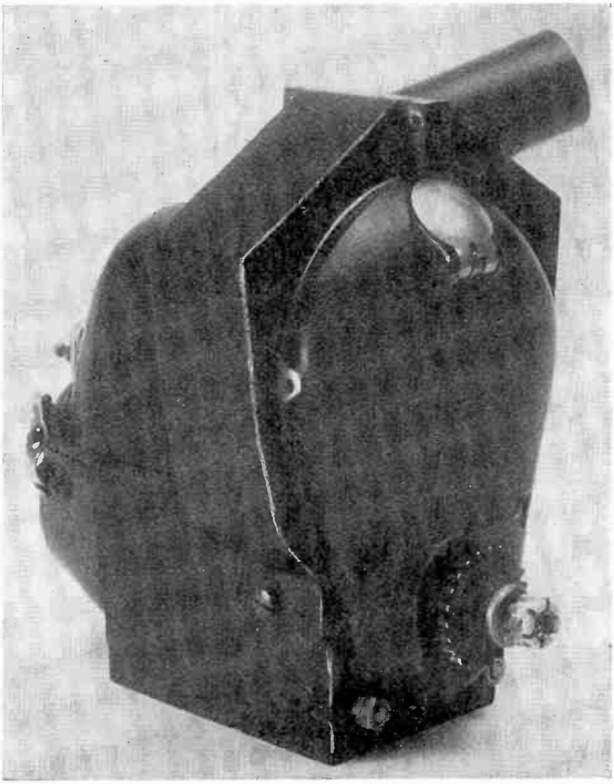


Fig. 7—Completely shielded magneto with single outlet for the ignition distributing leads. Liquid-proofing is assured by this arrangement for shielding.

effected. The elbow also served as mechanical protection for the ignition leads at their points of maximum exposure. Whipping of the leads in the propeller slip-stream was thereby prevented. The magneto distributing heads, Fig. 7, were totally enclosed, a single outlet being provided for the nine ignition distributing leads. In addition to providing complete liquid proofing this also improved the shielding of the booster and switch leads.

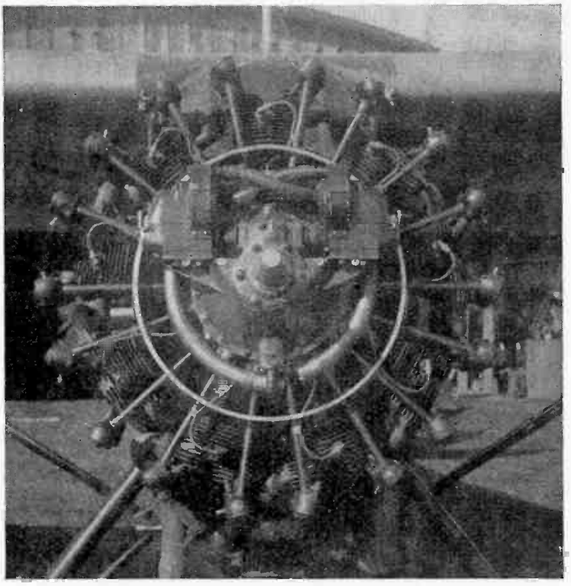


Fig. 8—Early shielding installation on Wright J-5 airplane engine. A special shielded ignition distributing harness is here employed.

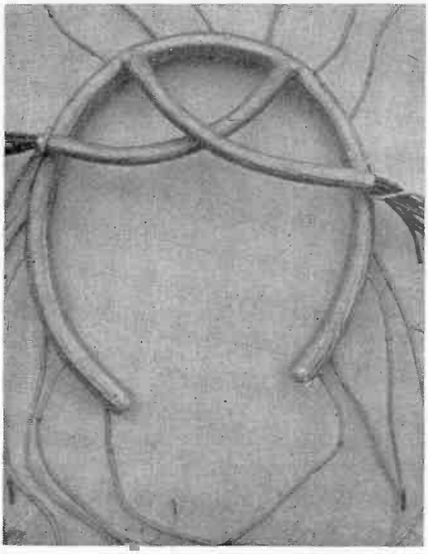


Fig. 9—Shielded ignition distributing harness used in installation of Fig. 8.

Simultaneously with this development, a second shielding installation was made on the Bureau's experimental airplane (also

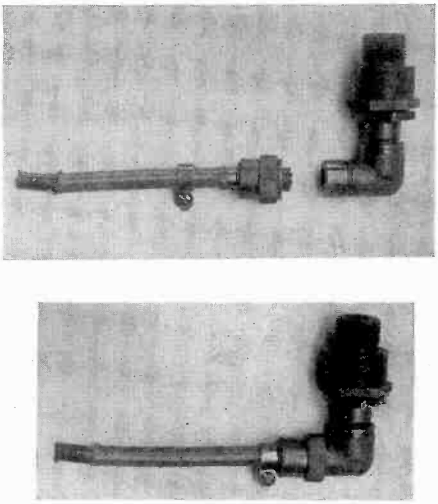


Fig. 10—Elbow type shielded spark plug used in installation of Fig. 8.

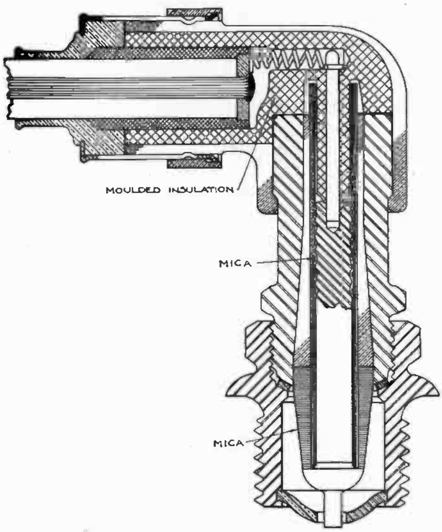


Fig. 11—Diagram showing cross-section of elbow type shielded spark plug.

equipped with a Wright J-5 radial-type air-cooled engine). A photograph of this installation is shown in Fig. 8. A complete ignition harness, developed through the cooperation of the Belden Mfg. Co., (see Fig. 9) was employed with the leads grouped together in a common ring. The nine leads to each magneto were also grouped. A closely woven copper shielding braid surrounded each group of wires, liquid-proof loom being used as a cushioning fabric between the groups of wires and the copper braid. Braiding the individual leads from the ignition harness to the spark plugs was still employed. The grouping of the leads and the use of shielding braid around the groups rather than on individual leads relieved consideraly the added dielectric

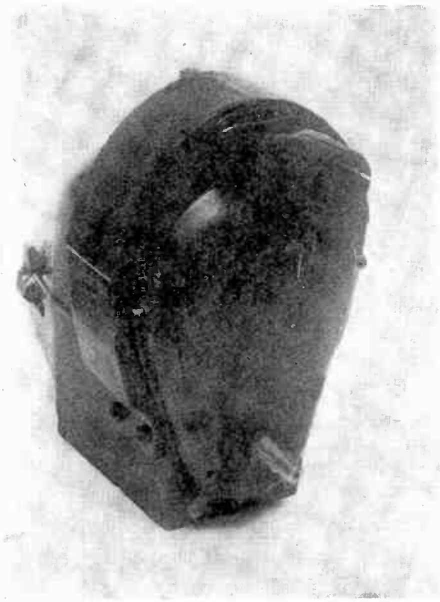


Fig. 12—Completely shielded magneto used in installation of Fig. 8 with side entrance for the ignition distributing leads.

stress on the ignition cable due to shielding. It also served to decrease the capacitance to ground of each ignition lead, an average value of 160 $\mu\mu$f per lead being obtained as compared with 400 to 500 $\mu\mu$f per lead in the other type of installation.

The shielded spark plugs used were of an improved type, the B. G. Corporation having modified their early design in order to incorporate the features found essential in the Bureau's tests. A photograph of the new design showing also the method of connecting the ignition lead is reproduced in Fig. 10. The cross-sectional diagram of Fig. 11 shows the details of assembly. The feature of right-angle entrance of the ignition lead was found very satisfactory from an installation and maintenance viewpoint. It was made possible after considerable experimental work on the part of the manufacturer, the provision of continuous insulation within the elbow proving particularly difficult. The type of shielded magneto employed is shown in Fig. 12. For conven-

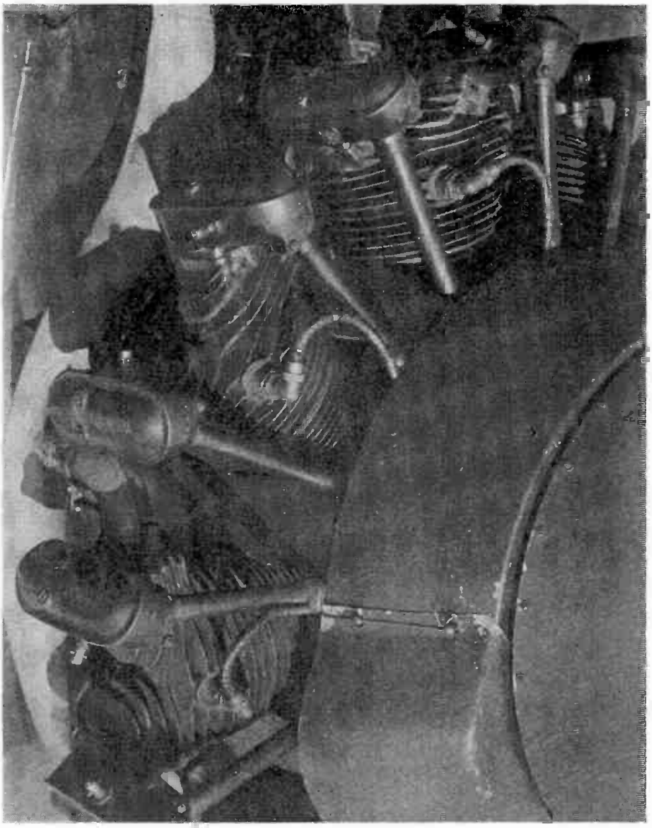


Fig. 13—Photograph showing the method used in the installation of Fig. 8 for protecting the ignition leads against the effects of oil, water, etc.

ience in installation the single outlet for the nine distributing leads was brought out on the side rather than on top of the shielding cover.

While this second shielding assembly proved somewhat more durable in service than the first type described, the wire braid over the portions of the ignition cable from the shielding harness to the spark plugs continued to be a source of trouble. The braid acted like a wick to hold oil or water and to lead it along the cable to the spark plugs. Sealing the spark plugs against moisture proved difficult. The oil held in contact with the rubber insulation of the cable rapidly deteriorated the rubber, whenever the lacquered film was broken, and caused faulty ignition. It was found necessary to replace the ignition harness after only thirty hours of operation. By winding oil tape over the shielded wire (see Fig. 13) the life of the second harness was increased to about fifty hours.

The necessity for replacing the complete ignition harness because of faults developing in several leads demonstrated that it was economically unsound to use an assembly of this type. It became evident that an important requirement for a shielding assembly was that the

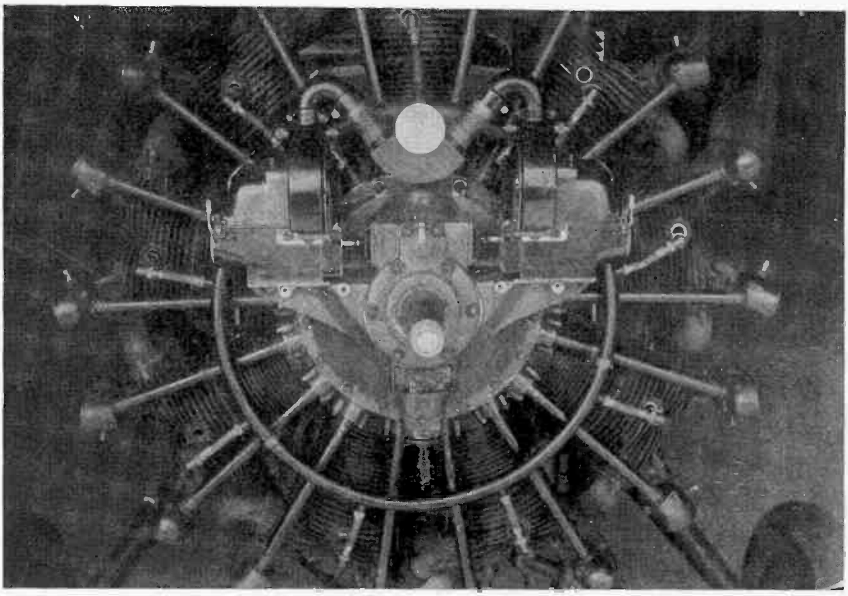


Fig. 14—Improved shielding installation on Wright J-5 airplane engine. Flexible metal tubing is used for shielding the exposed portions of the ignition cable.

individual leads should be readily replaceable. It was also apparent that some method of shielding the individual leads from the ignition manifold to the spark plugs other than by the direct application of metal braid over the high-tension cable was necessary.

2. Improved Shielding Assembly Manifold Type

At about this time a cooperative program on ignition shielding was begun with the Wright Aeronautical Corporation, the Pratt-Whitney Aircraft Company, and the Breeze Corporations. The engineers of these companies were in agreement with the conclusions drawn from the Bureau's experiments. A joint study of the situation resulted in the shielding installation shown in Fig. 14. A metal manifold ring was employed, with unshielded high-tension cable drawn through it in the usual way. To complete the shielding of the ignition leads from the manifold to the spark plugs, each lead was enclosed in a liquid-proof flexible aluminum tube, which was provided with a threaded fitting at one end for attachment to the manifold and with a cap fitting at the other end for attachment to the shielded spark plug. The groups of leads from the manifold to the magneto outlet were similarly enclosed in flexible aluminum tubing of proper size. This larger tubing was connected to the manifold through a suitable union box and to the

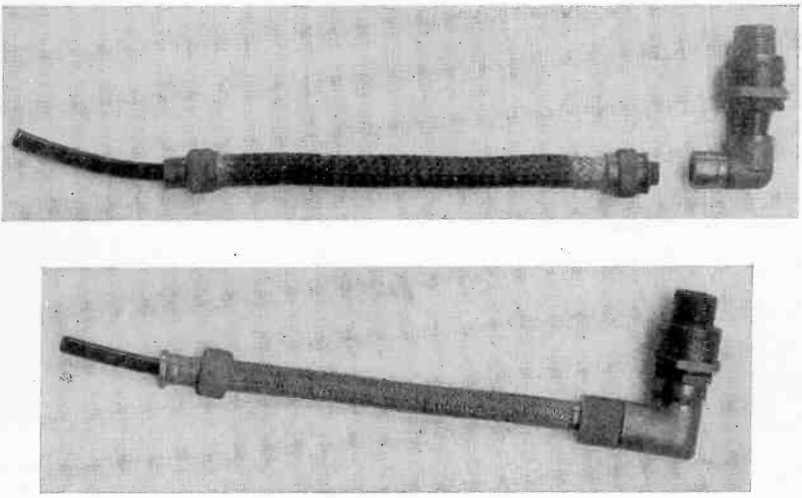


Fig. 15—Photograph showing arrangement for connecting the flexible meta tubing to the elbow type shielded spark plug.

shielded magneto by means of an elbow fitting. To insure efficient shielding, it was desirable to surround the flexible tubing with closely woven copper braid.

The shielded spark plug used was of the B. G. elbow type. The method of connecting the flexible aluminum tubing to the spark plug may be seen in Fig. 15. Servicing of the spark plugs is obviously very easy.

The magneto shielding employed, Fig. 16, was developed through the cooperation of the Scintilla Magneto Company. The feature of complete liquid proofing, found desirable in the Bureau's tests, was incorporated in this design. The irregular surfaces of the magneto which had made liquid proofing difficult in the experimental models, Figs. 7 and 12, were eliminated by the use of new castings, special grooves being provided in these castings to insure a liquid-tight joint for the shielding covers. A split shielding cover with an auxiliary elbow fitting was adopted, making possible the inspection of either distributor block without removing the cover from the other block. This also permitted the use of different shaped elbows to suit installations on different engines. The small outlets (a_1, a_2) for the leads to the booster magneto and the ignition switch were also split. An inspection of the magneto is thus possible without the necessity for disconnecting a single lead.

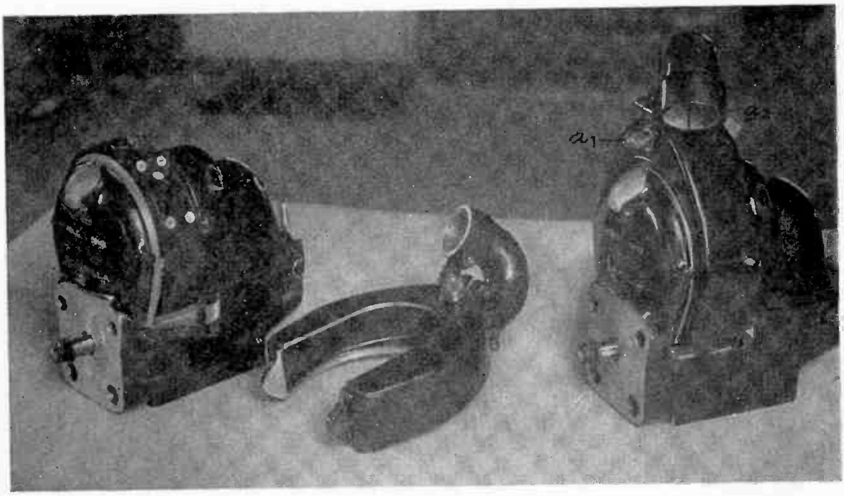


Fig. 16—Completely shielded magneto with single vertical outlet for the ignition distributing leads. A special elbow fitting is employed which may be varied to suit different installations.

The use of flexible metal tubing was extended to the shielding of the booster and switch leads, for the added mechanical protection for these leads was considered desirable.

The advantages of the manifold type shielding assembly described above are obvious. The assembly provides full mechanical protection for the component parts of the ignition system; liquid proofing of the magnetos, spark plugs, and ignition cable; and ease of installation and of servicing. The electrical design is also sound. The ignition cable is subjected to as low dielectric stress as is possible with a completely shielded system. The average capacitance per lead is comparatively small (180 $\mu\mu$f).

Two installations were made using this type of shielding, one on the Bureau's experimental airplane and one on a transport airplane.

Both gave satisfactory service with not a trace of faulty ignition. On the transport airplane, special test flights were made during rain, and satisfactory operation was had.

The success obtained with the manifold type shielding assembly led to the commercial development of an assembly having the same fundamental design. Shielding for the Wright *J-5* and *J-6* engines and for the Pratt-Whitney Wasp engines has thus become commercially available. Several improvements over the Bureau's design are of interest. Fig. 17 is from a photograph of the commercial product for

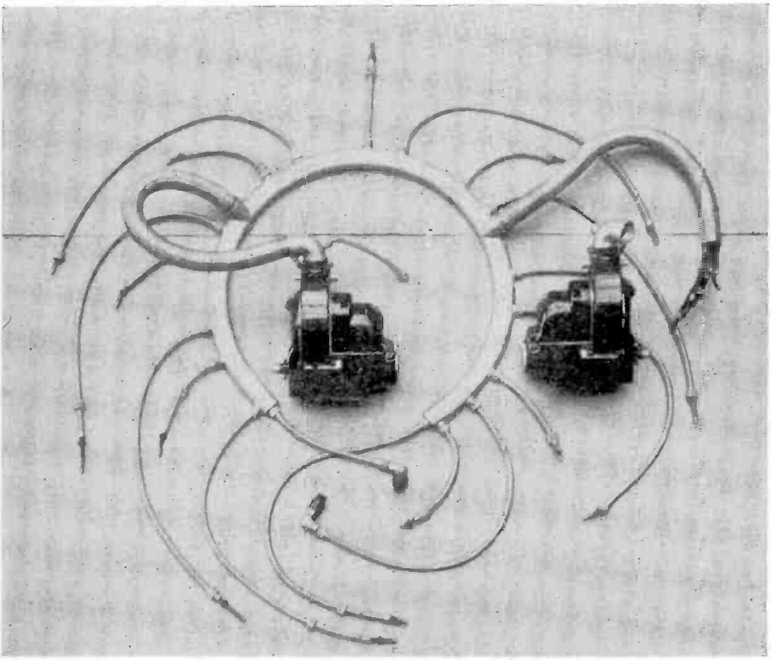


Fig. 17—Commercial shielding assembly for Pratt-Whitney Wasp engine, patterned after assembly shown in Fig. 14.

a Pratt-Whitney Wasp engine. Note that the union box for connecting the large flexible metal tubing to the manifold ring has been eliminated. This removes the possibility of damage to the insulation of the ignition cable due to sharp edges. The elbow fitting of the shielded magneto provides outlet for the booster and switch leads which permits the use of the convenient arrangement shown in Fig. 18 for shielding these leads. The shielded spark plugs shown in Fig. 17, and in greater detail in Fig. 19, differ from the B. G. elbow type in the manner in which the insulation within the elbow is provided. Instead of molding the insulation within the metal elbow, a nickel-plated isolantite elbow is used. Either type of shielded spark plug may be employed in the assembly of Fig. 17. Since weight is an important

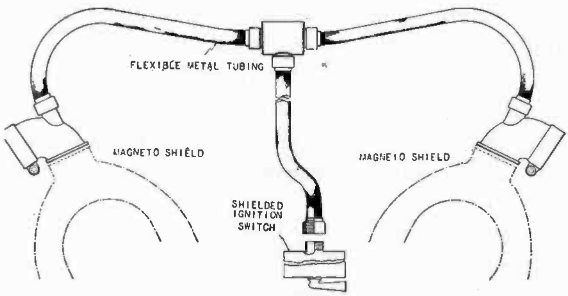


Fig. 18—Diagram showing the use of flexible metal tubing for shielding the booster and switch leads.

consideration in the design of equipment for aircraft, it is interesting to note that the weight added to the ordinary ignition assembly in order to provide complete shielding as well as liquid proofing, is but five to six pounds.

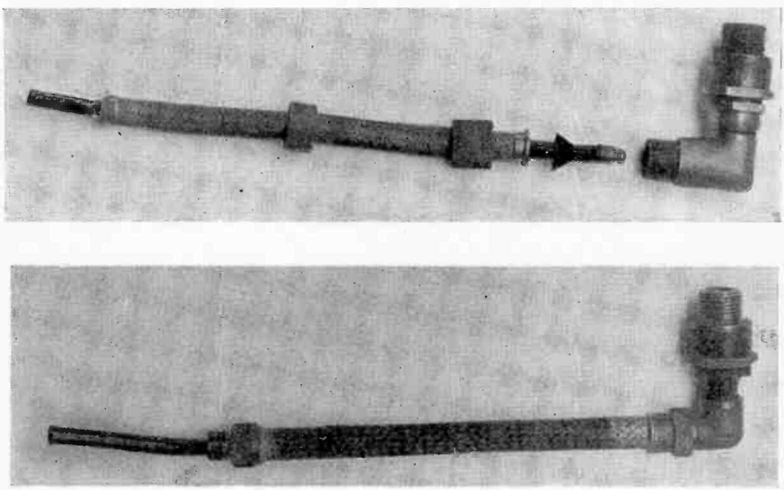


Fig. 19—Elbow type shielded spark plug using nickel-plated isolantite elbow. Note the arrangement for sealing the spark plug against moisture.

Fig. 20 shows the installation of a shielding harness of the commercial type on the Bureau's experimental airplane, which is now equipped with a Wright *J-6* engine. The shielding of the booster and switch leads is shown in Fig. 21. The shielded ignition switch is not shown.

IV. Bonding of Aircraft—Shielding of Auxiliary Electrical Apparatus

Additional sources of disturbance exist on aircraft other than the engine ignition system. Ineffective bonding of the airplane is often the cause of interference with the radio receiving apparatus. *Bonding* is the inter-connection of all metal parts of the aircraft by means of electrical conductors. If bonding is not provided, noises may be produced in the radio receiver due to sparks occurring between two metal members having a difference of potential due to the collection of static charges. Varying resistance between rubbing or vibrating metal parts is also a cause of noises in the radio receiver.

Fig. 20—Installation of the commercial type shielding assembly on Bureau's Wright J-6 airplane engine.

Complete specifications for bonding are given in Technical Order No. 08-5-1, Office of the Chief of Air Corps, War Department, Washington, D.C.

A certain amount of noise in the radio receiver output may result owing to commutator sparking of the generator used for battery charging or for supplying power to transmitting apparatus and receiving apparatus on aircraft. The sparking of the vibrating type voltage regulators used with these generators is an additional source of disturbance. Wherever possible, any piece of apparatus in which a spark occurs should be completely enclosed in metal. A photograph of a shielded generator and control box is given in Fig. 22. Completely enclosing the generator is not sufficient, since the disturbance may be carried by way of the leads from the generator. This requires

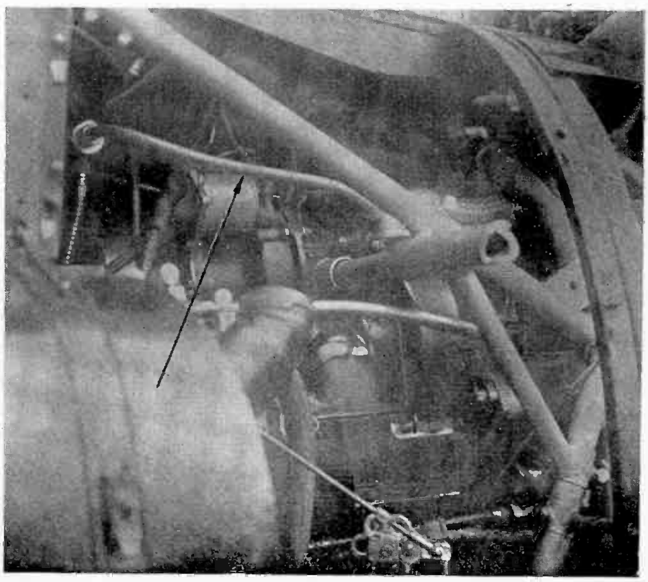


Fig. 21—Photograph showing the arrangement employed for shielding the switch and booster leads.

shielding of all the leads. If the generator serves as a source of supply for the receiving equipment, suitable filter units must be employed in addition, to keep the commutator noises out of the radio receiver.

Further information on this subject may be obtained by reference to mimeographed notes* on the "Minutes of conference on airplane engine ignition shielding held at the Bureau of Standards, June 11, 1929." This conference was called by the Bureau of Standards in response to a number of requests from representatives of the aircraft and radio industries. The purpose of the conference was fourfold:

* Copies of these notes may be obtained on application to the Radio Section, Bureau of Standards, Washington, D. C.

(1) To coordinate the experience and knowledge of the numerous organizations interested in this problem.

(2) To formulate the requirements essential to safe shielding.

(3) To stimulate the standardization of shielding assembly practice.

(4) To set up standard tests whereby the mechanical, electrical, and radio efficiency of a given shielding installation may be determined.

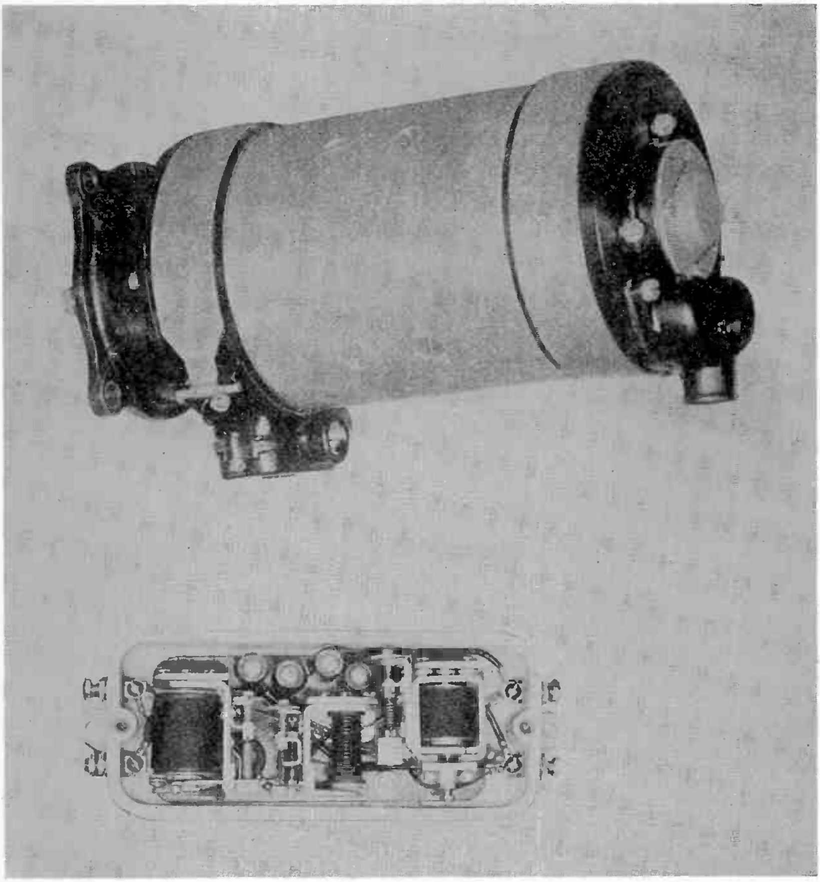


Fig. 22—Completely shielded double-voltage generator and control box.

V. Tests for Practicability of Shielding System

It is to be emphasized that the manifold type of shielding assembly described in this paper is not necessarily the only practicable solution of the problem of ignition shielding. The problem may be approached from numerous angles, so that other solutions entirely as practicable are possible. For this reason a set of standard tests was tentatively adopted at the conference on ignition shielding whereby the practicability of any shielding assembly, no matter of what type, may be determined. These tests are outlined below. The usefulness of these tests is now under investigation.

1. Test for Shielding

The best test for radio shielding is the actual use of the shielding assembly mounted on the airplane engine. The radio receiver must be suitably installed on the airplane, with an antenna of at least 6 feet extending vertically above the fuselage, and must be adjusted to maximum sensitivity. The receiver should have an overall voltage amplification of the order of 1,000,000 to 3,000,000. If the shielding is complete, no ignition noise should be heard in the headphones (connected in the output of the receiver) for all engine speeds and for all tuning adjustments of the receiver. In this test it is understood that the engine is functioning normally in every way, i.e., spark plug gaps properly adjusted, etc., that the noise level in the radio receiver output due to atmospheric disturbances is normal, and that the airplane itself is suitably bonded and all auxiliary apparatus, such as generators, voltage regulators, or any other circuit wherein a spark occurs, are effectively shielded.

2. Test of Complete Assembly For Sparkover

This test with the two following should be made previous to installing the shielding assembly on the airplane engine. In this test the ignition leads are enclosed in the shielding manifold and terminate in the magneto distributor blocks with shielding covers at one end and in the shielded spark plugs at the other end. All connections between the component parts of the shielding assembly must be the same as when installed on the airplane engine. Provision should be made to ground the shielding assembly at points corresponding to grounds made when installed on the airplane engine. The magnetos are not used in this test in order to prevent damage to them. Mica insulators should be placed between the spark plug points to prevent sparking at the test voltage to be employed. A voltage of 15,000 volts effective (of 60 cycles or higher frequency) should then be applied between all the ignition wires in parallel and the ground for a period of 5 minutes. Under this condition no sparking should occur. The condition fo sparking may be determined by a sudden increase in the deflection of an indicating instrument connected in series with the above circuit. A regulating resistor is then also necessary to prevent burning out of this instrument.

3. Test for Insulation Resistance During and After Exposure

The same setup as in the previous test shall be employed, except that the mica should be removed from the spark plug gaps and provision made to protect the interior of the spark plugs from moisture. The complete assembly should be subjected to a spray of water for a period of three hours and readings of the insulation resistance of the individual leads to ground taken at intervals of one hour during this exposure. At no time should the insulation resistance of any lead to ground be less than one megohm.

4. Test for Corona

A suitable length of high-tension cable shielded in exactly the same way as the ignition leads extending from the main portion of the ignition manifold or casing to the spark plugs, and flexed at the least radius of curvature used shall be subjected to a voltage of 15,000 volts effective (60 cycles or higher in frequency) between conductor and shield for a period of two hours. Under this condition no sparking should occur.

Proceedings of the Institute of Radio Engineers
Volume 18, Number 5 *May, 1930*

THE PIEZO-ELECTRIC RESONATOR IN HIGH-FREQUENCY OSCILLATION CIRCUITS*

By
Yasusi Watanabe
(Department of Electrical Engineering, Tohoku Imperial University, Sendai, Japan)

Parts II, III, IV

Summary—*By "piezo-electric coupler" is understood a piezo-electric resonator provided with two pairs of electrodes, by which, in the neighborhood of a frequency of mechanical resonance, electric energy may be transferred from one circuit to another. As the voltage transformation ratio between primary and secondary voltages is especially important in practice, this transformation ratio is investigated somewhat fully, and some experimental results are described. It is noted that this ratio must have a negative real component in order that the coupler may act as a regenerative linking device between anode and grid circuits of a tube oscillator.*

In the study of the effects of a crystal resonator on an electric circuit in which it is placed, the application of its motional admittance circle diagram has many advantages. Some theoretical applications are, for example, made in the present paper in considering the characteristics of a piezo-electric oscillator and of a piezo-electric frequency stabilizer. Representing the crystal resonator, which is an electro-mechanical vibrator, by an electrical circuit, we can obtain the conditions for the building up of oscillations in a piezo-electric oscillator. Three types of oscillators are treated here.

The effective frequency-stabilizing action of a tube oscillator by means of a crystal resonator is considered from the point of view of the so-called "Zieherscheinung" in the case of a tube oscillator containing coupled oscillation circuits.

Part II. The Characteristics of the Piezo-Electric Coupler†

Introduction

THE PIEZO-ELECTRIC coupler, as we shall call it, consists of one piezo-electric resonator and two pairs of electrodes. One pair consists of the primary or driving electrodes and is used for the purpose of vibrating the resonator by impressing a high-frequency sinusoidal voltage upon it, and the other the secondary or generating electrodes for the purpose of producing potential difference across the secondary impedance connected to these electrodes.

* Dewey decimal classification: R214. This investigation was done in Tohoku Imperial University at Sendai, Japan, with aid from Saito Ho-On Kai (the Saito Gratitude Foundation). Part I was published in the Proceedings for April, 1930.

† *Jour. I. E. E.* (Japan), No. 466; May, 1927.

This potential difference is produced by the reaction of the piezo-electric resonator under the conditions of mechanical resonant vibration.

Such a piezo-electric coupler is used in one type of the piezo-electric oscillator.[2–8] In the following, the equivalent circuit of this coupler is treated, and the mathematically obtained results are verified with some experiments. The experiments are made by means of the high-frequency "C-R type" potentiometer, which was previously devised by the author.

THE EQUIVALENT CIRCUIT OF THE PIEZO-ELECTRIC COUPLER

Although it may appear difficult to treat theoretically the electro-mechanical coupling system shown in Fig. 24, its practically important

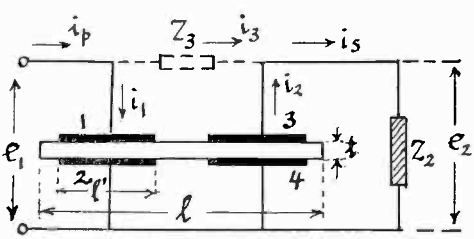


Fig. 24—Piezo-electric coupling system.

characteristics can be discussed by considering the equivalent circuit. For this purpose, the writer makes the following assumptions: (1) there is no air-gap, (2) both electrodes are of equal size and are placed symmetrically with regard to the center of the resonator, (3) the vibrating mechanical force is proportional to the vector sum of the potential difference between 1 and 2 and that between 3 and 4, and also that the mechanical forces due to the potential difference between 1 and 4 and those between 2 and 3 are assumed to be negligible. Letting e_1 and e_2 be the vector values of the primary and secondary terminal voltages, respectively, the vector value of the mechanical force which causes the resonator to vibrate is given by assumption (3), A being a constant of proportionality:

[2] W. G. Cady, PROC. I.R.E., 2, 83; April, 1922.
[3] S. L. Quimby, *Phys. Rev.*, 25; April, 1925.
[4] S. Butterworth, *Proc. Phys. Soc.*, 27, 410; 1915.
[5] K. S. van Dyke, *Phys. Rev.*, 25; June, 1925.
[6] D. W. Dye, *Proc. Phys. Soc.* (London), 38; August, 1926.
[7] E. Mallet, *Wireless World*, 16; 1925.
[8] Y. Watanabe, Denki Hyoron, January, 1926.

$$F = A(e_1 + e_2). \tag{30}$$

In the following equations, the quantities are to be considered as vectors. We let z_m, as before, represent the mechanical impedance of the resonator referred to the point of maximum velocity, that is, the mechanical impedance of an equivalent system possessing one degree of freedom, the velocity and amplitude of vibration being the same as at either end of the actual resonator, where the motion is a maximum. The maximum velocity v and the maximum displacement x are then given as follows:

$$v = \frac{F}{z_m} = \frac{A(e_1 + e_2)}{z_m}, \quad x = \frac{v_m}{j\omega}. \tag{31}$$

As before, the strain is $2x/l$, and the polarization due to the piezo-electric effect is $P = 2x\epsilon/l$.

The value of the sinusoidal e.m.f., which may be supposed to be induced inside the piezo-electric resonator under the electrodes, is given by

$$e_0 = \frac{q}{C_d} = \frac{bl'P}{\frac{kbl'}{4\pi t}} = \frac{b'\epsilon A(e_1 + e_2)}{j\omega C_d z_m}, \tag{32}$$

where $b' = 2l'b/l$, and q is the charge.

Hence we can represent the piezo-electric coupler by the equivalent circuit as shown in Fig. 25, where Z_3 is the electrical impedance between the primary and secondary circuits and may be considered as of very high vlaue.

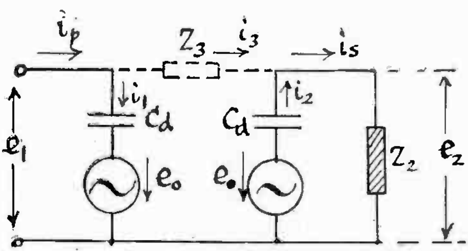


Fig. 25—Equivalent circuit of a coupler.

It must be noted in this equivalent circuit that when the piezo-electric reasonator makes its fundamental longitudinal vibration, the directions of the two induced e.m.f.'s are the same, and that when it resonates to its first harmonic vibration, their directions are opposed.

Referring to this equivalent circuit, we obtain the following simultaneous equations:

$$e_0=\frac{b'\epsilon A(e_1+e_2)}{j\omega C_d z_m}, \tag{33}$$

$$e_2=Z_2(i_2+i_3), \tag{34}$$

$$e_2+e_0+\frac{i_2}{j\omega C_d}=0, \tag{35}$$

$$e_1-e_2=Z_3 i_3, \tag{36}$$

$$e_1+e_0=\frac{i_1}{j\omega C_d}\cdot \tag{37}$$

In (33) to (37) the assumption is made that Z_2 is small in comparison with the impedance of C_d.

Solving these equations, we can easily obtain the following relations with regard to the impressed voltage e_1.

$e_0=\beta e_1$, β = induced voltage ratio,

$e_2=\gamma e_1$, γ = voltage transformation ratio,

$i_p=i_1+i_3=Y_p e_1$, Y_p = primary self-admittance,

$i_s=i_2+i_3=Y_s e_1=\left(\frac{\gamma}{Z_2}\right)e_1$,

Y_s = secondary mutual admittance.

The voltage transformation ratio is practically the most important. General solutions are given by the following equations.

$$\beta=\frac{Y_0\left(1+\frac{Z_2}{Z_3 p}\right)}{j\omega C_d\left(1+\frac{Y_0 Z_2}{p}\right)}, \tag{38}$$

$$\gamma=\frac{Z_2}{Z_3 p}-\frac{Y_0\left(1+\frac{Z_2}{Z_3 p}\right)}{Y_0+\frac{p}{Z_2}}=\frac{\frac{1}{Z_3}-Y_0}{Y_0+\frac{p}{Z_2}}, \tag{39}$$

$$Y_p=j\omega C_d+\frac{1}{Z_3}\left(1-\frac{Z_2}{Z_3 p}\right)+\frac{Y_0\left(1+\frac{Z_2}{Z_3 p}\right)}{1+\frac{Y_0 Z_2}{p}}, \tag{40}$$

$$Y_s=\frac{\gamma}{Z_2}=\frac{1}{pZ_3}-\frac{Y_0\left(1+\dfrac{Z_2}{Z_3p}\right)}{p+Z_2Y_0}=\frac{1}{p}\cdot\frac{\dfrac{1}{Z_3}-Y_0}{1+\dfrac{Z_2Y_0}{p}}. \tag{41}$$

where
$$p=1+j\omega C_dZ_2+\frac{Z_2}{Z_3},$$
$$Y_0=\frac{b'\epsilon A}{z_m}=Y_m\frac{l'}{l},$$

where Y_m is the motional admittance as given in (5). Y_m is here the motional admittance of the C_m, L_m, R_m branch in Fig. 8, as in (5), on the assumption that the electrodes cover the entire area of the quartz plate, i.e., that the length of the electrodes is equal to l. Y_0 differs from Y_m only in that it applies to the case where the plate is excited by the electrodes 1, 2 of Fig. 24, of length l', so that the motional admittance is reduced in the ratio l'/l. Considering the piezo-electric coupler from the primary side as a simple resonator, we can take the first and the last terms of (40), as the capacity admittance Y_d and the motional admittance Y_m, respectively, and it is evident that the motional admittance is appreciably affected by the secondary impedance.

In the following, we shall discuss simply two special cases:
(a) $Z_3=\infty$.

In this case, the primary and secondary circuits are coupled with each other only by means of the piezo resonator.

$$e_0=\frac{e_1Y_0}{j\omega C_d\left(1+\dfrac{Z_2Y_0}{1+j\omega C_dZ_2}\right)}, \tag{42}$$

$$e_2=-e_1\left[\frac{Y_0}{Y_0+\dfrac{1+j\omega C_dZ_2}{Z_2}}\right]=-e_0\frac{j\omega C_dZ_2}{1+j\omega C_dZ_2}. \tag{43}$$

$$i_p=i_1=e_1\left[j\omega C_d+\frac{Y_0}{1+\dfrac{Z_2Y_0}{1+j\omega C_dZ_2}}\right]. \tag{44}$$

$$i_s=i_2=-e_1\frac{Y_0}{Z_2Y_0+1+j\omega C_dZ_2} \tag{45}$$

(b) When Z_2 is very small compared with Z_3 or $1/\omega C_d$.

When the coupler is used as a piezo-electric oscillator, Z_2 corresponds to the input impedance of the tube, which is very small in comparison with $1/\omega C_d$. In this case, p is approximately equal to unity, and consequently we get

$$e_0 = \frac{e_1 Y_0}{j\omega C_d(1+Z_2 Y_0)} \tag{46}$$

$$e_2 = e_1 \left[\frac{Z_2}{Z_3} - \frac{Y_0\left(1+\dfrac{Z_2}{Z_3}\right)}{Y_0+\dfrac{1}{Z_2}} \right] \doteqdot -\frac{e_1 Y_0}{Y_0+\dfrac{1}{Z_2}}, \tag{47}$$

$$i_p \doteqdot e_1 \left[\left(j\omega C_d + \frac{1}{Z_2+Z_3}\right) + \frac{Y_0\left(1+\dfrac{Z_2}{Z_3}\right)^2}{1+Z_2 Y_0} \right]. \tag{48}$$

If $$Y_0 \ll \frac{1}{Z_2},$$

$$\left.\begin{aligned} e_2 &\doteqdot -e_1 Y_0 Z_2 \\ e_0 &\doteqdot \frac{e_1 Y_0}{j\omega C_d}. \end{aligned}\right\} \tag{49}$$

This last result is important since it expresses the fact that the generated secondary voltage depends upon the secondary impedance and upon the piezo-electric resonator.

Experiments

We now consider the experimental results with special reference to the voltage transformation ratio. These results cannot, however, be considered in a strict sense as the verification of the previous mathematically-obtained results, because the actual conditions are far from the above assumptions. But the writer thinks that they are sufficient to show the characteristics of the piezo-electric coupler.

In our experiment, we use the author's high-frequency "C-R type" potentiometer (capacity-resistance type) in order to measure the secondary voltage e_2 in magnitude and in phase relation to the primary voltage e_1. This method of measurement by means of the C-R type potentiometer is exactly the same as was employed in the experimental studies of the input admittance of a triode valve at high frequency.[9] The circuit arrangement is shown in Fig. 26.

[9] Y. Watanabe *Jour. I. E. E.* (Japan), June, 1926.

In the capacity-resistance potentiometer the capacities due to coil windings are avoided. In order to measure the ratio e_2/e_1, we balance e_2 against the potentiometer drop across C_g. Over a certain range in frequency this may be done directly (phase-reversing switch, Fig. 26, in down position). When the frequency is such that the piezo-electric reactions cause the phase relation between e_2 and the drop across C_g to assume values for which this is not possible, the switch is changed to the up position. e_2 is then balanced against the drop across L_pR_p, the phase of which can be made exactly opposite to that of the potential drop across C_g. This phase reversal is caused by the tube at the left, and L_p serves to compensate for the grid-anode capacity of the tube. The ratio e_2/e_1 is computed in terms of R_1, C_1, R_g, C_g, R_p, L_p, and the voltage amplification.

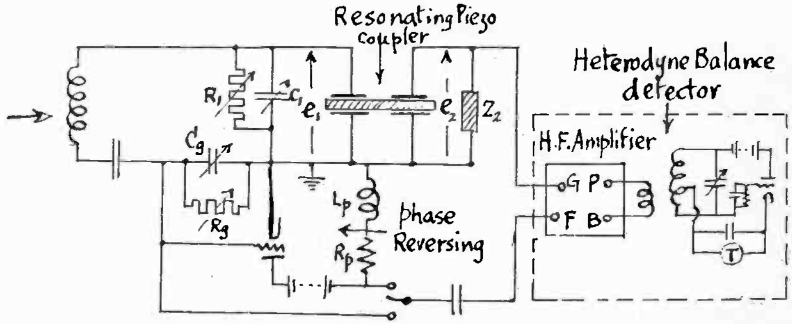


Fig. 26—Measurement by means of a high-frequency "C-R type" potentiometer.

In the design of apparatus and in carrying out this method, the following precautions must be observed: (1) the admittance of the parallel circuit C_1R_1 must be much larger than Y_p of the resonator under test; (2) the balance detector, which operates on the heterodyne principle, must be entirely shielded from the oscillator; (3) the stability of frequency of the oscillator must be extremely good, as it takes rather a long time to make one experiment.

(A) Voltage Transformation Ratio Circle Diagram.

It follows from (39) that the locus of the vectors representing the voltage transformation ratio $\gamma = e_2/e_1$, is a circle diagram when the impressed frequency is varied across the resonant frequency of the resonator. This may be seen from the fact that Y_0, like Y_m, has a circular locus, and that Z_3, p, and Z_2 are approximately constant over the small frequency range involved.

(1) The case where the resonator resonates in the fundamental mode of longitudinal vibration. Fig. 27 shows one example of the

experimental results and it represents the circle diagram for resonator No. 10, of natural frequency about 60 kc.

(2) The case when the resonator resonates in the mode of the first harmonic of longitudinal vibration. Fig. 28 shows the result obtained with the same resonator, which resonates in this case at the fre-

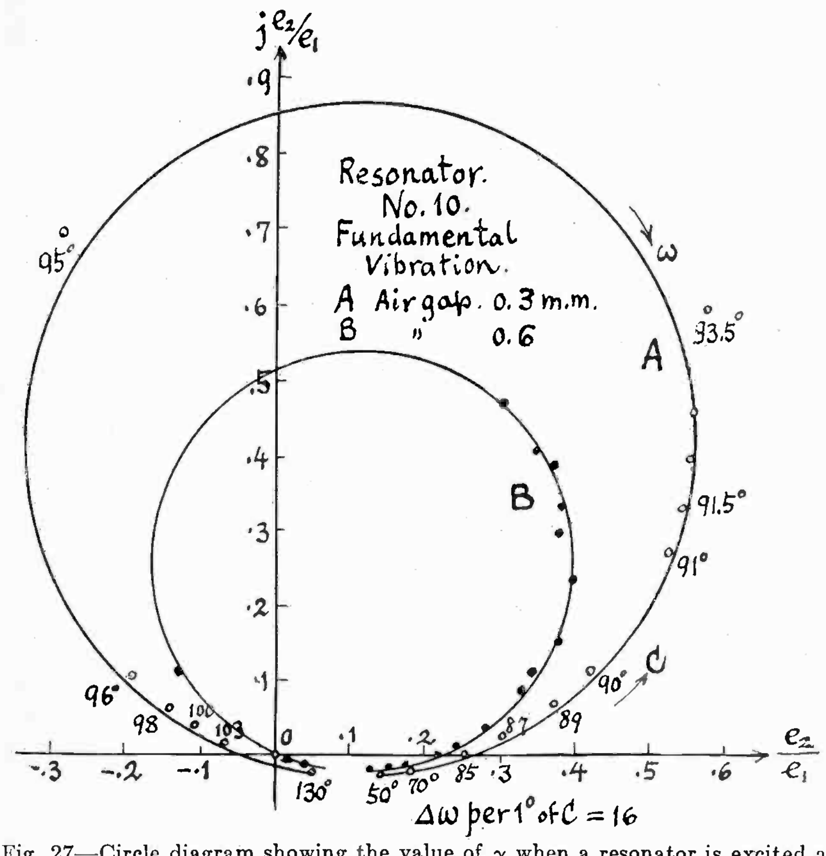


Fig. 27—Circle diagram showing the value of γ when a resonator is excited at its fundamental vibration.

quency of about 120 kc. As the induced voltage in the secondary circuit is opposite to that for the primary circuit, the circle diagram becomes opposite in phase to the previous case of Fig. 27.

Fig. 29 shows the secondary voltage resonance curve for these two cases.

It is noteworthy here that it is an important characteristic of the piezo-electric coupler that, in order to give regenerative coupling when serving as a piezo-oscillator, the γ circle diagram have a negative real component for some values of the frequency, as shown in Figs. 27 and 28. This point will be discussed more precisely in the following paragraph.

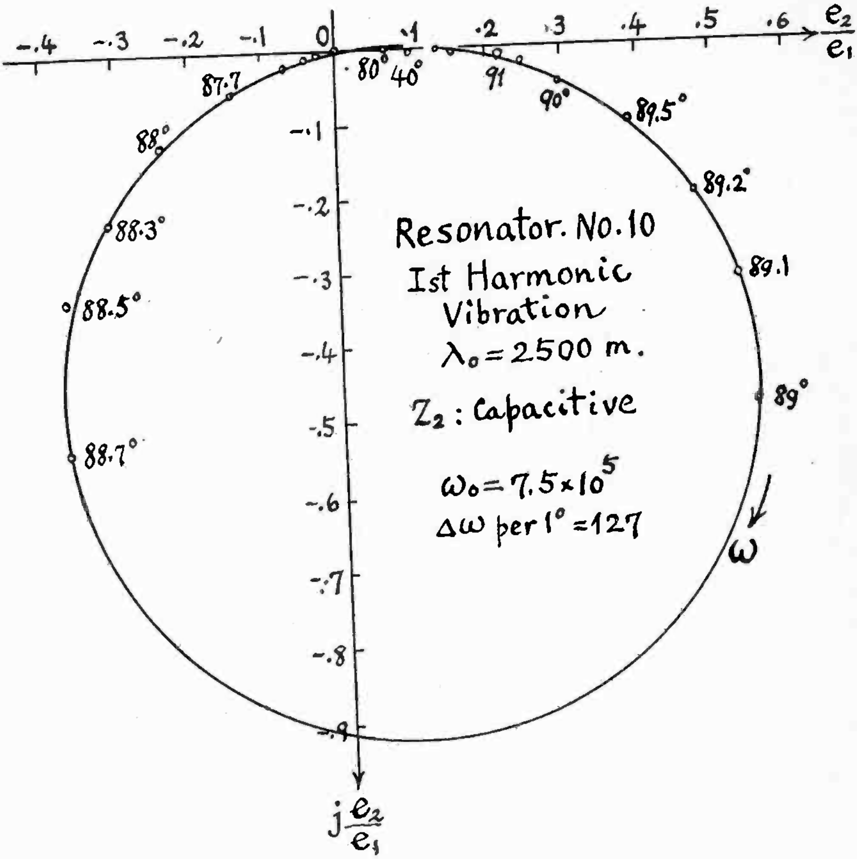


Fig. 28—Case of 1st-harmonic vibration.

(B) The Relation between Secondary Impedance and Voltage Transformation Ratio.

The object of the experiments about to be described was to investigate the dependence of e_0 and e_2 upon the secondary load Z_2, which consisted of a fixed resistance R_2 and a variable capacity C_2. The secondary voltage e_2 depends evidently upon the external secondary impedance Z_2. In the following experiment a variable condenser C_2 and a fixed resistance R_2 are connected in parallel and the frequency is kept at a constant value. The only quantity varied is C_2.

Assuming that the induced e.m.f. has a constant value given by (49), the equivalent secondary circuit may be represented by Fig. 30 where C_2 is the leakage capacity of the connecting wires.

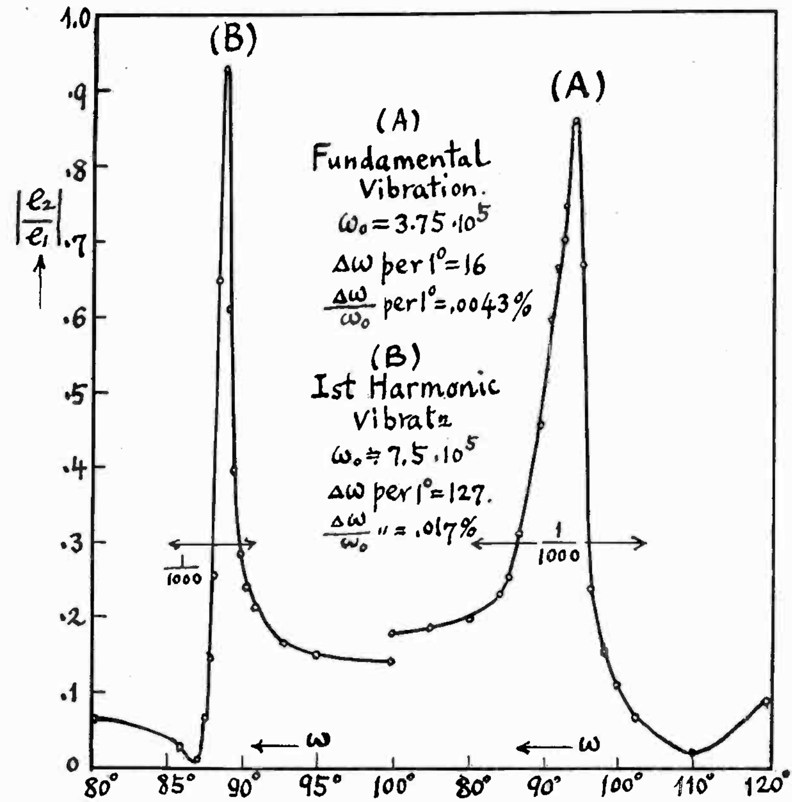


Fig. 29—Dependence of voltage transformation ratio upon frequency.

By means of the C-R type potentiometer, we can measure the variation of the voltage transformation ratio as the variable capacity C_2 is changed. As Fig. 31 shows, the locus of γ is also a circle diagram and is given by the following relation:

$$\gamma = \frac{e_2}{e_1} = \frac{e_0}{e_1\left(1 + \frac{C_2 + C_2'}{C_d} - j\frac{1}{\omega C_d R_2}\right)}. \tag{50}$$

Fig. 31 shows a part of this locus, and also the locus of the reciprocals Ob, Oc, etc., of the vectors Ob', Oc', etc. The vectors Ob, Oc, etc., will be found to terminate in a straight line bd. Upon this line we erect the perpendicular Oa from the origin. The angle θ, which the normal makes with the axis of ordinates, gives the angle of the

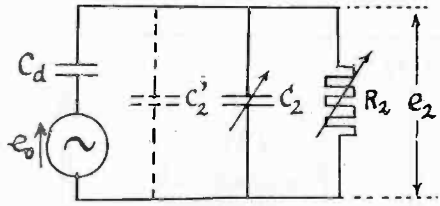


Fig. 30—Circuit for measuring the induced e.m.f. e_0.

phase lag of e_0 with respect to the primary voltage e_1, and the magnitude of e_0 is given by

$$e_0 = \frac{e_1\left(\frac{e_2}{e_1}\right)}{\omega C_d R_2}. \tag{51}$$

It is found that the relation between the length ab, ac, ... and the corresponding values of the capacity C_2 is represented by a straight

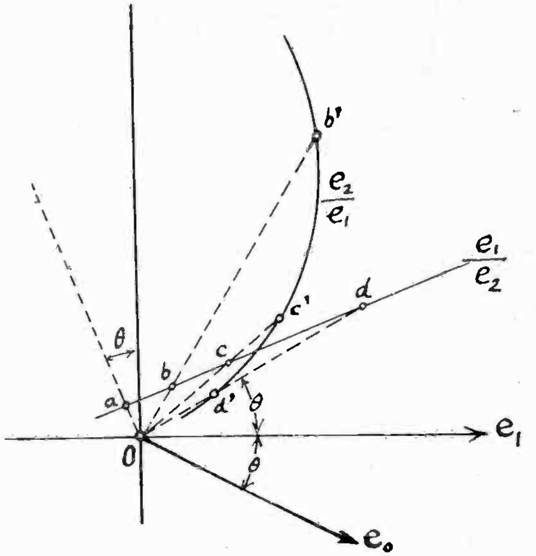


Fig. 31—Relation of γ to variable C_2.

line, which cuts the abscissa axis at $-(C_d+C_2')$, and hence we can find the value of C_2'. The inclination of this straight line is

$$\text{tg}\,\alpha = OA\cdot\omega R_2 = \left(\frac{e_1}{e_0}\right)\frac{1}{C_d}. \tag{52}$$

As an example, one result is shown in Fig. 32 for resonator No. 11, and $R_2=2000\Omega$, $C_d=2$ $\mu\mu$f. From the curve we see that $C_2'=6$

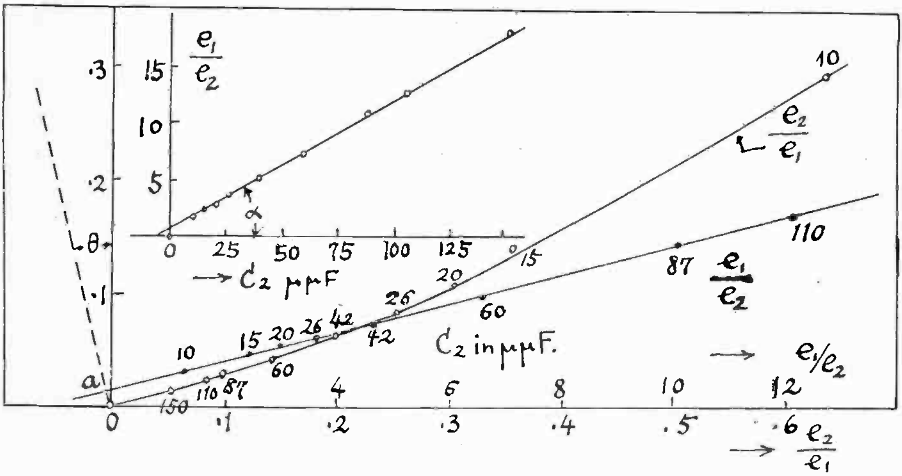


Fig. 32—Relation between voltage transformation ratio $\gamma=e_2/e_1$ and C_2. A portion of the circular locus of the vector γ as C_2 is varied is shown; also, as in Fig. 31, the reciprocal values e_1/e_2 whose locus is a straight line. On both loci the values of C_2 are indicated. The insert shows the relation between C_2 and e_1/e_2.

$\mu\mu$f and $\text{tg}\,\alpha=0.12$ $(\mu\mu\text{f})^{-1}$, and that therefore $e_0=4e_1$ in magnitude. e_0 lags behind e_1 by 15 deg.

Part III. The Piezo-Electric Oscillator*

Introduction

Piezo-electric oscillators may be classified in the following three types from the point of view of the self-oscillating action. In the first oscillator, the regenerative coupling between the plate and the grid circuits of the triode is due to the coupling action given by means of the piezo-electric coupler, the second to regenerative coupling by means of the piezo-electric resonator, and the third simply to the pulling characteristic due to tube capacity coupling.

Each type of piezo oscillator is considered with special reference to the conditions for the building up of the oscillations, and some experimental results are given in verification.

In order to find these conditions it is necessary to consider the piezo-electric coupler and resonator and also the input admittance of the triode amplifier, in which the plate and grid circuits are connected by means of some kind of impedance. The former two problems are

* *Jour. I. E. E.* (Japan), No. 469; August, 1927.

treated in the previous parts and the latter has been considered already by the author.

The constancy of frequency of oscillations produced by means of a piezo-electric oscillator is stated in the paper cited, and it is concluded that a fairly accurate constancy can be obtained by any of these types, but the oscillator of the piezo-coupler type has a comparatively appreciable variation of frequency on account not only of the tuning of the plate oscillation circuit but also of the variation of filament current.

The Piezo-Electric Oscillator of the Piezo-Electric Coupler Type

There are two methods of connecting the piezo-electric coupler to the valve oscillator, as shown by *A* and *B*, Fig. 33. It is only neces-

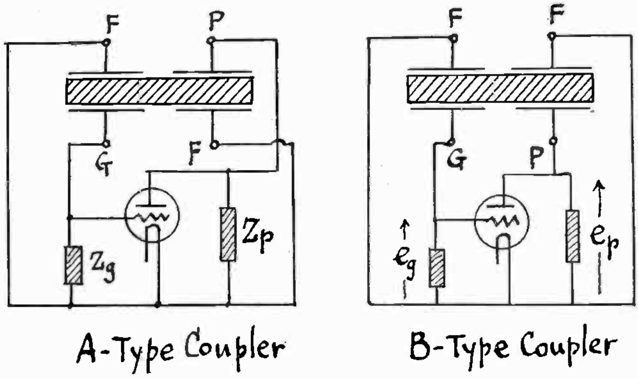


Fig. 33—Two kinds of coupling.

sary here to consider in what manner the grid voltage, e_g, which is provided by the mechanical vibration of the resonator, is related to the plate voltage, e_p, that is, to consider the voltage transformation ratio $\gamma = e_g/e_p$ of this piezo-electric coupler with respect to such tube circuit conditions as plate impedance and grid impedance.

(A) B-type Oscillator.

For most of the tube oscillator circuits, the input admittance is capacitive. For such a grid capacitive impedance as shown in Figs. 27 and 28, the voltage transformation ratio circle diagrams are represented by I and II, Fig. 34, for the fundamental mode of vibration and the first harmonic mode, respectively.

As above stated, it is an important characteristic of the regenerative coupling that it has a negative real component for some range of the frequency. Therefore, from the point of view of the ordinary regenerative tube oscillator, it becomes very easy to find the conditions for self-building-up of the oscillations.

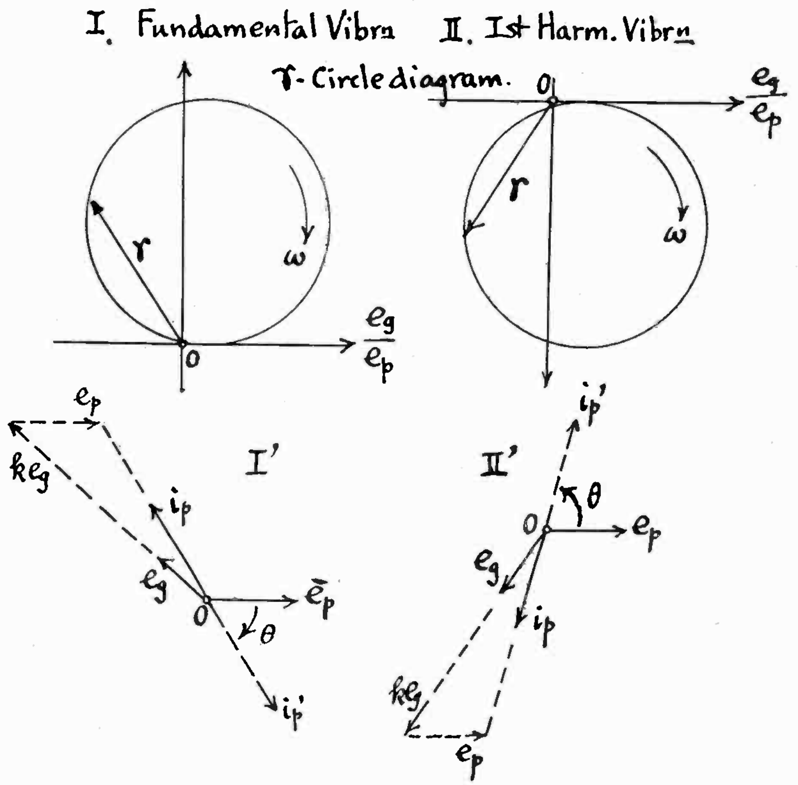


Fig. 34—Coupling: *B*-type.

The vector diagrams of Fig. 34 I′ and II′ represent clearly the relation between plate voltage, grid voltage, and plate current for these oscillators, and the condition for the building up of oscillations is simply expressed by the following equations:

$$\frac{k\gamma - 1}{R_i} = \frac{1}{Z_p}, \quad \text{or} \quad \gamma = \frac{e_g}{e_p} = \frac{R_i + Z_p}{kZ_p} \tag{53}$$

where

γ = voltage transformation ratio.
k = voltage amplification constant of the tube.
R_i = plate internal resistance.
Z_p = plate external impedance.

From this consideration, we come to the following conclusions with regard to the plate impedance of the oscillator. For the *B*-type

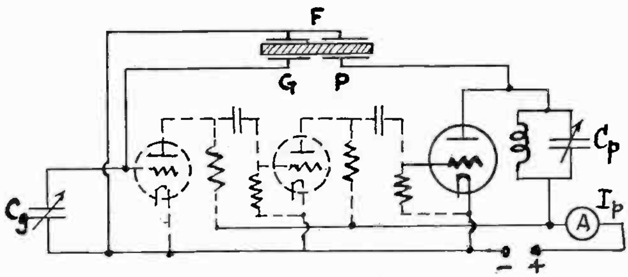


Fig. 35—Circuits for Fig. 36.

coupler oscillator with capacitive grid impedance, the plate impedance must be inductive or capacitive according to whether the piezo-

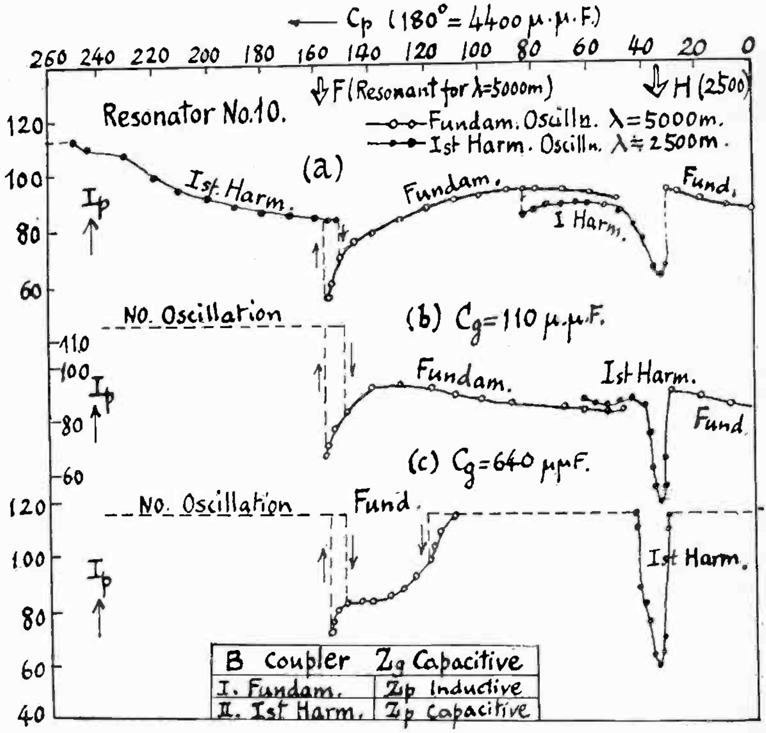


Fig. 36—Range of building-up of fundamental and 1st-harmonic oscillations.

electric resonator resonates in the fundamental or the first-harmonic mode of vibration.

This result can be verified by examination of Fig. 36. In our experiment, the three-stage resistance amplifier is used, and Fig. 35 shows the circuit arrangement. The effect of the oscillations is to decrease the plate direct-current component for this oscillator.

Referring to the resonant points F and H (Fig. 36) of the tuning condenser of the plate resonance circuit for the fundamental and the first harmonic oscillations, respectively, we see that the fundamental oscillation, which has a frequency of about 60 kc in this case, is produced only with an inductive plate impedance, while the first harmonic oscillation, of frequency about 120 kc, can build up with a capacitive impedance.

It may also be seen from this result (1) that the less the grid impedance, the less the voltage transformation ratio becomes, with the result that the oscillations can build up only when the plate circuit is near the resonant point, and (2) that when the value of the voltage transformation ratio is sufficiently large, there is a range of plate impedance within which either the fundamental or the first harmonic oscillation can build up.

(B) A-type Oscillator.

As the type A oscillator has an opposite grid phase to that of type B, the criterion for the plate impedance required for self-oscillation is that, for the piezo-coupler type oscillator with capacitive grid impedance, the plate impedance must be capacitive or inductive cor-

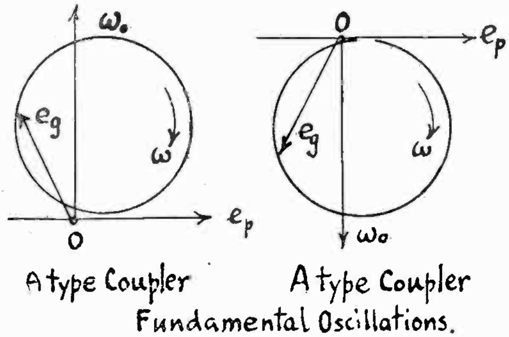


Fig. 37—Relation between natural frequency and coupling.

responding to the fundamental or the first harmonic oscillations, respectively.

It must be noted here that, as shown by the two voltage transformation ratio circle diagrams of Fig. 37, the frequencies of the fundamental oscillations generated by these two oscillators are different, that is, the A-type fundamental oscillation has a higher frequency than the resonant frequency f_0, and the B type a lower frequency than f_0.

(C) Relation between Grid Impedance and Conditions for Oscillations.

As shown by (49), the secondary grid voltage of the piezo-electric coupler has an approximately proportional relation to the grid im-

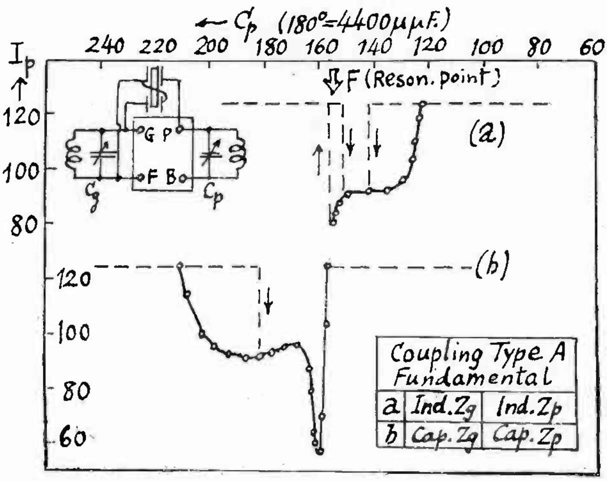


Fig. 38—Relation between building-up of an oscillation and grid circuit.

pedance, so that it may be said that the relation between the plate impedance and the mode of vibration of the piezo resonator with

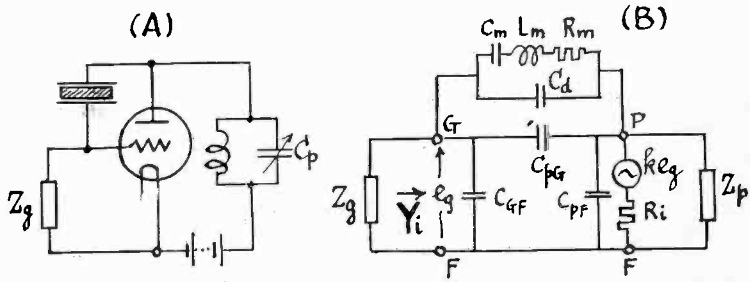


Fig. 39—Regenerative coupling by a resonator and its equivalent circuit.

inductive impedance is opposite to that for the capacitive grid impedance. This relation is clearly verified by the experimental result shown in Fig. 38.

The Piezo-Electric Oscillator with Regenerative Coupling by Means of the Resonator

In the case of a piezo-electric oscillator in which the piezo-electric resonator is connected across the plate and grid terminals, the regenerative coupling is produced as a result of mechanical resonance of

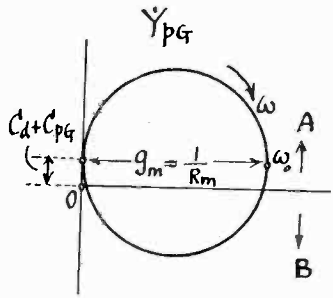


Fig. 40—Circle diagram of regenerative admittance.

the resonator. Consequently, we can consider the characteristics of this oscillator by treating its equivalent electric circuit as shown in Fig. 39. It is only necessary at present to find the conditions in order

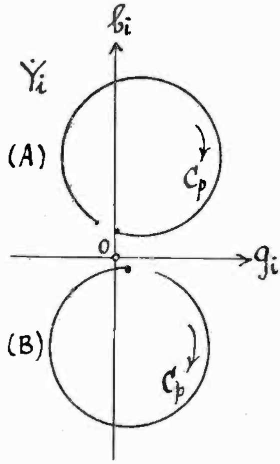


Fig. 41—Circle diagrams of tube input admittances. b_i and g_i are input susceptance and conductance, C_p is tuning condenser in plate circuit of Fig. 39. In A the coupling admittance is capacitive, in B it is inductive.

to give to the input admittance of the tube amplifier a negative conductance component.

A few years ago the writer considered, by the use of circle diagrams, the problem of the tube generator for the case where anode and grid were connected by any impedance whatever.[10,11] The results of this investigation essential to the present paper are illustrated in Figs. 40 and 41. In Fig. 40 we have the circular locus of the vectors representing the admittance Y_{pg} which couples plate to grid; the frequency is here the only variable parameter. Now, on the other hand, the circle diagram of the input admittance of the tube may be represented by Fig. 41, A and B, for the two cases where the coupling

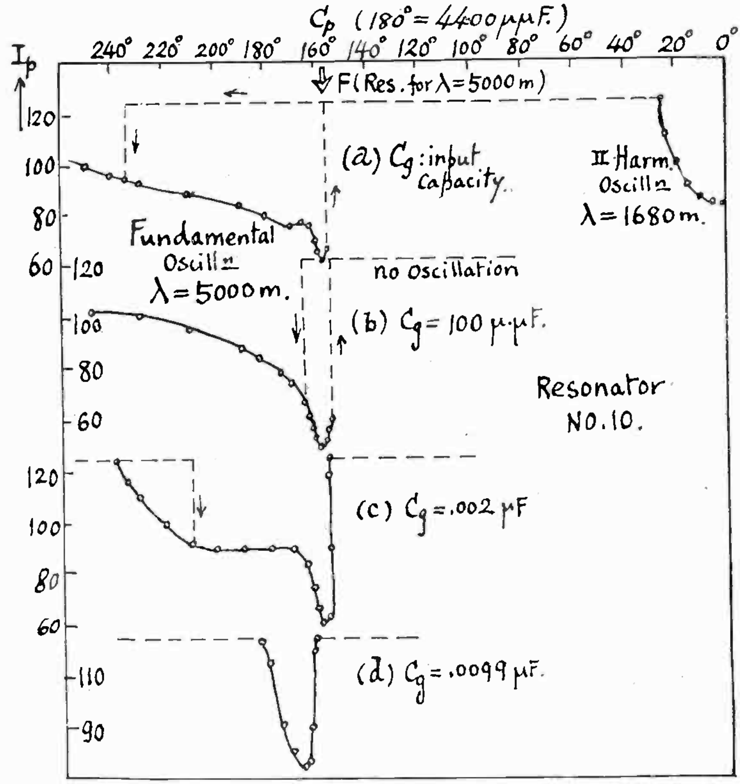


Fig. 42—Regenerative range for various anode and grid conditions.

admittance is capacitive or inductive, respectively, and the plate tuning condenser is varied.

In this figure the input admittance Y_i is as shown in Fig. 39, having components b_i and g_i. As C_p is increased, assuming the frequency to remain practically constant, being that of the crystal, the locus of Y_i is traversed in the clockwise direction. The size of the circle increases

[10] Y. Watanabe, *Jour. I. E. E.* (Japan), March, 1926.
[11] Y. Watanabe, *Jour. I. E. E.* (Japan), February, 1926.

as the coupling between plate and grid increases. Now since the maintenance of oscillations requires a certain minimum of negative input conductance, it is evident that the circle must attain a certain size before oscillations can set in. This negative input conductance must be supplied by the quartz resonator. When the crystal vibrates close to resonance on the low-frequency side, it furnishes a capacitive coupling, and if the capacitive motional admittance of the quartz is sufficiently great, and if C_p is not too large, the circuit will oscillate, the operating point being on circle A. It is also possible for the circuit to oscillate on the high-frequency side of crystal resonance, in which case the admittance of the crystal is inductive and the locus of the input admittance is circle B. C_p in this case must be greater than a certain minimum. It is, of course, essential that the damping of the crystal be much smaller than that of the tuned output circuit, so that the frequency shall be determined only to a slight extent by variations of C_d.

Through these considerations, we may come to the following conclusions for the conditions of building-up of oscillations.

(A). With inductive plate impedance and inductive grid impedance, the capacitive coupling action of the piezo resonator can make oscillations build up, the frequency of which is generally less than its natural frequency.

These oscillations may be produced even without the piezo resonator, that is, they build up by means of the electrostatic coupling due to $C_{PG}+C_d$. Therefore it is necessary to diminish this coupling in order to obtain the action of the piezo-electric oscillator.

(B). With capacitive plate impedance and capacitive grid impedance, the inductive coupling action of the piezo resonator can build up oscillations, which have a frequency higher than its natural frequency.

It is evident that this type of oscillation can be produced only by the coupling action of the motional admittance, and that it is necessary to have a sufficiently large motional admittance and to diminish the electrostatic coupling between the plate and grid circuits. The following remarks may be added with regard to thistype of piezo-electric oscillator.

(1) When the motional admittance for harmonic vibrations parallel to the Y-axis (transverse effect), or for vibrations parallel to the X-axis (longitudinal effect, which Dye calls "transverse vibrations") is sufficiently great, the oscillations corresponding to this mode of vibration may also be built up easily. For this purpose Case B, for which the grid impedance is capacitive, is well suited.

(2) In order to build up oscillations corresponding to the first harmonic vibration of the piezo resonator, we employ two pairs of electrodes as stated in Part I for the purpose of varying the mode of vibration.

(3) This class of oscillator has a fairly high constancy of frequency, as shown in the following paragraph.

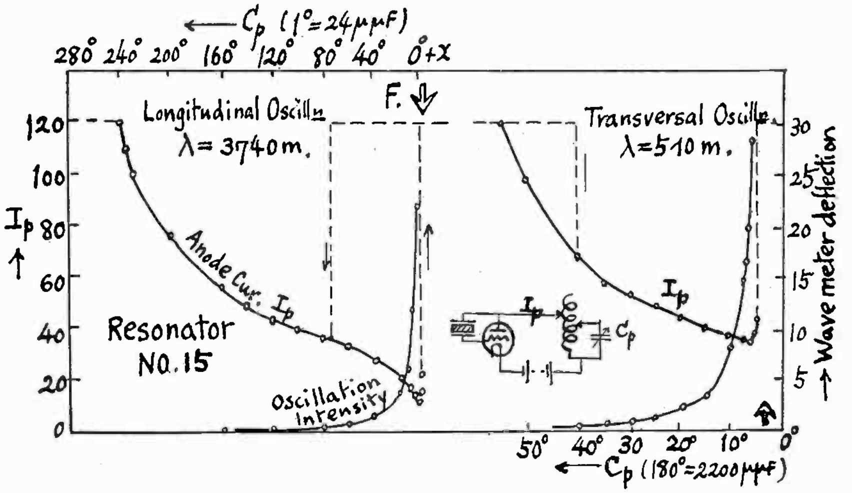


Fig. 43—Excitation of longitudinal and transverse oscillations.

Experiments

One of the experimental results is represented by Fig. 42, which shows the relation between grid capacity and plate impedance. Fig.

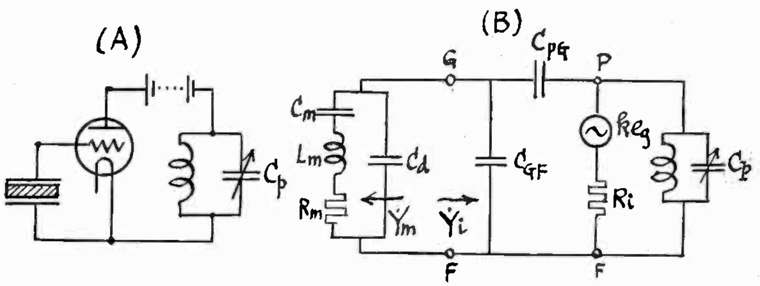


Fig. 44—Oscillation production with grid-cathode resonator and its equivalent circuit.

43 shows another result, where the oscillations correspond to vibrations of the piezo-electric resonator in the Y-direction (longitudinal) and X-direction (transverse) respectively. These results verify the above stated conditions for the case of capacitive grid impedance.

Oscillator with Piezo-Electric Resonator Connected Between Grid and Filament

The piezo-electric resonator in the oscillator shown in Fig. 44-A cannot take any part in the regenerative coupling. The regenerative coupling is due wholly to the electrostatic capacity between plate and grid, and the resonator acts as a high inductance with a very low damping constant. Consequently, it becomes a simple matter to consider the equivalent circuit of Fig. 44-B.

We represent in Fig. 45 two circle diagrams, one of which is the input admittance of the tube for variable plate tuning capacity (see Fig. 41-A), and the other is the motional admittance circle diagram of the resonator with inverted phase, for variable frequency near the resonant frequency of the resonator.

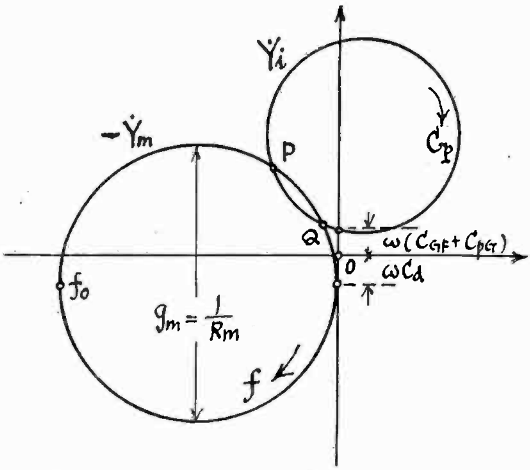


Fig. 45—Circle diagrams of input admittance and motional admittance.

Considering that these two circles must intersect in order to build up oscillations, we come to the following conclusions:

(1) The diameter of the motional admittance circle diagram must be at least larger than $\omega_0(C_d+C_{PG}+C_{GF})$. It is well known that, in some cases, an increase in the coupling capacity C_{PG} stops the oscillations.

(2) The plate impedance must be inductive, and the frequency of the oscillations produced is higher than the natural frequency of the piezo-electric resonator, because the resonator must act as an inductive impedance.

(3) It may be easily understood that, if the coupling between the plate and the grid is so inductive as to give an inductive input impedance, the oscillations are more easily built up.

This principle is also easily realized by means of a two-stage resistance amplifier, in which the output circuit is coupled to the input circuit through a suitable capacity. The writer believes that Dr.

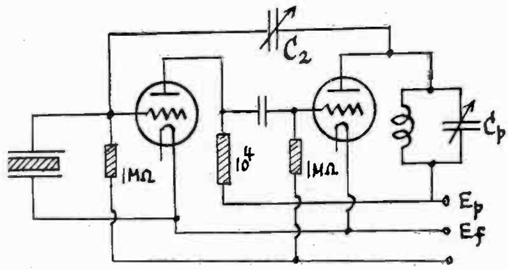


Fig. 46—Dr. Heegner's oscillator circuit.

Heegner's circuit[12] (Fig. 46) employs this principle for the production of oscillations. But it must be noted that the oscillation can be built up easily by this oscillator even without the piezo-electric resonator,

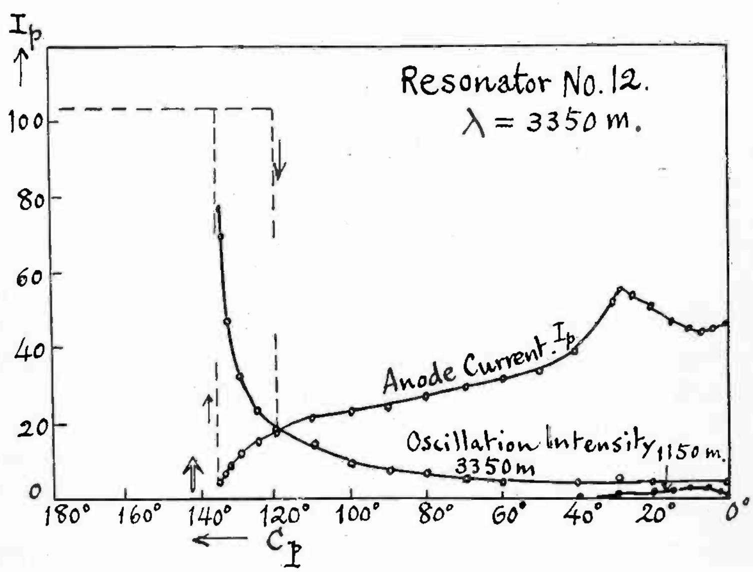


Fig. 47—Oscillating range for the oscillator of Fig. 44.

and that considering the characteristics, it may be classified as one type of piezo-electric frequency stabilizer. As an experimental verification, Fig. 47 is shown.

[12] A. Meissner, *Zeits. Tech. Phys.*, 7, 1926.

The Frequency Constancy of the Piezo-Electric Oscillator

With regard to the frequency constancy, we must notice the following topics:

(1) From the previous studies we know that the frequencies of oscillation produced by means of the various types of piezo-electric oscillators are different from one another and, of course, from the natural frequency of the resonator, according to the kind of oscillator.

(2) The natural frequency of the piezo-electric resonator itself depends upon the air-gap length, area of electrodes as shown in Part 1, and moreover it depends appreciably upon the temperature.

(3) As in the ordinary valve oscillator, the frequency depends not only upon the electrical circuit conditions, but also upon the tube conditions, such as filament heating, etc.

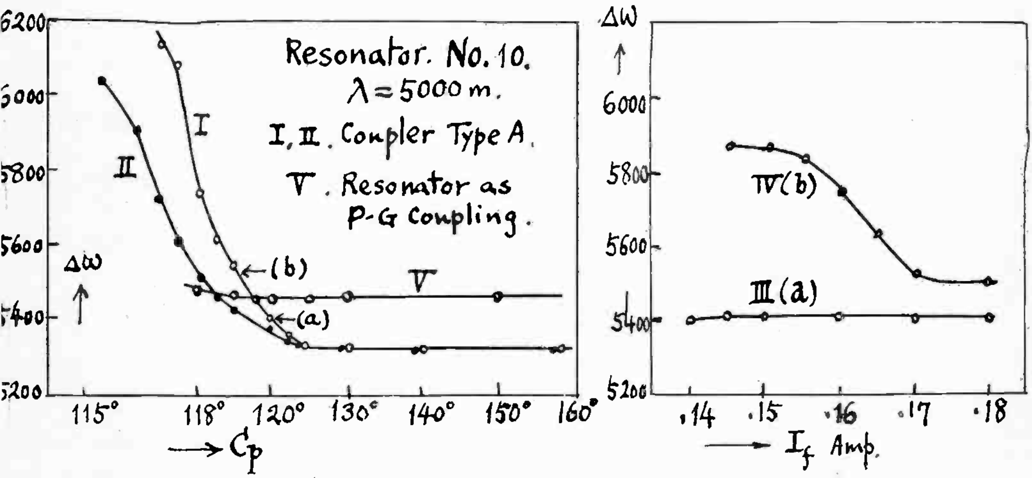


Fig. 48—Variation of frequency depending upon the anode tuning condition and filament heating.

It is ascertained experimentally that the main causes for the frequency variation are the tuning of the plate oscillation circuit and the filament temperature.

In the following paragraphs we shall consider the third topic. Although it is not difficult to treat the frequency variation mathematically, the writer shows only the experimental results. In our experiments the frequency variation of the piezo oscillator is measured by the beat method, using a constant frequency local oscillator.

The experimental results presented in Fig. 48 show the frequency variation caused by variation of the tuning for the piezo-electric coupler-type oscillator and for the plate-grid resonator coupling-type oscillator, and also the frequency variation caused by filament temperature corresponding to two points *a* and *b* of curve 1.

The next result, Fig. 49, shows the variation in frequency corresponding to the first harmonic vibration of the resonator by means of the coupler *A*-type oscillator and the plate-grid resonator coupling-type oscillator.

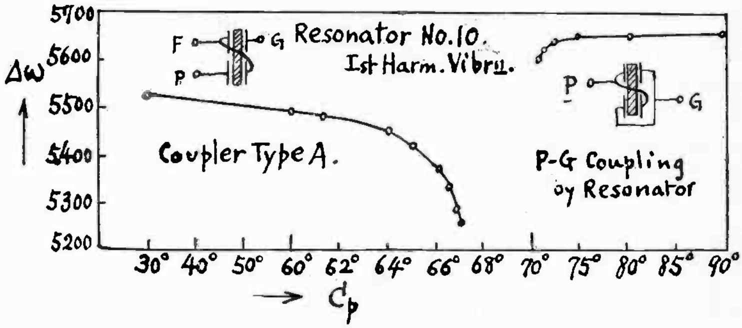


Fig. 49—Variation of frequency depending upon method of self-excitation.

From these results, we see that the piezo-electric coupler type oscillator has an unsatisfactory constancy of frequency in comparison with other types, and that when the plate circuit is detuned a little, a fairly good constancy may be attained.

Part IV. The Piezo-Electric Frequency Stabilizer*

Introduction

The frequency stabilizing action by means of a piezo-electric resonator may be explained from the well-known frequency characteristics of the "Zieherscheinung" (pulling) which takes place in the coupled-circuit tube oscillator. Although the natural frequency of the tube primary oscillation circuit may be widely changed, the frequency of the generated oscillations can be stabilized to a nearly constant value under certain conditions by means of the piezo-electric resonator, which acts as an electrostatically coupled secondary oscillation circuit. The natural frequency of this secondary circuit may be considered as constant.

This coupled circuit including the resonator may be easily represented by an equivalent electrical coupled circuit, and conversely we can determine the equivalent electrical constants of the resonator by observing the frequency characteristic curve near the resonant point.

* *Jour. I. E. E.* (Japan), No. 469; August, 1927.

The effectiveness of the stabilizing action of the resonator is shown by some experimental results.

The Stabilizing Action and the Equivalent Constants of the Piezo Resonator

It is a well-known fact that the frequency characteristics of the coupled-circuit tube oscillator are represented by Fig. 50-A and B.[13] The former shows the "Zieherscheinung" when the natural frequency

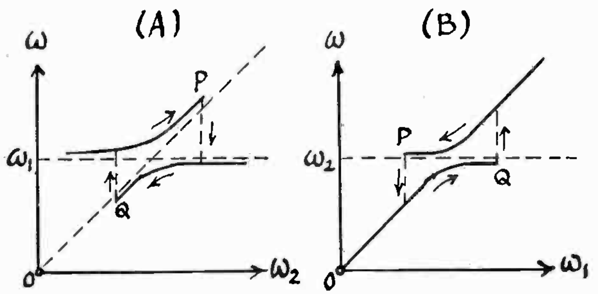


Fig. 50—"Ziehen" characteristics of coupled-circuit tube oscillator.

of the secondary circuit is varied, and the latter for the case of a variable primary oscillation circuit. In the latter case, it may be observed that the frequency of the generated oscillation does not vary appreciably near the two breaks at P and Q, notwithstanding the large

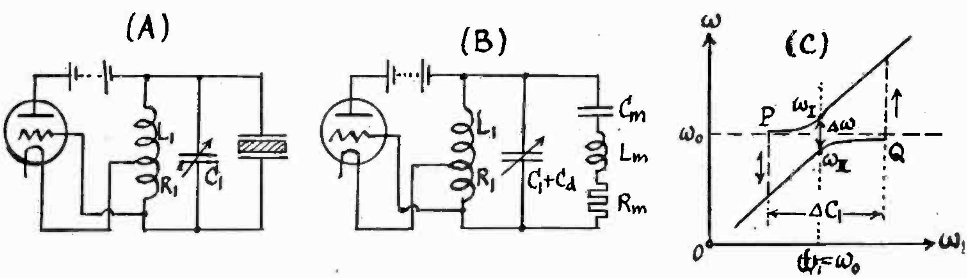


Fig. 51—Explanation of stabilizing action of piezo-resonator.

variation of the primary oscillation circuit. This phenomenon represents evidently that the frequency produced by means of the tube oscillator can be stabilized fairly by coupling, magnetically or electrostatically, a secondary oscillation circuit of a constant natural frequency. The frequency stabilization by means of the piezo-electric resonator is, as will be explained, nothing but an electrostatically coupled circuit oscillator.

[13] Y. Watanabe, *Jour. I. E. E.* (Japan), March, 1925.

(A) The tube oscillator coupled with a piezo resonator as shown in Fig. 51-A may be represented by an equivalent electrical circuit as in Fig. 51-B. Therefore the frequency characteristic of this oscillator is represented by Fig. 51-C.

The coupling coefficient k is given by the following equation:

$$k^2 = \frac{1}{1+\frac{C_1+C_d}{C_m}} \doteq \frac{C_m}{C_1+C_d} \doteq \frac{C_m}{C_1} \tag{54}$$

The equivalent capacity C_m of the resonator is so small that the coupling coefficient becomes very small. Consequently, the damping constant must be very small in order to give effective stabilization, because it is necessary to secure a wide range of pulling, ΔC_1 in Fig. 51-C.

The difference between the two coupling frequencies at the point of resonance is given by

$$\begin{aligned}\Delta\omega &= \omega_{I} - \omega_{II} \\ &= \omega_0\sqrt{1+k} - \omega_0\sqrt{1-k} \doteq \omega_d k.\end{aligned} \tag{55}$$

Now we can measure accurately the frequency characteristic curve by observing the variation of frequency by the beat method, and consequently we can find the value of $\Delta\omega$ experimentally. Thus by (55), we can find the coupling coefficient k and thence by (54) the equivalent capacity of the resonator.

In Table III, an experimental result is shown. The resonator No. 4 used for this experiment has the dimensions $l = 1.68$ cm, $b = 0.3$ cm, $t = 0.1$ cm. The experimentally obtained value of the equivalent capacity C_m is 0.016 $\mu\mu$f and the calculated value is 0.013 $\mu\mu$f by (8).

TABLE III

C_1 $\mu\mu$f	$\Delta\omega$	k	C_m $\mu\mu$f
1930	3000	0.00288	0.016
1140	4000	0.00384	0.017
600	5100	0.00490	0.014

Moreover, it is found that for many resonators the values of C_m obtained by the above method are in good agreement with those obtained by observing the motional admittance circle diagram.

(B) The next problem is to consider the relation between the stabilizing ability and the motional admittance of the piezo-electric resonator. The greater the pulling range ΔC_1 is, the more effectively the frequency is stabilized, therefore we may take the value of ΔC_1 as the measure of the stabilizing ability.

It is, of course, possible to treat the relation mathematically, but as such a mathematical treatment is too complicated and not so interesting, we shall consider this phenomenon in the following manner.

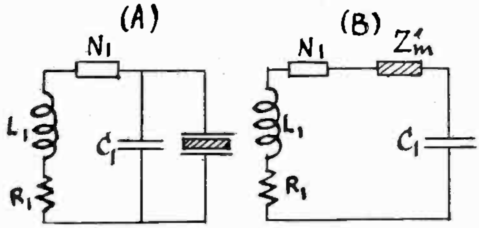


Fig. 52—Equivalent circuit of an oscillation generator.

The oscillator circuit is represented approximately by the equivalent circuits Fig. 52-A and -B, where N_1 denotes the negative resistance due to the regenerative action, and Z_m', the equivalent impedance of the crystal, is given approximately by

$$Z_m' = \gamma_m + jx_m \doteqdot \frac{Y_m}{\omega^2 C_1^2} \tag{56}$$

The crystal reactance x_m is represented as ordinate in Fig. 53, showing the variations near the resonant point. Abscissas are values of ω.

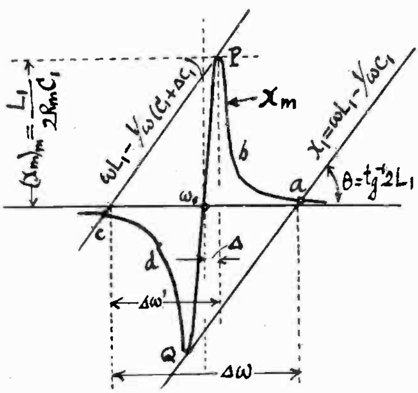


Fig. 53—Apparent reactance of a resonator.

As ω decreases we get the portion aP of the x_m curve, which continues until the curve is intersected by the approximately straight line representing the reactance x_1 of L_1, R_1, and $(C_1+\Delta C_1)$, when a sudden jump to the point C occurs. Similarly, on increasing the frequency, a jump takes place from Q to a. The two x_1 lines make an angle θ with the horizontal axis. The tangent of θ is approximately given by $\tan\theta = 2l$. Now, if we suppose that the breaks take place at P and Q of the curve x_m under the condition that N_1 is large, we have the following relation (notation as in Fig. 53):

$$\Delta\omega' = (x_m)_{\max} \cdot \cot\theta = \frac{L_1}{2R_mC_1} \cdot \frac{1}{2L_1} = \frac{1}{4R_mC_1} .$$

and

$$\Delta\omega = 2\Delta\omega' - 2\Delta = \frac{1}{2R_mC_1} - \frac{R_m}{L_m} \doteqdot \frac{1}{2R_mC_1} \tag{57}$$

and combining the result with the equation $\Delta\omega/\omega = -(\Delta C_1)/(2C_1)$, we have

$$R_m \doteqdot \frac{1}{\omega_0 \Delta C_1} \tag{58}$$

In other words, the diameter of the motional admittance circle diagram is proportional to ΔC_1. Therefore we may simply find the value of R_m from the value of ΔC_1 by observing the two breaks by means of the simple "click method" with a telephone receiver. As the above result shows, ΔC_1 is independent of the value of C_1. Owing to the complexity of the problem, however, it cannot be expected that the "click method" will yield precise results for the damping of the resonator.

In the experiment shown in Fig. 54, the value of ΔC_1 by the click method is about 140 $\mu\mu$f, while that obtained from the motional admittance is about 150 $\mu\mu$f.

As stated above, the stabilizing action of the piezo-electric resonator can be explained very simply from the point of view of a coupled circuit, and conversely the equivalent electrical constants of the resonator can be found easily by observing the frequency characteristics.

But we find that, in some cases, the range ΔC_1 is not only dependent upon the resonator, but also that it varies appreciably with tube conditions. This point will be discussed in the following paragraph.

Stabilizing Ability and Tube Conditions

The stabilizing action or the range of pulling depends appreciably upon the conditions of the tube oscillator circuit, such as filament current and plate impedance.

(1) Fig. 54 shows that when the filament current is increased or the resistance in the plate oscillation circuit is small, the range ΔC_1

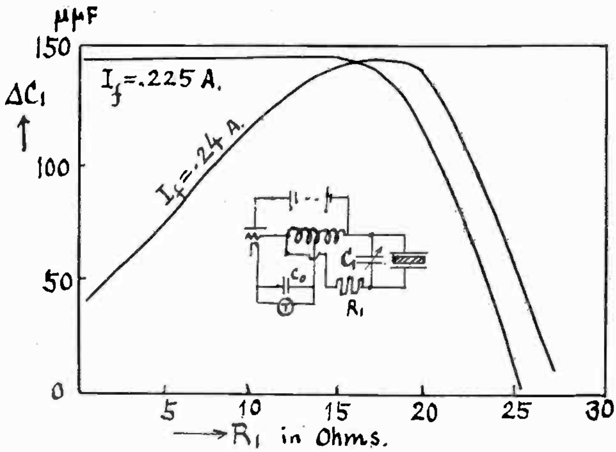


Fig. 54—Range of "Ziehen" depending on damping of oscillation circuit.

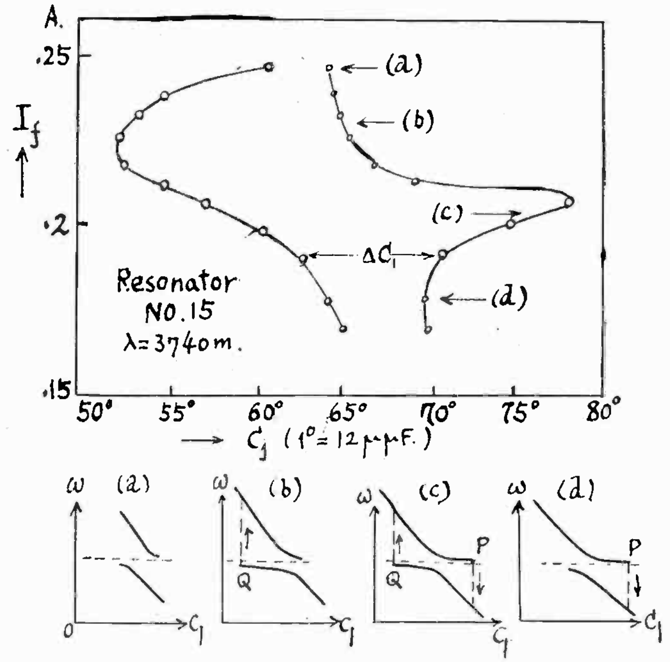


Fig. 55—Dependence of points of discontinuity upon filament heating.

is much decreased. But the obtainable maximum value of ΔC_1 is found, from many experiments, to be nearly equal to the value found from the motional admittance method. For example, in this case, the former value is 140 $\mu\mu$f and the latter is 150 $\mu\mu$f.

(2) Fig. 55 shows the dependence of the range ΔC_1 upon the filament current. The frequency characteristic curves have four kinds of shape as shown in the annexed figures (a) (b) (c) (d). Fig. 56 shows more clearly the frequency characteristic curve corresponding

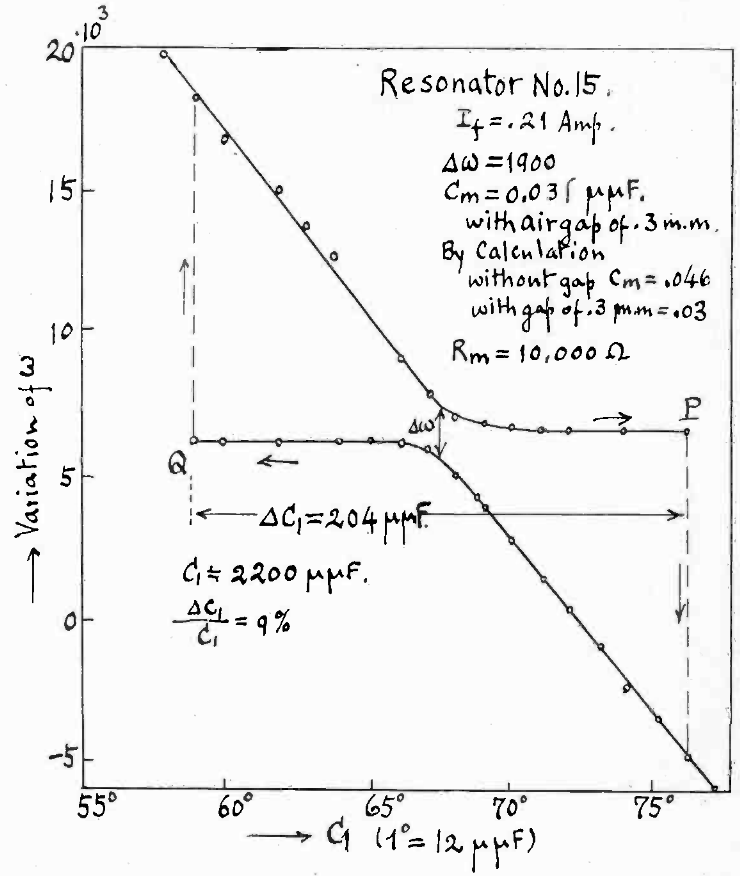


Fig. 56—Frequency curve illustrating good stabilizing action by a resonator.

to the point *a* in Fig. 55. Fig. 57 illustrates the case when the resonator vibrates in the mode of "transverse vibration" parallel to X-axis at a frequency of about 590 kc.

The question why the frequency characteristic curve does not always have the form shown in Fig. 56, or why the ΔC_1 range is affected so greatly by the oscillator conditions cannot be explained rigorously and it still remains as a problem to be solved for the piezo-electric frequency stabilizer.

The effectiveness of frequency stabilization by means of the piezo resonator is clearly shown by the previous statements. There are many factors which influence the frequency. It is observed that variation of the filament current has a particularly marked effect upon the frequency. Nevertheless, when a piezo-electric resonator is connected

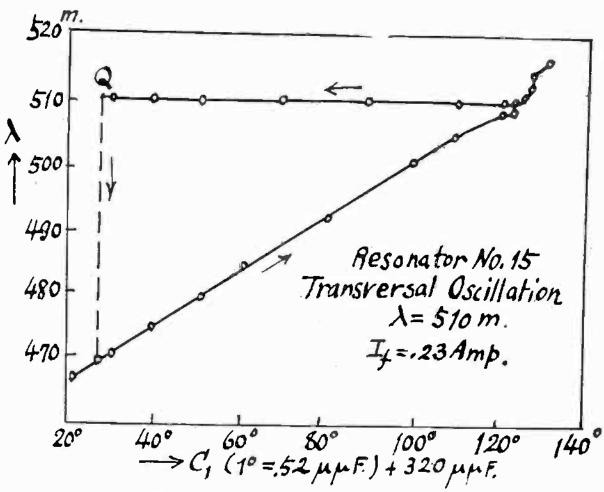


Fig. 57—Case of a transverse vibration.

to such an oscillator as we have considered and the primary oscillation circuit is adjusted at a suitable point on the stabilizing range, the frequency of the generated oscillations may be kept constant in spite of variation of the filament current. This fact is also verified experimentally with great exactness.

In conclusion the author wishes to express his great appreciation to Professor Cady for his helpful advice and assistance in the preparation of the present paper.

BOOKLETS, CATALOGS, AND PAMPHLETS RECEIVED

The following list of bulletins, catalogs, and note books describing electrical measuring and recording equipment may be obtained upon application to the Leeds and Northrup Company, 4901 Stenton Ave., Philadelphia, Pa.

Bulletin No. 235, describing vibration galvanometers for balance indicators for null measurements for frequencies from 5 cycles to 200 cycles.

Bulletin No. 429 describes a portable Kelvin bridge ohmmeter for measuring resistance from 0.0001 ohm to 11 ohms.

Bulletin No. 434, entitled "Students' Kelvin Bridge", describes a slide wire type of Kelvin bridge.

A power cable fault bridge for locating faults in cables by the Murray loop method is described in Bulletin No. 536.

The type *T* testing set, described in Bulletin No. 541 is useful for making resistance measurements, and for locating faults by the Varley and Murray loop methods.

A portable current transformer testing set, embodying the null principle in a method for the comparison of two current transformers of the same nominal ratio, is described in Bulletin No. 715.

Bulletin No. 716 describes a portable potential transformer testing set designed for routine testing either in the laboratory or in the field.

The White potentiometer, described in Bulletin No. 726, has been designed for the measurement of temperature and temperature differences by means of thermocouples.

Bulletin No. 755 describes the Leeds and Northrup type *K* potentiometer.

The Brooks deflection potentiometer, and accessory apparatus, is listed in Bulletin No. 763.

Technical details of students' potentiometer and accessory apparatus are given in Bulletin No. 765.

"Frequency Measurement and Control" is the title of Bulletin No. 985 listing frequency recorders for 110-volt circuits.

Bulletin No. L-874 deals with, and is entitled, "Remote Recording and Totalizing System".

Apparatus for capacitance, inductance, and magnetic measurements is thoroughly described in Catalog No. 10.

Catalog No. 20 lists galvanometers which cover practically the entire range of applications for which galvanometers may be used.

Keys and switches which will be found useful around the laboratory are listed in Catalog No. 30.

"Apparatus for Electrical Resistance Measurements" is the title of Catalog No. 40 listing equipment for measuring direct- or alternating-current resistance.

Catalog No. 84 deals with potentiometers for automatic temperature control.

"Optical Pyrometers" is the subject of Catalog No. 86.

For the accurate control of temperature between —300 deg. F and 2800 deg. F thermocouple potentiometer pyrometers are universally employed. Suitable pyrometers for this temperature range are described in Catalog No. 87.

The Leeds and Northrup Note Book No. 2, entitled "Notes on Moving Coil Galvanometers" is a data book compiled to enable the prospective purchaser to select the instruments best suited to his needs.

Note Book No. 4 contains general information relative to Kelvin bridges and is entitled "Notes on the Kelvin Bridge."

A bridge, which determines whether or not the resistor unit under measurement is within prescribed limits is the Leeds and Northrup No. 4270 per cent limit bridge, described in a recent circular.

The Sensitive Research Instrument Corporation, 142 to 154 East 32nd St., New York City, has recently issued Catalog No. 30 which lists numerous sensitive d-c and a-c (audio-frequency) voltage and current measuring instruments. Copies of this catalog may be obtained upon request.

Graphic Instruments, Bulletin No. 830, issued by the Roller-Smith Co., 233 Broadway, New York, describes recording voltmeters, ammeters, and wattmeters.

Copies of the service manual on the Colonial Model 32 A. C. and D.C. receivers may be obtained for twenty-five cents per copy from the Colonial Radio Corporation, 25 Wilbur Ave., Long Island City, N. Y.

Service organization doing service work on receivers can obtain copies of a service manual covering the No. 47 and No. 48 screen-grid chassis from the United States Radio and Television Corporation, 3301 South Adams St., Marion, Ind.

A leaflet on quartz piezo-electric plates may be obtained on application from S. J. Wise and Co., 47 Rue Nationale, Antwerp, Belgium.

A brochure describing the advantages and outlining the installation of centralized radio equipment for hotels and apartments may be obtained from the International Broadcasting Equipment Co., 3112 West 51st St., Chicagso Ill.

The following radio data sheets, punched to fit standard Lefax binders, may be obtained from Lefax, Ninth and Sansom Streets, Philadelphia:

The Pentode Tube
Average Characteristics of Receiving Radiotrons
Constructing a Modulated Oscillator
Audio-Frequency Amplification with Screen-Grid Tubes
A Dry-Cell Screen-Grid Tube
Some Facts About Acoustics in Cabinets
Revolutionizing High-Frequency Tuner Design.
Public Address and Centralized Radio Systems (Part 1)

The March, 1930, issue of the *General Radio Experimenter* contains an article on "The Standard Signal Method of Measuring Receiver Characteristics". A yearly subscription to the *Experimenter* may be obtained without charge upon application to the General Radio Co., 30 State Street, Cambridge, Mass.

A copy of the fourth issue of the Standards Yearbook, compiled by the National Bureau of Standards, may be obtained for seventy-five cents from the Government Printing Office, Washington, D. C.

Proceedings of the Institute of Radio Engineers
Volume 18, Number 5 *May, 1930*

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 the professional radio engineers which have recently appeared in periodicals, books, etc. The number at the left of each reference classifies the reference by subject, in accordance with the scheme presented in "A Decimal Classification of Radio Subjects—An Extension of the Dewey System," Bureau of Standards Circular No. 138, a copy of which may be obtained for 10 cents from the Superintendent of Documents, Government Printing Office, Washington, D. C. The various 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.

R000. Radio Communication

R007.9 Premier reunion du Comite Consultatif International de Radioelectricite. (First meeting of the International Consulting Committee on Radio). *L'Onde Electrique*, 9, pp. 23–24; Jan., 1930.

(A report is given of the work of the International Consulting Committee on Radio at The Hague Conference, 1929. (to be continued))

R100. Radio Principles

R112.1 Fleming, A. The wave band—theory of wireless transmission. *Nature* (London), 125, p. 92; Jan. 18, 1930.

(The concept of the radiation of a modulated carrier wave as the radiation of waves of frequencies distributed over a band is questioned.)

R112.1 Linfoot, E. H.; Newbold, A. A.; Fleming, A. The "wave band" theory of wireless transmission. *Nature* (London), 125, p. 306; March 1, 1930.

(Letters discussing the question raised by Sir Ambrose Fleming in *Nature* (London), Jan. 18, 1930 with regard to the "wave band" theory of radio transmission are recorded.)

R113 Esau, A. and Hahnemann, W. M. Report on experiments with electric waves of about three meters, their propagation and use. Proc. I.R.E., 18, pp. 471–89; March, 1930.

(Experiments upon the maximum range obtainable with wavelengths of about three meters are reported and brief explanations are given concerning the apparatus and methods used. Directive devices in the form of parabolic reflectors were used successfully. The results clarify the phenomena of propagation of these wavelengths and indicate the possibility of their practical application to short range signaling and possibly to television.)

R113 Jouaust, R. Les ondes tres courtes. (Very short waves). *L'Onde Electrique*, 9, pp. 5–17; Jan., 1930.

(The transmission of waves of very high frequency ($\lambda = < 10$ m) is discussed. The treatment is historical, the theoretical and experimental work of French scientists being specially noted. Transmission phenomena found in the application of the very high frequencies to telephone communication between France and Corsica are explained by the use of the theory of refraction.)

R113.5 Colwell, R. C. Weather forecasting by signal radio intensity: Part I. Proc. I. R. E., 18, pp. 533–36; March, 1930.

(At Morgantown, W. Va., 60 miles from Pittsburgh, the night intensity of KDKA sometimes rises above the day signal and sometimes falls below it. Observations during 1927 and 1928 have shown that this phenomenon foreshadows weather conditions from twelve to twenty-four hours ahead. A rising curve after nightfall indicates an approaching storm while a falling curve is followed by fair weather. Typical curves are shown.)

R113.7 Rolf, B. Graphs to Prof. Sommerfeld's attenuation formula for radio waves. Proc. I. R. E., **18**, pp. 391–402; March, 1930.

(Graphs resulting from calculations of Prof. Sommerfeld's attenuation formula are presented. By using them predictions may be made of the field strength for all wavelengths over soil, the electrical constants of which are known. An abac is included and instructions are given for its use to obtain the inductivity and conductivity of the ground over which a series of fieldstrength measurements have been made.)

R116 Takagishi, E. On a double hump phenomenon of current through a bridge across parallel lines. Proc. I. R. E., **18**, pp. 513–32; March, 1930.

(A theoretical and experimental investigation is presented to show that in a parallel wire system for use in frequency determination, a double hump phenomenon of bridge current occurs necessarily quite apart from the well known absorption effect encountered when the coupling between the generating set and the system is too close. The sufficient conditions for the occurrence of the phenomenon are given).

R133 Hollmann, H. E. Zusammenfassender Bericht: Die Erzeugung kürzester elektrischer Wellen mit Elektronenröhren. (Summary report: Production of ultra short waves with electron tubes). *Zeits. f. Hochfrequenztechnik*, **35**, pp. 21–27; January, 1930.

(A complete report on the latest developments in producing very short electric waves with vacuum tubes of special type is given.

R133 Ito, Y. Theorie der Zweielektrodenröhren und Erzeugung elektrischer Schwingungen von extra niedriger Frequenz. (The theory of two-electrode tubes and the production of electric oscillations of very low frequency). *Zeits. f. Hochfrequenztechnik*, **35**, pp. 12–20; January, 1930.

(A method of controlling the plate current in a two-electrode tube by means of varying the filament temperature is discussed. Characteristics of such a tube operating as an amplifier, as an oscillator and as a rectifier are described.)

R138 Langmuir, I; MacLove, S.; Blodgett, K. B. The effect of end losses on the characteristics of filaments of tungsten and other materials. *Phys. Rev.*, **35**, pp. 478–503; March 1, 1930.

(The leads of a tungsten filament in vacuum, by cooling the ends of the filament, are known to affect its voltage, candle power, electron emission, and other properties. Tables and formulas are presented which allow ready calculation of the effects of the leads on the properties of any long tungsten filament for which the current and diameter are known. The theory is extended to cover the cases of filaments in gases and filaments of other materials. Figures are also given from which may be found the properties of filaments so short that the first theory does not apply.)

R139 Ballantine, S. and Cobb, H. L. Power output characteristics of the pentode. Proc. I. R. E. **18**, pp. 450–470; March, 1930.

(The power output characteristics of the pentode are discussed theoretically. The characteristics treated are distortion and power sensitivity, a quantity defined as the square root of the power output divided by the effective value of the applied sinusoidal grid voltage. Experimental measurements on a specimen low-power pentode are given and a simplified technique is described.)

R140 Reed, M. Electrical wave filters. *Experimental Wireless and Wireless Engr.* (London), 7, pp. 122–28; March, 1930.

(In the first section of an extended review of American work on wave filters the fundamental formulas for a symmetrical structure are derived. It is shown that these formulas may be applied to wave filters.)

R146 Mesny, R. Au sujet de la multiplication des frequences par les triodes. (Concerning the multiplication of frequencies by three-electrode tubes.) *L'Onde Electrique*, **9**, pp. 18–22; January, 1930.

(A simplified mathematical analysis is given whereby the conditions may be predetermined under which a three-electrode tube functions best as a harmonic amplifier.)

R161 Colebrook, F. M. The balance of power in aerial tuning circuits. *Experimental Wireless and Wireless Engr.* (London), 7, pp. 129–140: March, 1930.

(The problem of coupling an antenna to receiving set to obtain optimum sensitivity is dealt with analytically. Various tuning systems are treated, and in each it is shown that the most efficient possible tuning arrangement exists when a balance of power is established between the antenna and the receiving system, such that equal power is consumed in each.)

R200. Radio Measurements and Standardization

R214 Vigoureux, J. E. P. The valve-maintained quartz oscillator, *Jour. I. E. E.* (London), 68, pp. 265–95; February, 1930.

(The results of a theoretical and experimental investigation of two types of quartz-controlled generator are presented. In the first type the quartz plate is connected between the grid and the plate and in the second type between the grid and the filament of the tube. The object of the investigation is the study of frequency variation due to variations in the air-gap between the quartz plate and the electrodes, to variations in the constants of the plate circuit, and to variations of the inter-electrode capacities and conductances.)

R214 Hall, E. L. Method and apparatus used at the Bureau of Standards in testing piezo oscillators for broadcast stations. Proc. I. R. E., 18, pp. 490–509; March, 1930.

(A method used by the Bureau of Standards for measuring the frequencies of piezo oscillators to be used for checking broadcast station frequencies as well as for calibration of frequency meters and measurement of station frequencies is described. The method combines high accuracy with precision due to the employment of visual indioation instruments in the zero beat method and with flexibility due to the use of harmonics.)

R214 Heaton, V. E. and Brattain, W. H. Design of a portable temperature-controlled piezo oscillator. *Bureau of Standards Jour. of Research*, 4, pp. 345–50; March, 1930. Research Paper No. 153. Obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C.

(The essential details of a portable shielded temperature-controlled piezo oscillator, constant in frequency to better than 1 part in 100,000, are described. The circuit arrangement, the temperature control, and the quartz plate mounting are explained.)

R240 Iinuma, H. A method of measuring the r-f resistance of an oscillatory circuit. Proc. I. R. E., 18, pp. 537–43; March, 1930.

(A method of measuring the resonance impedance and r-f resistance of an oscillatory circuit, using a screen-grid tube is described. It is based upon the principle of the dynatron oscillator, and it requires neither r-f measuring instruments and standards, nor sources of r-f currents. The results obtained by this method at frequencies from 600 to 1250 kc per second agreed within 2.5 per cent with those obtained by the usual resistance variation method.)

R240 Jackson, W. High-frequency resistance measurement by the use of a variable mutual inductance. *Jour. I. E. E.* (London), 68, pp. 296–304; Feb., 1930.

(A method of high-frequency resistance measurement employing a variable mutual inductance is given. The source and magnitude of the errors likely to occur are dealt with mathematically. The results of coil resistance measurements are given and compared with calculated values and with the results obtained by the resistance-variation method. The application to condenser resistance measurement is considered.)

R300. Radio Apparatus and Equipmemt

R330.4 White, W. C. Standardization in the radio vacuum-tube field. Proc. I. R. E., 18, pp. 371–390; March, 1930.

(In vacuum-tube engineering the base dimensions, the filament voltage, plate voltage, and grid-bias voltage are the features that require standardization to the greatest degree. The history and present status of standardization of these features are given. Only tube types commonly used for broadcast reception and transmission are included.)

R340 Okabe, K. Ueber die Verstärkung und Gleichrichtung von sehr kurzen elektrischen Wellen. (Concerning the amplification and detection of very short electric waves). *Zeits. f. Hochfrequenztechnik*, **35**, pp. 3–6; Jan., 1930.

(Circuits of receiving sets using two-electrode and three-electrode "Barkhausen-Kurz" vacuum tubes are described in their application to ultra short wave reception in the neighborhood of 50 cm. Experimental curves showing the relationships existing between the various circuit parameters for the condition of maximum amplification are given.)

R344 Warren, S. R. The four-electrode vacuum tube as beat frequency oscillator. Proc. I. R. E., **18**, pp. 544–49; March, 1930.

(This paper describes briefly the use of one UX-222 four-electrode vacuum tube as a double oscillator and detector. Audio-frequency output is obtained as the beat note between the fundamental of the oscillation due to one grid and the second harmonic of that due to the other.)

R350 Byrnes, I. F. and Coleman, J. B. 20–40 kilowatt high-frequency transmitter. Proc. I. R. E., **18**, pp. 422–49; March, 1930.

(A high-frequency transmitter with an output rating of 20–40 kw developed for service in commercial long distance communication systems is described. The frequency range of the transmitter is from 6670 to 21,500 kc. Any two predetermined frequencies within this range may be selected for use. Problems met and solved in the development are given.)

R500. Applications of Radio

R521 Diamond, H. and Gardner, F. G. Engine-ignition shielding for radio reception in aircraft. *Bureau of Standards Jour. of Research*, **4**, pp. 415–424; March, 1930. Research Paper No. 158. Obtainable from Superintendent of Documents, Government Printing Office, Washington, D. C.

(The work of the Bureau of Standards in the development of satisfactory and safe engine-ignition shielding to permit the use of highly sensitive radio receivers on aircraft is described. The problems of electrical and mechanical design involved are listed. Tests for the practicability of a shielding system are outlined.)

R526.1 Diamond, H. and Kear, F. G. A 12-course radio range for guiding aircraft with tuned-reed visual indicator. *Bureau of Standards Jour. of Research*, **4**, pp. 351–69; March, 1930. Research Paper No. 154. Obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C.

(There is described a radio-directive beacon of the visual indicating type developed by the Bureau of Standards to provide radio marked courses at air terminals where more than four airways converge. The beacon provides 12-equisignal zones which may be oriented within rather wide limits and made to coincide with converging airways. Circuit features of the transmitter are treated in detail.)

R526.1 Kear, F. G. and Jackson, W. E. Applying the radio range to the airways. *Bureau of Standards Jour. of Research*, **4**, pp. 371–81; March, 1930. Research Paper No. 155. Obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C.

(Methods employed in adjusting the space pattern of the aural radiobeacon system in order that the courses might align with the fixed airways are discussed. By using a vertical wire antenna in addition to the loop antennas and by varying the relative power in the two loop antennas, it was found possible to secure practically any array of courses desired.)

R526.1 Dellinger, J. H.; Diamond, H.; and Dunmore, F. W. Development of the visual type radiobeacon system. *Bureau of Standards Jour. of Research*, **4**, pp. 425–59; March, 1930. Research Paper No. 159. Obtainable from Superintendent of Documents, Government Printing Office, Washington, D. C.

(A review is given of the work of the Bureau of Standards through the period 1926–1929 on the development of the visual type airway radiobeacon system. In the review descriptions are given of the aural radiobeacon system, the double-modulation visual beacon system, the triple-modulation visual beacon system, airplane receiving equipment, and marker beacons.)

R550 Gerth, F. A German common frequency broadcast system. Proc. I. R. E., 18, pp. 510–511; March, 1930.

(The system according to which the first three German common frequency broadcast transmitters operate is described. Two cables between the transmitters are used, in which the carrier frequency is between 1500 and 2000 cycles per sec. Multiplication of frequency is accomplished by static frequency changers in three stages.)

R565 Shearing, G. and Dorling, J. W. S. Naval wireless telegraph communication. *Jour. I. E. E.* (London), 68, pp. 237–64; February, 1930.

(An account of the development of radio apparatus for naval purposes is given. The historical development is referred to, the radio lines required for naval ships are outlined, and the essential requirements and chief features of some of the apparatus used under seagoing conditions are briefly described. The organization for giving effect to the policy of H. M. Board of Admiralty is also indicated.)

R600. Radio Stations: Equipment, Operations and Management

R610 Hallborg, H. E. The radio plant of R. C. A. Communications Inc. Proc. I. R. E., 18, pp. 403–21; March, 1930.

(The world-wide communication system of R.C.A. Communications, Inc. is described and contrasted with the long-wave system of long distance communication of six years ago. Transmitting, receiving and central office equipment and installations are illustrated. The details and the effectiveness of the directive antenna systems employed are shown. The present status of photo radio and facsimile development with a typical sample is outlined.)

R800. Non-Radio Subjects

537.65 Chaikin, S. Ueber eine direkte Metjode zur Messung von kleinen Dämpfungen bei Piezokristallresonators. (A direct method for the measurement of small damping in quartz-plate resonators). *Zeits. f. Hochfrequenztechnik*, 35, pp. 6–9; Jan., 1930.

(A new method of measuring small damping in quartz plate resonators is described. The quartz plate is forced into oscillation by a driving oscillator circuit and when this is shut off, the energy produced by the freely oscillating quartz plate in a second circuit is measured by a galvanometer. These data are sufficient to determine the damping coefficient. The method is especially valuable for measuring very small damping coefficients.)

537.65 Hund, A. and Wright, R. B. New piezo oscillations with quartz cylinders cut along the optical axis. *Bureau of Standards Jour. of Research*, 4, pp. 383–94; March, 1930. Research Paper No. 156. Obtainable from Superintendent of Documents, Government Printing Office, Washington, D. C.

(It is shown that oscillations of a new type may be produced using a quartz cylinder cut along the optical axis. To produce them it was found necessary to use highly regenerative circuits to drive the quartz. The oscillations were studied experimentally through the medium of glow discharge patterns and theoretically by comparing the observed frequencies of oscillation with the computed values for the three different modes of vibration. The study indicated that oscillations were of a true piezo-electric character. Several types of electrode mounting were used.)

Proceedings of the Institute of Radio Engineers
Volume 18, Number 5 *May, 1930*

CONTRIBUTORS TO THIS ISSUE

Dellinger, J. H.: Born July, 3, 1886 at Cleveland, Ohio. Educated at Western Reserve, 1903–1907; received A. B. degree, George Washington University, 1908; Ph. D. degree, Princeton University, 1913. Instructor, physics department, Western Reserve, 1906–1907. Joined staff of Bureau of Standards as physicist, 1905; Chief of Bureau's Radio Section, 1919 to date; U. S. delegate to Interallied Technical Conference on Radio Communication at Paris, 1912; member of technical staff of the Conference on Limitation of Armaments and Far East Problems at Washington; Secretary U. S. Government Inter-depart ment Radio Advisory Conferences, 1922–1923; member of all four National Radio Conferences, 1922–1925; chairman of Committee on Radio Apparatus, Federal Specifications Board; member of technical advisory staff of International Radio Conference, Washington, 1927; one of the technical advisors to American Delegation of International Technical Consulting Committee, 1929. Vice-president of the Institute of Radio Engineers, 1924; president, 1925. Chairman of Committee on Meetings and Papers, 1928; present chairman of Committee on Standardization. Member, Board of Direction of the Institute, 1928–1931. Fellow, Institute of Radio Engineers, 1923.

Diamond, H.: Born February 12,1900 at Quincy, Mass. B.S. degree, Massachusetts Institute of Technology, 1922; M. S. degree, Lehigh University, 1925. Engaged in research work in mechanical engineering with General Electric Company, 1922–1923; instructor in electrical engineering, Lehigh University, 1923–1927; summer work, General Electric, B. F. Sturtevant, and Boston Elevated Companies. Associate radio engineer, Bureau of Standards, 1927–1928; radio engineer in charge of development of radio aids to air navigation, Bureau of Standards, 1928 to date. Member, A. I. E. E., 1929. Associate member, Institute of Radio Engineers, 1926.

Dunmore, F. W.: Born January 24, 1891 at Haverhill, Mass. Commercial radio operator, summers, 1911–1913. B. S. degree, Pennsylvania State, 1915. Student engineering course, General Electric Company, 1915–1917; research department, American Radio and Research Corporation, 1918; radio laboratory staff, Bureau of Standards, 1918 to date, specializing in research work in radio direction finder, directional transmission and radio aids to air navigation. Non-member, Institute of Radio Engineers.

Gardner, Frank G.: Born March 15, 1897 at Girard, Illinois. University of Illinois, 1915. Enlisted in Air Service of the United States, 1915; ten years in Air Corps. Field manager, Bureau of Standards Experimental Flying Field, College Park, Maryland, 1927 to date. Member, National Aeronautic Association; Reserve Officers Association; U. S. Air Force Association. Non-member, Institute of Radio Engineers.

Hooper, S. C.: Associated with radio work of the Navy since its inception; fleet radio officer and head of radio division of the Bureau of Engineering, Navy Department; during Arms Conference in Washington served on advisory committee; also technical advisor to the American delegation of the International Radiotelegraph Conference in Washington, 1927; at present director of naval communications and technical advisor to the Federal Radio Commission. Associate member, Institute of Radio Engineers, 1913; Member, 1915; Fellow, 1917.

Hund, August: Born December 17, 1887, at Offenburg, Baden, Germany. Educated at Carlsruhe, Heidelberg, and California; E. E. degree, 1911, and Dr. Eng. degree, 1913 from Carlsruhe. Research engineer in research laboratory of the General Electric Company at Schenectady, 1912–1914, part of the time in Dr. Steinmetz's private laboratory; assistant professor of physics and electrical engineering, University of Southern California, 1915–1917; consulting research engineer, San Francisco, 1918–1922; electrical engineer, Bureau of Standards, doing research work in radio and electro-acoustics, 1922 to date. Member, Institute of Radio Engineers, 1916; Fellow, 1927.

Watanabe, Yasusi: See PROCEEDINGS for February, 1930.

Wright, R. B.: A. B. degree, Stanford University, 1922; M. S., Massachusetts Institute of Technology, 1928. Assistant physicist, Bureau of Standards, 1928 to date. Non-member, Institute of Radio Engineers.

To
Think of

TRANSFORMERS

is to
Think of

THORDARSON

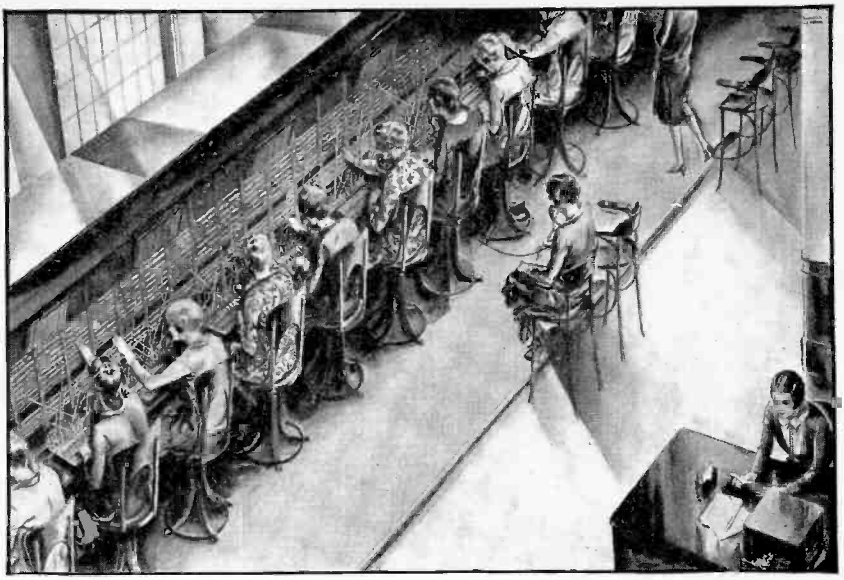
TRANSFORMER SPECIALISTS • *Since 1895*

Microphone Transformers • Line to Tube, Tube to Line, Line to Line • Mixing Transformers • Coupling Reactors • Filter Chokes • Audio Transformers • Impedance Matching Transformers • Power Compacts • Speaker Coupling Transformers • Complete Amplifiers . . . .

THORDARSON ELECTRIC MANUFACTURING CO.

Huron, Kingsbury and Larrabee Sts.
Chicago, Illinois, U. S. A. . . . . . .

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*



EACH CALL MUST BE HANDLED SEPARATELY, EACH FITTED TO THE NEEDS OF THE INDIVIDUAL WHO MAKES IT

65 million calls a day . . . each one made to order

An Advertisement of the American Telephone and Telegraph Company

WHEN you pick up your telephone, you may use $10,000 worth of equipment to talk to your neighbor three blocks away, or $10,000,000 worth of equipment to talk 3000 miles across the continent. Each call must be handled separately, each made to order. To render this service in a way that fits the needs of the American people, the operation of the System is conducted by 24 different companies, each adapted to the area it serves.

These Associated Companies have the benefit of study and analysis by the staff of the American Telephone and Telegraph Company, leading to progressive improvements in service.

Each of the Bell Companies takes advantage of the research findings of the Bell Laboratories, commanding scientific talent unsurpassed in any industry.

The quality and precision manufacture of the telephone equipment and apparatus used by the entire System are assured by the specialized production methods of the Western Electric Company, which manufactures for the Bell System.

Today the Bell System is building ahead of the requirements of the public—to the end that the people of this nation may have the greater telephone facilities which they will need tomorrow.

AMERICAN TELEPHONE & TELEGRAPH CO. AND ASSOCIATED COMPANIES
BELL SYSTEM

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

LYNCH RESISTORS are used *in laboratories of*

General Electric Co.
Westinghouse Electric & Mfg. Co.
Grigsby-Grunow Company

Western Electric Co.
Bell Laboratories
Triad Mfg. Co.

—by

De Forest Radio Co.
R.C.A.—Theremin
Ferranti, Inc.
National Co., Inc.

Radio Frequency Laboratories
Scott Transformer Co.
Powers Cinephone Co., Inc.
Jenkins Television Corp.

—AND WHERE THERE CAN BE
NO COMPROMISE WITH QUALITY!

2 Watt Dynohmic
Cartridge Type
LR-3

Pigtail Type LR-4
250 ohms to
200,000 ohms

Midget Type
½ Watt
Dynohmic Pigtail
Type
LF-4½
250 ohms
to 5.
megohms

1 Watt Dynohmic
Cartridge Type
LR-1

Pigtail Type LF-4
500 ohms to
10. megohms

Exact Sizes

The resistance element is based on the famous metallized principle which has proved its superiority for accuracy and uniformity. Lynch Resistors embody the following improvements:

1—Casings are ceramic—permitting maximum heat dissipation, and sturdy enough to withstand heavy shocks and jars, thus minimizing possibility of breaking by crushing.

2—Caps are molded on, insuring positive mechanical and electrical contact—tapered for easy mounting where interchangeability is desired.

3—Pigtails are tinned copper, molded into the caps, not soldered or strapped—thus insuring positive contact and proof against noise caused by faulty connection.

LYNCH Precision Wire Wound Resistors

1/2 to 1% Tolerance

Especially Adaptable for Milliameter and Voltmeter Multipliers

Send us your Resistor Specifications and requirements, so that we can submit samples and prices.

LYNCH MANUFACTURING COMPANY, Inc.

1775 Broadway — New York City

Manufacturers of
QUALITY RADIO PRODUCTS

1919

10 YEARS of RADIO MANUFACTURING

Plus Over 12 Years of Pioneering in Electrical Reproduction of Sound

1930

IN 1919 when the Pacent Electric Company began to manufacture radio essentials, the industry was truly in its infancy. The years since have seen a steady and healthy growth, until today, the company enjoys the distinction of being one of the oldest and most far-sighted manufacturers.

Today Pacent Electric Company has the largest engineering and research staff in its history. All Pacent devices are examples of modern leadership in engineering and in sound, creative manufacturing.

Pacent Quality and Service are enemies of business depression.

PACENT ELECTRIC CO.

91 Seventh Avenue, New York

Manufacturing Licensee for Great Britain and Ireland:
IGRANIC ELECTRIC CO., Ltd., Bedford, England
Licensee for Canada: White Radio Limited, Hamilton, Ont.

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

THE RCA Radiotron Company, Inc., because of its preeminent position, is at all times prepared to anticipate the vacuum tube needs of the radio industry.

This organization is backed by the entire research facilities of the General Electric Company and the Westinghouse Electric and Manufacturing Company, as well as the vast resources of the Radio Corporation of America, with their scientists and engineers.

Any order . . . *regardless* of size . . . and any problem, regardless of what that problem may be, not only receives the immediate attention of the RCA Radiotron Company's Research Laboratories and Engineers . . . but it also benefits through the combined resources of the six RCA Radiotron Company factories located at Newark, Harrison, Cleveland, and Indianapolis.

The RCA Radiotron Company is the largest producer of vacuum tubes in the world. Why not let us help you find the answers to your knotty questions? The RCA Radiotron Company exists solely to serve the radio and allied industries. Give us the problem . . . we will give you the product.

Look for this mark on every Radiotron

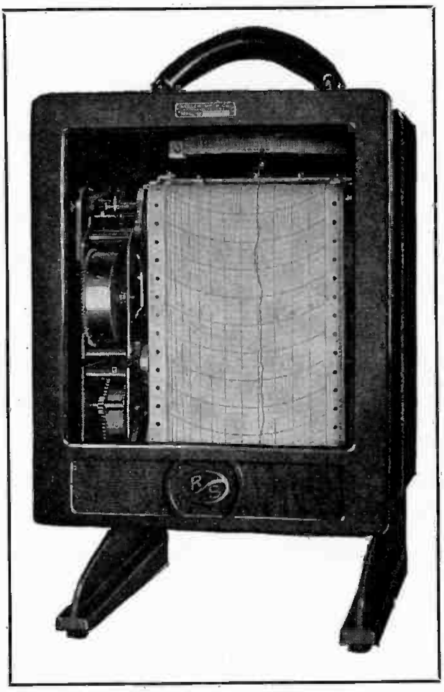
RCA RADIOTRON CO., INC.
HARRISON, N. J.

RCA Radiotron

THE HEART OF YOUR RADIO SET

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

ROLLER-SMITH
Announces . . . Graphics



AFTER years of research, development, tests and thoughtful consideration of what users require in a Graphic we take great pride in announcing this important addition to

The line comprises switchboard, wall and portable types, A.C. and D.C., ammeters, voltmeters, single and polyphase wattmeters and power factor meters.

Every man interested in Graphics will want a copy of new Bulletin No. K-830. Your copy is ready.

ROLLER-SMITH COMPANY

Electrical Measuring and Protective Apparatus

Main Office:
2134 Woolworth Bldg.
NEW YORK

Works:
Bethlehem,
Pennsylvania

Offices in principal cities in U. S. A. and Canada
Representatives in Australia, Cuba, Japan and Philippine Islands

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

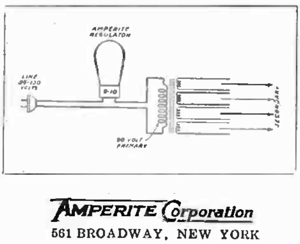
CONQUERS *Fluctuating Line Voltages!*

Insures Perfect Operation of A.C. Receivers Regardless of Regional Power Supply Variations

The AMPERITE Self-Adjusting Line Voltage Control *automatically* regulates the voltage from the A.C. power main. Assures the right voltage for most efficient operation regardless of line variations between 95 and 135 volts.

Operates *instantly*. Prevents sudden line surges from damaging tubes and filter equipment.

Trouble-free, long lasting. No radio can be modern without it. *Does not add to chassis cost.*



The AMPERITE Self-Adjusting Line Voltage Control is used with a power transformer having a primary either wound or tapped for 90 volts.

The circuit connections, are shown in the diagram. The type AMPERITE used depends upon the current drain of the set.

AMPERITE Corporation
561 BROADWAY, NEW YORK

AMPERITE
Self-Adjusting
LINE VOLTAGE CONTROL

MAIL COUPON FOR TECHNICAL BULLETIN

AMPERITE CORPORATION, Dept PE5,
561 Broadway, New York.

Please send technical bulletin on the AMPERITE Self-Adjusting Line Voltage Control.

Name ....

Manufacturer ....

City ....

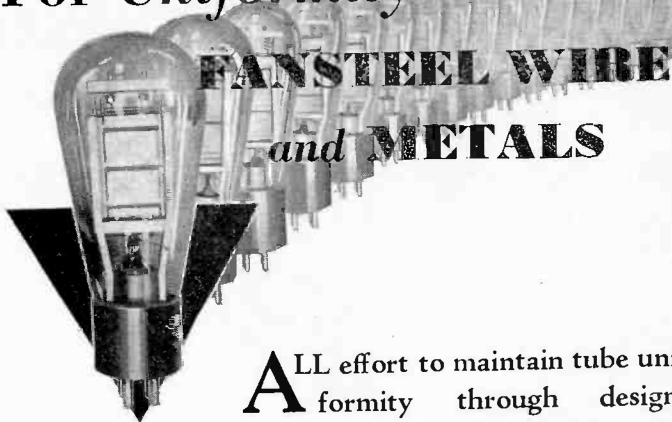
State ....

RARE METALS AND ALLOYS

TANTALUM · TUNGSTEN · MOLYBDENUM · CAESIUM · RUBIDIUM

For *Uniformity* in Tubes

FANSTEEL WIRE *and* METALS



ALL effort to maintain tube uniformity through design, manufacture or inspection is defeated unless the wire and metals from which the tubes are made run uniform.

FANSTEEL is the one source of supply for vacuum tube metals where ores are refined, metals purified and finished to uniform accurate dimensions and characteristics, all in one plant, all under one alert efficient laboratory control which guards uniformity every day in the year.

A special research laboratory, headed by an outstanding tube engineer, will aid your engineers in finding exactly the right metal or alloy for your requirements.

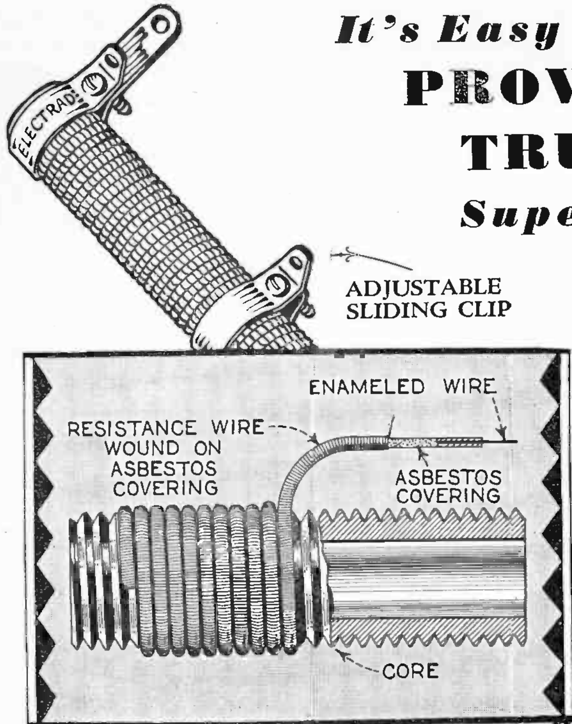
Ask for a FANSTEEL representative to call, or write for samples of FANSTEEL metals for testing — there's no obligation.

RUBIDIUM · CAESIUM · MOLYBDENUM · TUNGSTEN · TANTALUM

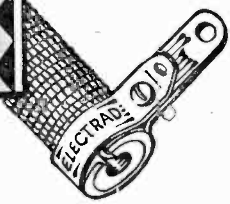
FANSTEEL PRODUCTS COMPANY, Inc.
NORTH CHICAGO, ILLINOIS

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

It's Easy to PROVE TRUVOLT *Superiority!*



TRUVOLT Resistances are DOUBLE WOUND. The resistance wire is first wound around an asbestos-covered copper core. This is then wound around the Fire clay base.



TRUVOLT ALL-WIRE Resistances from the first, have *sold themselves* to the radio industry. The patented open method of winding insures maximum air-cooling and consequently greater accuracy—more stability—and longer life.

TRUVOLT Fixed models have adjustable sliding clips, quickly set to the exact resistance values. Simplify power pack construction. No other resistance has this feature. Made with all usual resistance values and voltage ratings. *Test Samples to Manufacturers.*

TRUVOLT Variable Resistances have metal ventilating shield and one-hole mounting. Ideal for laboratory experiments where constant voltage variation is desired. Last longer due to endwise travel of contact over wire. 22 stock sizes. List $2.50

Dependable Resistances and Voltage Controls For Every Radio Purpose

Electrad manufactures a complete line of resistances and voltage controls for every radio and power supply purpose, including Television. Electrad Engineers are ready at all times to cooperate with you in the solution of your resistance problem, whether it is merely selecting a suitable stock resistance, or designing a special unit with unusual characteristics.

175 Varick St., New York, N.Y.

ELECTRAD INC.

ELECTRAD, Inc., Dept. PE5, 175 Varick St., New York, N.Y.
Please send me data on ☐ TRUVOLT Resistances
☐ All ELECTRAD Resistances ☐ TRUVOLT Test
Sample

Manufacturer ....

Address ....

I am Precision—the Soul of the Inanimate . . . You will find me wherever men strive to attain still higher levels of accuracy, and in their strivings place no petty premium upon perfection. Look for me in the Laboratory . . . You will not see me there, yet I am ever present amidst the chemist's test tubes and pipettes. Search for me in the Observatory . . . where new worlds are being charted and weighed. You will not see me there, yet I am always at the astronomer's elbow. Expect to find me in those factories where accuracy is more highly valued than mere acquisition. Again you will not see me, yet each day I guide the fingers of a million pairs of hands, and direct the destinies of countless busy machines. Wherever cutting, grinding, drilling and boring tools run hot against protesting metal you will find me present amid the reek of oil and the welter of fast-flying fragments . . . for I am Precision.

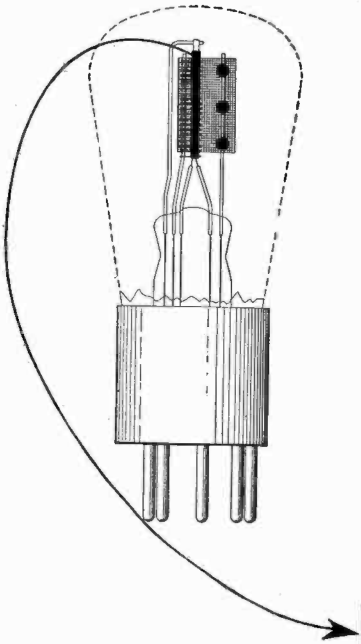
When I am present even in the smallest part or unit of a manufactured product, trouble ceases. When I am absent chaos enters. Look for me in products that must serve mankind faithfully and well, and when you find me know that their maker is worthy of your utmost confidence. For into his goods he has built an invisible quality which to him is of greater value than any mere outward and visible evidence of merit. For I am Precision, the Soul of the Inanimate—patron saint of those conscientious people who are satisfied only with the closest possible approach to that unattainable goal men know as Absolute Accuracy.

FROST-RADIO THE WORLD'S LARGEST . . . MANUFACTURERS OF HIGH GRADE VARIABLE RESISTORS. HERBERT H. FROST, INC. MAIN OFFICE AND FACTORY AT ELKHART, INDIANA. IN CHICAGO AT 160 NO. LASALLE ST. FROST-RADIO

FROST RADIO

Fused Pure Silica
Vitreosil

THE IDEAL INSULATION



PROGRESSIVE manufacturers, making the better kind of AC heater-type radio tubes use Vitreosil insulation for its freedom from gas and uniform wall which produces even heat distribution. It easily meets the thermal conditions of sudden heating and cooling, is mechanically strong, and available at low cost in single or multibore styles, and twin bore in either oval or circular cross section.

You can identify this Vitreosil product, illustrated herewith, by its smooth satin finish.

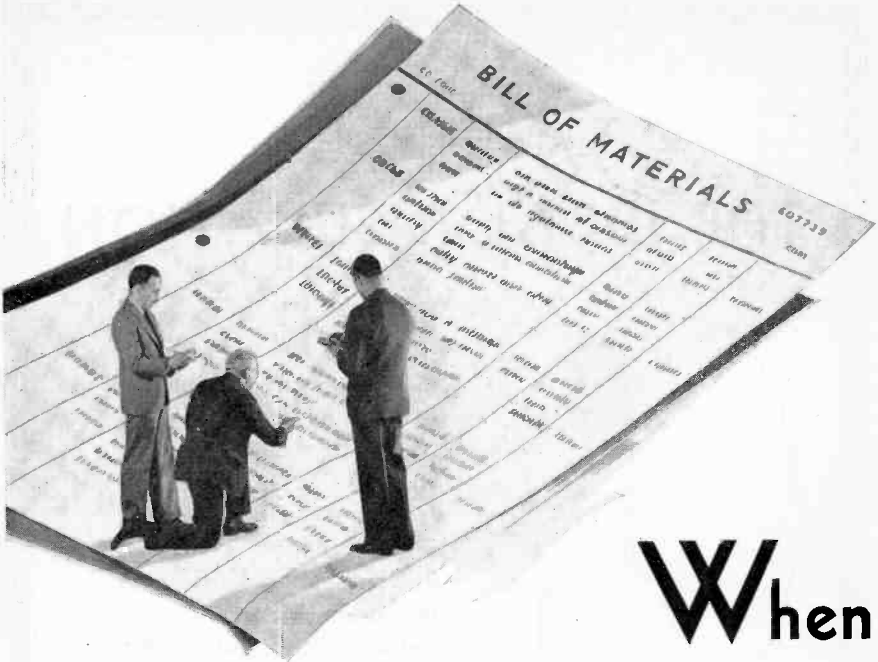
Let us send samples and quote on your requirements.

PURE FUSED SILICA
VITREOSIL
REG'D TRADE MARK
THE THERMAL SYNDICATE LTD.
WALLSEND-ON-TYNE

THE THERMAL SYNDICATE, Ltd.

1716 Atlantic Avenue Brooklyn, New York

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*



When

production costs must be cut

Dudlo's highly specialized engineers are most helpful. Their recommendations lead to important savings on magnet wire wound coils or to equally important economies in the handling of Dudlo Magnet Wire.

Dudlo's self-imposed high standard of quality insures the durability of your finished product . . . *at lowest cost.*

Engineering and manufacturing thoroughness make Dudlo the preferred source of supply for Coils and Magnet wire.

DUDLO

DUDLO MANUFACTURING COMPANY, FORT WAYNE, INDIANA
Division of General Cable Corporation

A Complete Family of Hammarlund "M"

MANUFACTURERS' MULTIPLE

Condensers

"M-Q"
Multiple-Quad.
"M-T"
Multiple-Trip.
"M-D"
Multiple-Duo.

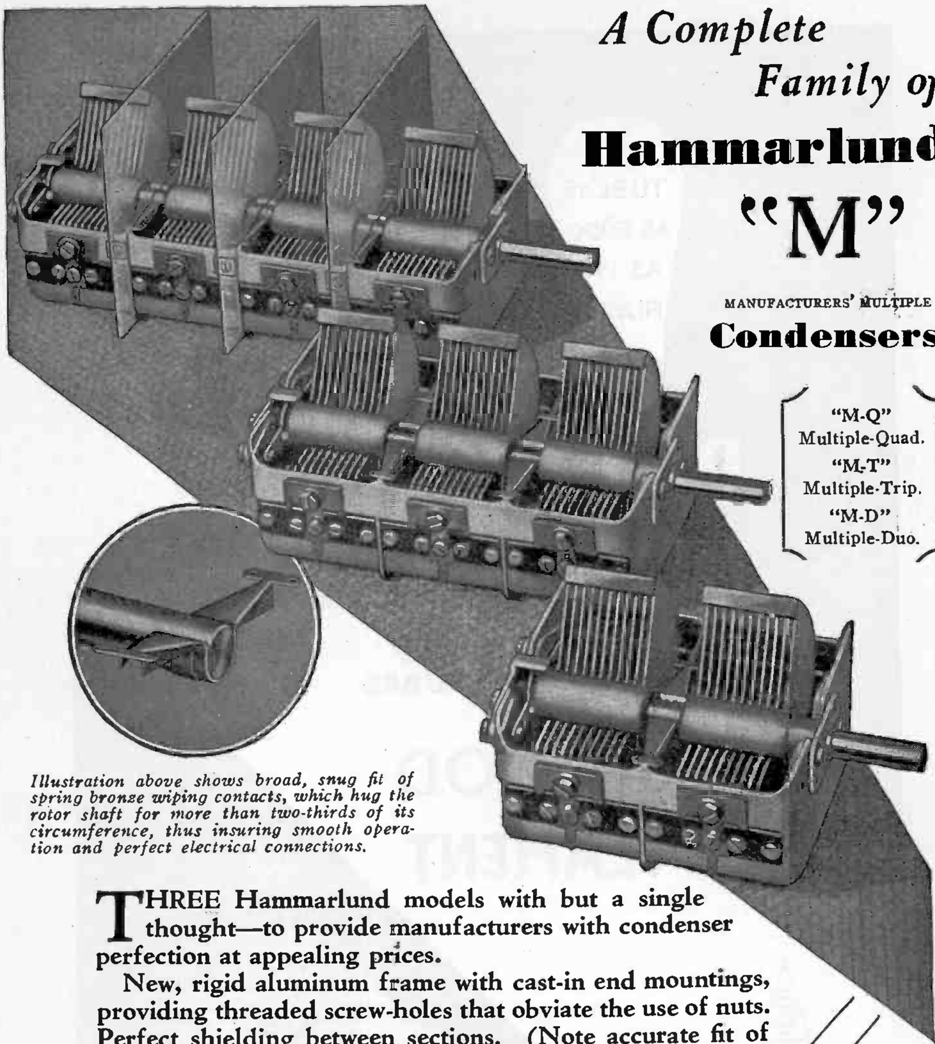


Illustration above shows broad, snug fit of spring bronze wiping contacts, which hug the rotor shaft for more than two-thirds of its circumference, thus insuring smooth operation and perfect electrical connections.

THREE Hammarlund models with but a single thought—to provide manufacturers with condenser perfection at appealing prices.

New, rigid aluminum frame with cast-in end mountings, providing threaded screw-holes that obviate the use of nuts. Perfect shielding between sections. (Note accurate fit of demountable upper shields, shown in phantom on quadruple model). Steel shaft working in long, hand-reamed bearings. Anchored, non-microphonic, aluminum plates. Separate stator insulating strips. Large area trimmer condensers.

You couldn't ask more of any condensers than these new Hammarlunds offer.

Write us your needs. Use coupon.

HAMMARLUND MFG. CO.
424-438 W. 33rd St., New York

For Better Radio
Hammarlund
PRECISION
PRODUCTS

MAIL COUPON FOR FULL PARTICULARS

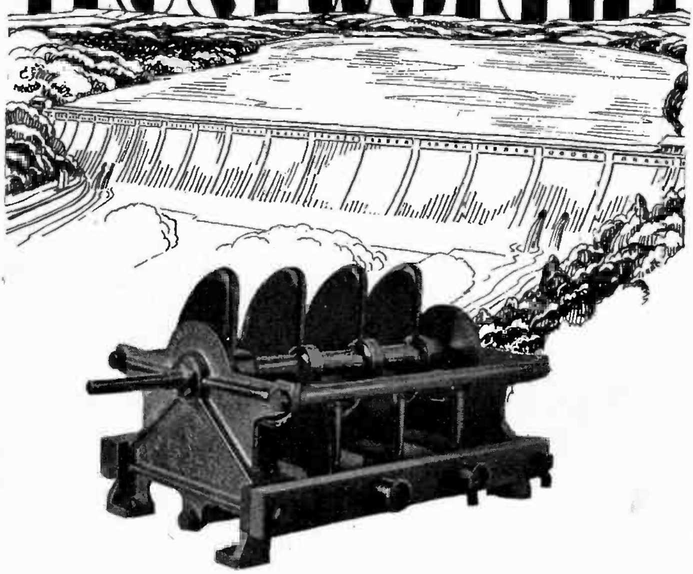
HAMMARLUND MFG. CO., Dept. PE5
424-438 W. 33rd St., New York
Please send information on "M" Condensers.

Name ....
Address ....

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*


A
TUBE IS
AS GOOD
AS ITS
FILAMENT
PRECISION
(UNCOATED)
FILAMENT
FOR RADIO
VACUUM TUBES
IS GOOD
FILAMENT
A Product of
SIGMUND COHN
44 Gold Street
New York
New York
Sigmund Cohn
FEET 1530
METAL Nickel
SIZE .001X.037
1.50
NET

TRUSTWORTHY



THE CONDENSER that must be depended upon to resist the tremendous energy held in leash in a powerful transmitter might be likened to a great dam impounding a reservoir of water and resisting mighty elemental forces tending to disintegrate it.

In the same manner as sound and proven engineering principles must be applied to the designing and building of a dam if disaster is to be avoided, so must condensers be designed and fabricated according to definite and well grounded rules. To use a second rate condenser is to court failure and disappointment.

Cardwell condensers, transmitting and receiving, are preferred by the Giants of the Radio Industry. Can you better afford to gamble than they?

CARDWELL CONDENSERS

THE ALLEN D. CARDWELL MFG. CORPN.
81 PROSPECT ST., BROOKLYN, N. Y.

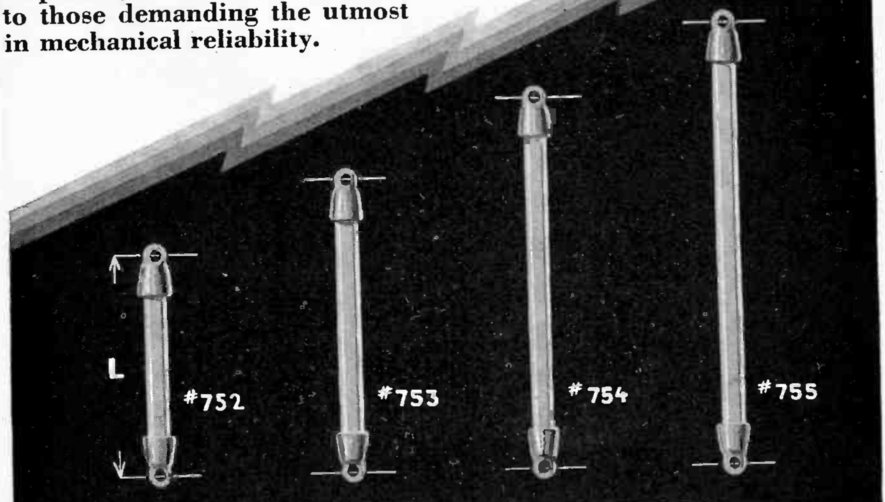
Since Broadcasting Began

"THE STANDARD OF COMPARISON"

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

A FAMILY OF HEAVY DUTY

ISOLANTITE now offers a new series of antenna insulators for the suspension of structures of the heavier types. These insulators are designed not only to support greater loads but provide a longer insulating path between fittings to give greater protection against electrical leakage and flash-over in the high voltage network. The insulators listed herewith are given individual load tests before shipment, a feature of added interest to those demanding the utmost in mechanical reliability.



Insulator Number	*Spacing "L"*	*Leakage Length*
No. 752	12 inches	8 inches
No. 753	16 inches	12 inches
No. 754	20 inches	16 inches
No. 755	24 inches	20 inches

Ultimate Strength 2,000 Pounds

Isolantite Company

SALES OFFICES

551 FIFTH AVE., NEW YORK CITY

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

ANTENNA INSULATORS—

by Isolantite

Full technical details and quotations will be made available to all radio engineers, upon request

Insulator Number	Spacing "L"	Leakage Length
No. 756	13 inches	8 inches
No. 757	17 inches	12 inches
No. 758	21 inches	16 inches
No. 759	25 inches	20 inches

Ultimate Strength 4,000 Pounds

of America, Inc.

FACTORY

BELLEVILLE, N. J.

ANNOUNCING

1930 ELECTRODYNAMIC SPEAKER

Let this be the basis of Your Decision

SENSITIVITY = SOUND WATTS OUTPUT / ELECTRICAL WATTS INPUT (40-7000 CYCLES)

We invite competitive tests, both aural and graphical. Our Engineering Department is available for your problems pertaining to audio amplification and reproduction.

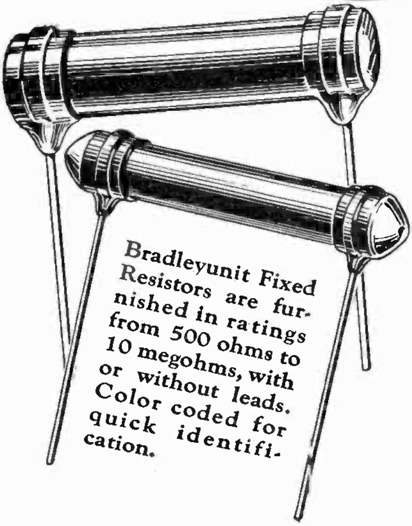
OPERADIO MFG. CO.
St. Charles, Ill.

MEMBER RMA

OPERADIO

PRECISION PRODUCTS

MILLIONS of Bradleyunits In Radio Sets TODAY



MANUFACTURERS of leading radio receivers are using millions of Bradleyunits for grid leaks and plate coupling resistors, because Bradleyunits are absolutely noiseless in performance. In radio sets, Bradleyunits are specified because their accurate rating is unaffected by temperature, moisture and age. In production, Bradleyunits are preferred because they are not fragile. There are no breakage losses. You too can benefit by standardizing on Bradleyunit Solid Molded Resistors.

Write for complete information and prices, today!

The huge Allen-Bradley plant at Milwaukee provides unlimited research and production facilities.

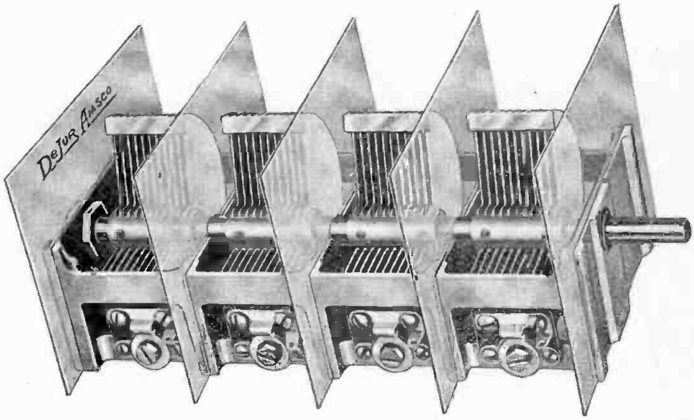
ALLEN-BRADLEY CO., 282 Greenfield Ave., Milwaukee, Wis.

Allen-Bradley

PERFECT RADIO A-B RESISTORS

DeJur-Amsco

Completely Shielded Condensers



Developed Especially For Screen Grid Receivers

Aluminum cast frame.

Aluminum cast shield plates.

Ball bearings at both ends.

Steel bushings and raceway.

Three-eighths inch steel shaft, centerless ground and highly polished.

Individual spring phosphor bronze wipe contacts to each rotor assuring perfect electrical contact.

Lugs attached for individual returns.

All metal parts except castings, rotor and stator plates heavily cadmium plated.

Mounting studs cast into bottom of frame.

Provision also made for side mounting.

Substantial compensating or trimming condensers.

Available in 2, 3, 4 and 5 gang units.

Write for engineering data and working drawings. Send us your specifications and let us quote. Samples on request.

We are also making special condensers for automobile radio and portable receivers.

DeJur-Amsco Corporation

Fairbanks Building

BROOME & LAFAYETTE STS., NEW YORK CITY

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

5-30

The Institute of Radio Engineers

Incorporated

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

APPLICATION FOR ASSOCIATE MEMBERSHIP

(Application forms for other grades of membership are obtainable from the Institute)

To the Board of Direction
Gentlemen:

I hereby make application for Associate membership in the Institute.

I certify that the statements made in the record of my training and professional experience are correct, and agree if elected, that I will be governed by the constitution of the Institute as long as I continue a member. I furthermore agree to promote the objects of the Institute so far as shall be in my power, and if my membership shall be discontinued will return my membership badge.

Yours respectfully,

....
(Sign with pen)

....
(Address for mail)

....
(Date) (City and State)

References:

(Signature of references not required here)

Mr. .... Mr. ....

Address .... Address ....

Mr. .... Mr. ....

Address .... Address ....

Mr. ....

Address ....

The following extracts from the Constitution govern applications for admission to the Institute in the Associate grade:

ARTICLE II—MEMBERSHIP

Sec. 1: The membership of the Institute shall consist of: * * * (d) Associates, who shall be entitled to all the rights and privileges of the Institute except the right to hold the office of President, Vice-president and Editor. * * *

Sec. 5: An Associate shall be not less than twenty-one years of age and shall be: (a) A radio engineer by profession; (b) A teacher of radio subjects; (c) A person who is interested in and connected with the study or application of radio science or the radio arts.

ARTICLE III—ADMISSION

Sec. 2: * * * Applicants shall give references to members of the Institute as follows: * * * for the grade of Associate, to five Fellows, Members, or Associates; * * * Each application for admission * * * shall embody a concise statement, with dates, of the candidate's training and experience.

The requirements of the foregoing paragraph may be waived in whole or in part where the application is for Associate grade. An applicant who is so situated as not to be personally known to the required number of members may supply the names of non-members who are personally familiar with his radio interest.

(Typewriting preferred in filling in this form) No..................

RECORD OF TRAINING AND PROFESSIONAL EXPERIENCE

1 Name ....
(Give full name, last name first)

2 Present Occupation..
(Title and name of concern)

3 Permanent Home Address...

4 Business Address ....

5 Place of Birth........................ Date of Birth.................. Age......

6 Education ....

7 Degree ....
(college) (date received)

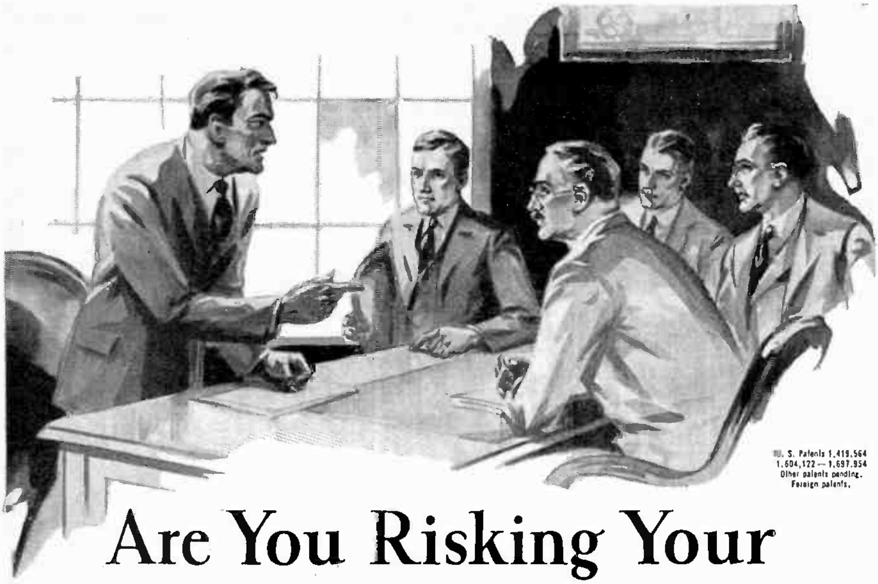
8 Training and Professional experience to date.................................

NOTE: 1. Give location and dates. 2. In applying for admission to the grade of Associate, give briefly record of radio experience and present employment.

DATES HERE	

9 Specialty, if any..

Receipt Acknowledged............. Elected............. Deferred.............
Grade........... Advised of Election........... This Record Filed...........



U. S. Patents 1,419,564
1,604,122 — 1,697,954
Other patents pending.
Foreign patents.

Are You Risking Your REPUTATION

on an Inferior Lock Washer?

THE performance of your product is definitely limited by its ability to withstand vibration. Should a single nut work loose, trouble will develop and your reputation is sure to suffer. That is why it is a serious and costly mistake to build your product without using throughout, the most efficient lock washer.

Shakeproof lock washers are acclaimed as the most efficient lock washer ever produced. The twisted steel teeth bite into both the nut and the work—it takes applied pressure to release their hold. They won't spread—they're tangle-proof and rust-proof, too. On production, Shakeproof lock washers handle easier—this means faster, neater work and lower costs.

A test in your own shop will prove all these facts—send for samples today. Please advise bolt sizes and type desired.

SHAKEPROOF
Lock Washer Company

(Division of Illinois Tool Works)
2529 N. KEELER AVE. • CHICAGO, ILL.

"It's the Twisted Teeth that lock"

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

Piezo Electric Crystals and Constant Temperature Equipment

Piezo Electric Crystals:

We are prepared to grind Piezo Electric Crystals for POWER use to your assigned frequency in the 550 to 1500 KC band, *accurate to plus or minus 500 cycles* for $55.00 fully mounted. Crystals for use in the HIGH FREQUENCY BROADCAST BAND (4000 to 6000 KC) for POWER use, accurate to plus or minus .03% of your assigned frequency, fully mounted, $85.00. In ordering please specify type of tube used, plate voltage and operating temperature. All crystals guaranteed with respect to output and accuracy of frequency. Deliveries can be made within three days after receipt of order.

Constant Temperature Equipment

In order to maintain the frequency of your crystal controlled transmitter to a high degree of constancy, a high grade temperature control unit is required to keep the temperature of the crystal constant. Our unit is solving the problem of keeping the frequency within the 50 cycle variation limits. Our heater unit maintains the temperature of the crystals constant to BETTER THAN A TENTH OF ONE DEGREE CENTIGRADE; is made of the finest materials known for each specific purpose and is absolutely guaranteed. Price $300.00. Further details sent upon request.

Low Frequency Standards:

We have a limited quantity of material for grinding low frequency standard crystals. We can grind them as low as *15,000 cycles.* These crystals will be ground to your specified frequency accurate to ONE HUNDREDTH OF ONE PER CENT. Prices quoted upon receipt of your specifications.

Scientific Radio Service

"The crystal specialists"

P. O. Box 86 Dept. R6 Mount Rainier, Md.

NEW

{ACTUAL SIZE .1}

and Greater Capacity

«CUB» Condensers

Now Available in Capacities
Ranging from .0001 to .25 Mfd.

Cut Labor Operations
and Cost 20% to 50% Less

Cornell

FILTER CONDENSERS
BY-PASS CONDENSERS
RADIO INTERFERENCE FILTERS
POWER FACTOR CORRECTION BANKS
UNIFORMLY HIGH INSULATION RESISTANCE
PAPER DIELECTRIC CONDENSERS

(ALL TYPES)

Cornell is equipped to give you what you want when you want it at prices within the range of commercial set manufacturing.

Write for a Sample "Cub" Condenser and Catalog of Complete Line of Cornell Products.

Cornell Electric Mfg. Co., Inc.
LONG ISLAND CITY, NEW YORK

Jewell Instruments *for* Radio Service

Through close contact and careful study of radio service problems, Jewell has developed instruments that exactly meet the requirements of radio testing.

Radio engineers and service managers can materially improve the servicing of their equipment by the recommendation of Jewell Set Analyzers and other equipment to their service men.

Jewell service instruments are available in a great variety of types for every radio testing requirement. Write for bulletin.

Pattern 579 Service Test Panel with remote control is one of the recent Jewell achievements. Seven large 5-inch meters with clean-cut, legible scales and knife edge type pointers, remote control with push button switches of the selective type, color coding of instruments and push buttons all combine to make the Pattern 579 the most convenient, rapid, and accurate equipment for laboratory testing of radio receivers.

Jewell Electrical Instrument Company

1642-D Walnut Street, Chicago

30 YEARS MAKING GOOD INSTRUMENTS

JEWELL

AEROVOX DRY ELECTROLYTIC FILTER CONDENSERS

A NEW Condenser for Filter Circuits

—0—
Dry
—0—
Low Cost
—0—
High Capacity
—0—
Improved Filtering
—0—
Better Tone Quality
—0—
High Voltage Rating
—0—
Long Lived
—0—
Surge Proof
—0—
Safe

We shall be glad to go over with you the advantages in quality, performance and savings which Aerovox Dry Electrolytic Condensers will make possible in your filter circuits.

The Research Worker is a free monthly publication treating on the proper application of condensers and resistors in radio circuits.

A 32-page Catalog containing detailed descriptions and specifications of condensers and resistors is yours for the asking.

Write for both the Research Worker and the Catalog.

Aerovox Dry Electrolytic Condensers are admirably suited for use in filter circuits in which the following characteristics increase the efficiency and safety of the filter circuit and reduce its cost.

1. DRY: Aerovox Dry Electrolytic condensers have no solution to spill or evaporate. They eliminate all trouble usually encountered in packing, shipping and servicing electrolytic condensers in which a liquid solution is employed.

2. FILTER ACTION: The filter action per microfarad of Aerovox Dry Electrolytic Condensers is equivalent to that of paper condensers.

3. COST: The cost of Aerovox Dry Electrolytic Condensers is much lower than paper condensers of equivalent capacity and voltage rating.

4. COMPACTNESS: The cubic contents of an Aerovox Dry Electrolytic Condenser is much less than that of a paper condenser of equivalent capacity and voltage rating.

5. EFFECT ON TONE QUALITY: The improved filtering obtainable from the higher capacity which can be utilized with Aerovox Dry Electrolytic Condensers per dollar of cost, makes possible a great improvement in tone quality by eliminating modulation of signal by the fundamental frequency and harmonics of the power supply.

6. VOLTAGE RATING: An improved process employed in making the Aerovox Dry Electrolytic Condensers has resulted in a marked increase in rating of this type of condenser to 500 volts D.C. maximum peak, permitting their use without resorting to expensive series connections, in circuits where ordinary electrolytic condensers cannot be employed. This feature is particularly important in connection with power supply units designed for operation with 245 type power tubes at rated characteristics.

7. SURGE PROOF: Puncture of the dielectric, due to surges, does not injure the condenser, the dielectric film healing itself automatically when the temporary surge dies out.

8. SAFETY: Within a short time after the voltage or charging source is discontinued, the energy of the residual charge is dissipated through leakage, thus eliminating the danger from shocks, often met with in paper condensers which hold their charge for long periods.

9. SURGE LIMITING CHARACTERISTICS: The comparatively high leakage current drawn temporarily as the power supply unit is turned on, limits the peak no-load voltages applied in the power supply circuits and protects bypass condensers in the various receiver and amplifier circuits.

10. LONG LIFE: Self-healing characteristics of the Aerovox Dry Electrolytic Condenser eliminates permanent breakdowns due to temporary overloads from surges and increases the life of the condenser almost indefinitely.

11. HUM ELIMINATION: Because of the much lower cost per microfarad of the dry electrolytic condenser, it is economically practical to use higher capacities than with paper condensers with consequent reduction of hum in filter circuits to a negligible minimum.

12. UNAFFECTED BY ATMOSPHERIC CONDITIONS: The Aerovox Dry Electrolytic Condenser sections are sealed to prevent any harmful effects from atmospheric conditions.

AEROVOX WIRELESS CORP.
80 WASHINGTON ST.
BROOKLYN, N. Y.

The "Synthetic" Age

THE true value to you, and *usefulness*, of ANY material, is not what it is,—*before* you are using it. Its *true* value depends on:

What it will do.......FOR you.
What you can do......TO it.
What you can do..WITH it.

In the STONE age, the advance in civilization was not in the Stone itself. It was in what people did WITH it, and TO it, and what it did FOR them.

In the IRON age,—our own rapid advances in civilization, and in standards of living, have been not merely from the fact that Iron *existed*,—but from what it does FOR us; what we have learned we can do TO it; and what we can do WITH it.

In the "SYNTHETIC" age,—the age of synthetic materials which we are entering now, exactly the same is true; it is conceded that the most important of the Synthetic Materials are the CELLULOSE GROUP, developments in which have been led by VULCANIZED FIBRE—the material of a million uses.

This company made the first Vulcanized Fibre in America, and for more than fifty years has led in scientific advancements which, starting from that crude first product fifty-seven years ago, have developed into the many different types of vulcanized fibre and phenolite which we now make,—perfected for the various requirements of Engineering and Industry.

Actually NEW materials, in terms of "What they will do FOR you; what you can do TO them; and WITH them."

* * *

In all Industry, there is now a new awakening to the fact that too often the *REAL* drag on profits, and on success in competition, is the using of *WRONG MATERIAL.*

In all the *New Thoroughness* there is the one indispensable factor,—the question — *Are you Thinking IN THE RIGHT MATERIAL?*

NVF

Write for Fact-Sheets of Industry, No. 1,—practical knowledge which hitherto has not been readily accessible—Mailed FREE to any worker or executive. Limited edition—Write NOW. State work you do, your company's product or business, and whether request is for self. Address Librarian (Dept. L-4) National Vulcanized Fibre Company, Wilmington, Delaware, U.S.A.

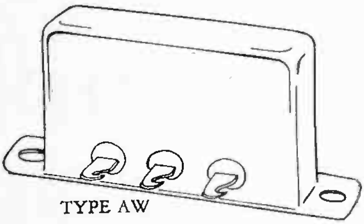
NATIONAL VULCANIZED FIBRE COMPANY

Makers of "Peerless" insulation; Special Phenolites; "righter" Bakelites; many kinds of Vulcanized Fibre; Material Handling equipment, etc . . . Serving America's industries from smallest to greatest.

Announcing

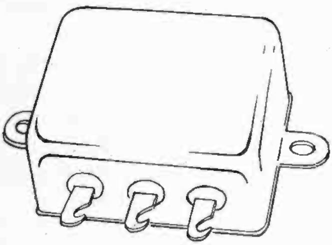
Two New Types of

BY-PASS CONDENSERS



TYPE AW

(Series A) Designed for use where chassis space is at a premium. Two or three lugs in position shown.



TYPE BW

(Series B) Designed for use where flat mounting is desirable. One or three lugs through side.

This announcement marks our entrance into the by-pass field. Materials and workmanship in this new line are of the same dependable quality that have caused our high voltage filter condensers to win the approval of the radio industry for their efficient performance. There are available over 240 combinations of capacity voltages and lug or lead arrangements. Write now, enclosing your specifications, for information and prices!

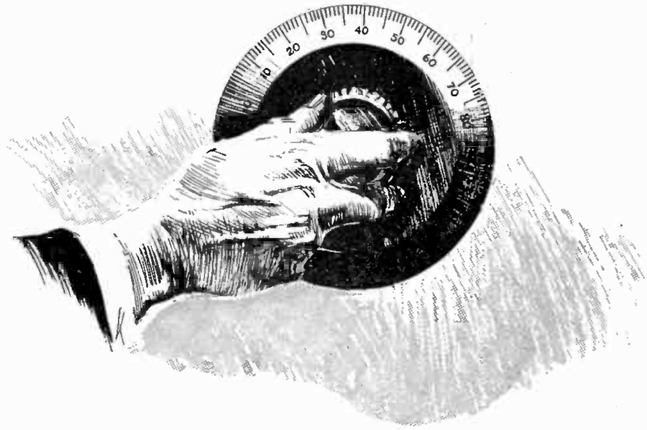
CONDENSER CORPORATION OF AMERICA

259 Cornelison Ave., Jersey City, N.J.

Factory Branches in

Chicago
Cincinnati

Los Angeles
Toronto



Tuning the Boilershop!

THERE'S a conglomeration of sounds in the air—words, music, static, and just sounds. Untuned, they would seem much like a boiler-shop to the ear. Tuned, they become just what the radio listener wants to hear.

It's a far cry from the old coil tuner to the modern variable condenser—but Scovill has been helping the radio engineer and the radio industry from those very earliest days—helping with parts that are right.

Scovill radio condensers, for instance, are recognized as the last word in quality by the foremost manufacturers. They are specified on the finest "sets"—they help the manufacturer to claim better tuning qualities for his product—they help to build his sales.

If you want to know more about Scovill products for radio, tune in a Scovill representative from the nearest office. You'll find the story an interesting one—and profitable.

SCOVILL

Established 1802

MANUFACTURING COMPANY

· WATERBURY ·· CONNECTICUT ·

BOSTON
ATLANTA
CHICAGO
PROVIDENCE
CLEVELAND
LOS ANGELES

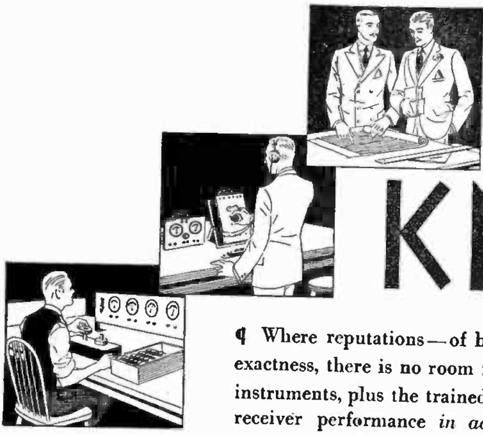
SCOVILL

NEW YORK
DETROIT
SAN FRANCISCO
PHILADELPHIA
CINCINNATI

In Europe—THE HAGUE, HOLLAND

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

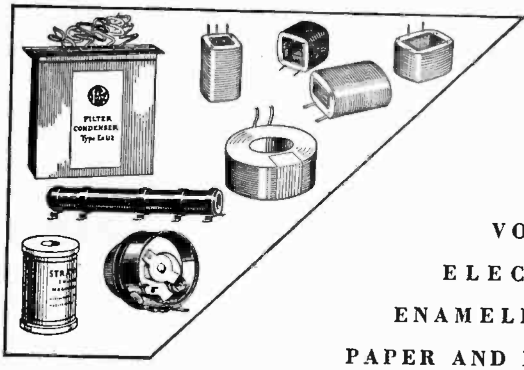
radio engineers do not guess—



THEY KNOW

¶ Where reputations—of both products and men—depend on exactness, there is no room for guesswork. ¶ Modern measuring instruments, plus the trained scientific mind, determine radio receiver performance *in advance.* The certainty of this performance is guaranteed by the use of tested and proven parts. ¶ Polymet Products have been approved by the engineering laboratories of practically all leading receiver manufacturers. Over 80% of them use Polymet Products in their production — — —

which is possibly the best proof that "Polymet Engineers do not guess;—*they know*, too!"



RESISTORS
TRANSFORMERS
VOLUME CONTROLS
ELECTRICAL COILS
ENAMELED MAGNET WIRE
PAPER AND MICA CONDENSERS

POLYMET MANUFACTURING CORP., 829 East 134th St., New York City

Polymet Products

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

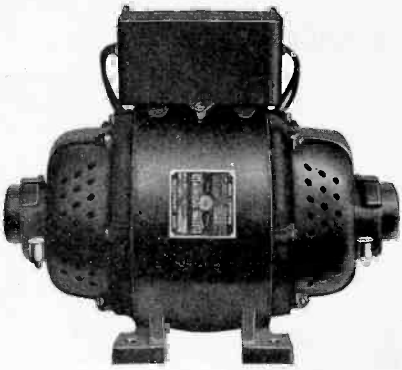
«ESCO» Power Supply for Radio Equipment

Machines for operating 60-cycle A. C. Radio Receivers, Loud Speakers and Phonographs from Direct Current Lighting Sockets Without Objectionable Noises of any Kind.

The dynamotors and motor generators are suitable for radio receivers and for combination instruments containing phonographs and receivers. Filters are usually required. The dynamotors and motor generators with filters give us good or better results than are obtained from ordinary 60-cycle lighting sockets. They are furnished completely assembled and connected and are very easily installed.

These machines are furnished with wool-packed bearings which require very little attention, and are very quiet running.

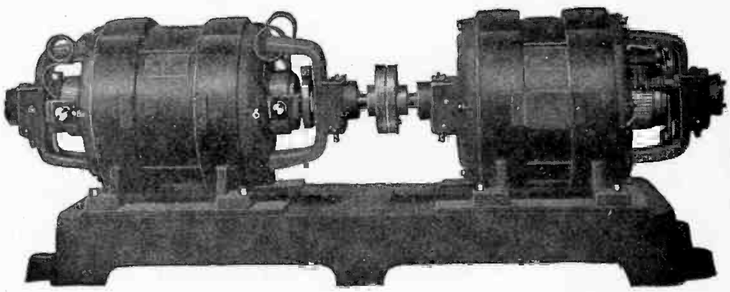
Write for Bulletin No. 243-D



Dynamotor with Filter for Radio Receivers

Type NA Aircraft Generator

Low wind resistance, light weight, non-corroding parts, ball bearings, tool steel shafts, steel shells, cast steel pole pieces, weather proof construction, many sizes to choose from, high voltage and low voltage windings to suit individual requirements, are a few of the many reasons for "ESCO" generators or dynamotors being the first choice.



Type BFR, Two Unit Motor Generator Set

"ESCO" two and three unit sets have become the accepted standards for transmission. The "ESCO" line consists of over 300 combinations. These are covered by Bulletin 237G.

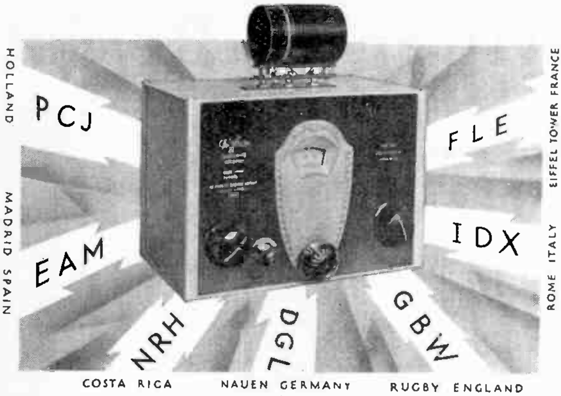
"ESCO" also manufactures synchronous motors for television and "talkie" projectors. Motor generators and dynamotors for power amplifiers and public address systems.

ELECTRIC ESCO SPECIALTY COMPANY

300 SOUTH ST., STAMFORD, CONN.

Manufacturers of motors, generators, dynamotors and rotary converters.

The latest achievement of the De Forest Laboratories



BRINGS THE WORLD OF RADIO
TO YOUR FIRESIDE
The NEW
DE FOREST SHORT WAVE RECEIVER

The new De Forest Radiophone Receiver, Type CS5 illustrated above, costs but $75.00. It is designed to receive both telephone and telegraph signals on all frequencies between 1,500 and 15,000 kilocycles (20 to 200 meters). Being small and light, it is excellent for portable work. Its enormous amplification giving loud speaker signals on a 10-ft. antenna.

The special circuit uses four Audions: two Screen Grid Audions as radio frequency amplifier and space-charge-grid detector (power detector) and two Audions in a transformer-coupled audio amplifier.

Housed in an aluminum case, 5" x 6" x 9", this receiver, although full-grown in strength and performance, makes an ideal short wave receiver for aircraft reception where light weight is a necessity. It is also adapted for general amateur use, small yachts, police cars and automobiles.

DE FOREST RADIO CO., PASSAIC, N. J.
Branch Offices Located in
Boston, New York, Philadelphia, Atlanta, Pittsburgh, Chicago, Minneapolis, St. Louis, Kansas City, Denver, Los Angeles, Seattle, Detroit, Dallas, Cleveland

de Forest
AUDIONS
RADIO TUBES

- - - - - - - USE THIS COUPON - - - - - - -

Specifications for DeForest Radiophone Receiver Type CS5
Battery Requirements. Operates either from dry cells using Audions 442A and 499 or from 6-volt storage battery using Audions 422 and 401A. For loud speaker operation either Audions 420, 412A or 471B may be inserted in the last audio stage. Two 45-volt "B" batteries furnish the plate power.
Features, extremely compact and light in weight. Screen grid R. F. Amplifier. Space-charge-grid power detector. Two stages of audio amplification. Zero body capacity. Frequency calibration independent of antenna used. Moisture and climate-proof. Negligible microphonics.

De Forest Radio Company
Passaic, New Jersey

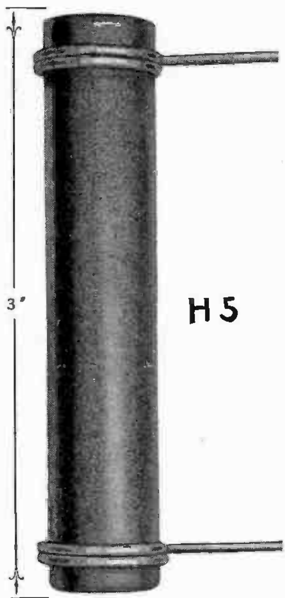
Enclosed please find $———for which send me one De Forest short wave receiver.

Name ....

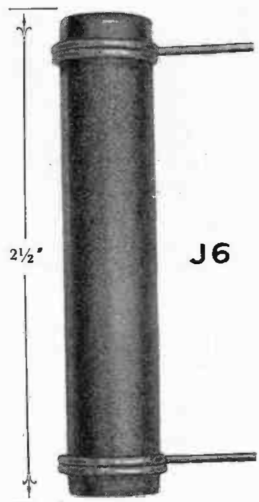
Address ....

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

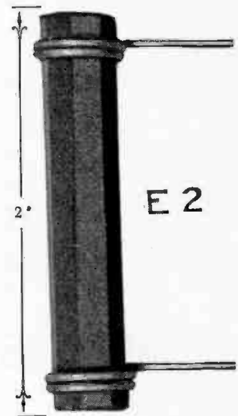
Continental Resistors



5 Watts



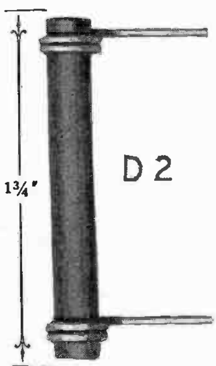
3½ Watts



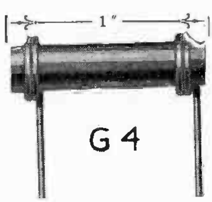
2 Watts

CHARACTERISTICS:

NOISELESS
RESISTANCE CONSTANT
SMALL TEMPERATURE COEFFICIENT
RUGGED
FIRMLY SOLDERED TERMINALS
DEPENDABLE
COLOR CODED



1 Watt

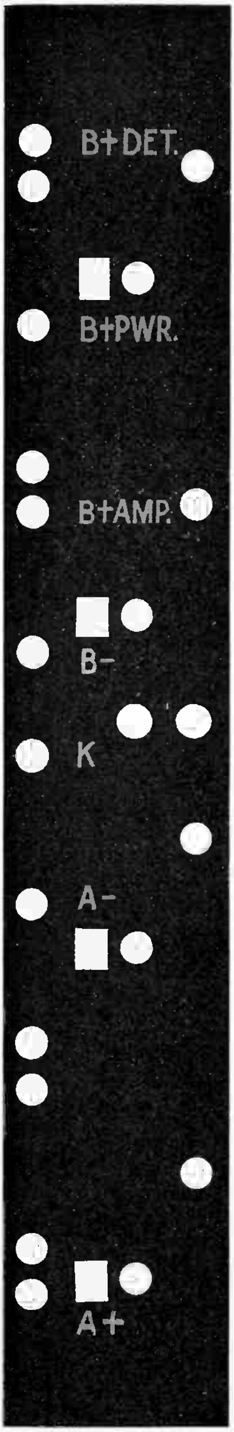


¾ Watt

½ Watt

Write for Information and Prices

CONTINENTAL CARBON INC.
WEST PARK, CLEVELAND, OHIO



Insulation . . .

that has the Engineers' Confidence

THE ENGINEERS of leading American electrical organizations have shown their confidence in Formica by specifying it for the past 17 years.

To deserve this confidence Formica has consistently added to its equipment and its organization. It has kept a competently manned laboratory constantly working on the improvement of the material.

Formica today is prepared to give better material than ever before in its history.

Send your blueprints for quotations

THE FORMICA INSULATION CO.
4646 Spring Grove Ave.
CINCINNATI, O.

FORMICA
Made from Anhydrous Bakelite Resins
SHEETS TUBES RODS

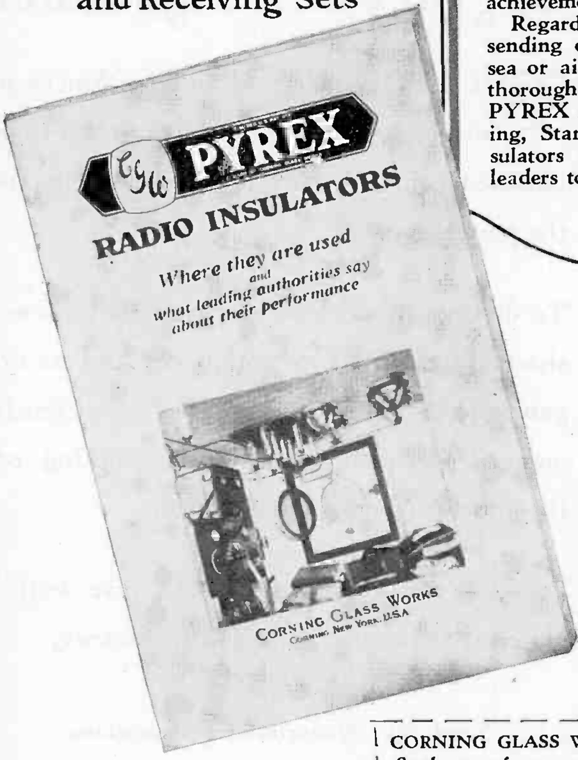
When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

A SAFE GUIDE

in the selection of insulation for Radio Transmitting and Receiving Sets

OVER 300 broadcasting stations, leading radio telegraph systems, the United States Army, Navy, Air Mail, Coast Guard and Ice Patrol Services, explorers like Commander Byrd, and exacting amateurs everywhere have utilized PYREX Insulators in many spectacular achievements.

Regardless of whether you are sending or receiving—on land, sea or airplane—you should be thoroughly familiar with the PYREX Antenna, Strain, Entering, Stand-off and Bus-bar Insulators that are helping these leaders to make radio history.



The new PYREX Radio Insulator booklet lists all types and sizes with data that you will want for ready reference.

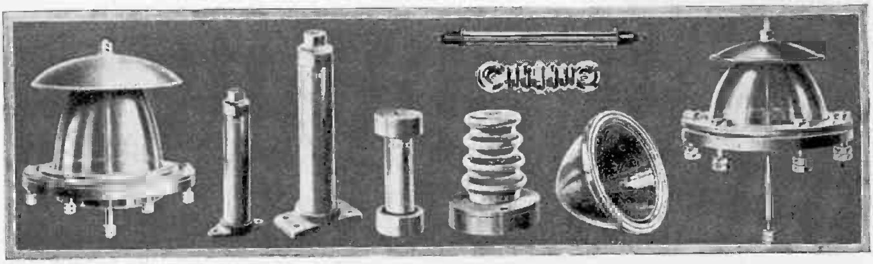
Return the coupon for your copy, and if you want further advice on any insulation problem, our Technical Staff will answer your questions promptly.

CORNING GLASS WORKS, Corning, N. Y.
Send copy of your new bulletin on Radio Insulators

Name ....

Address ....

I. R. E. 5-30



CHANGE IN MAILING ADDRESS OR BUSINESS TITLE

Members of the Institute are asked to use this form for notifying the Institute office of a change in their mailing address or any change in the listing of their company affiliation or title for the Year Book membership list.

- -

The Secretary,
THE INSTITUTE OF RADIO ENGINEERS,
33 West 39th Street,
New York, N.Y.

Dear Sir:

Effective .... please note change in my address
(date)
for mail as follows:

FROM

....
(Name)

....
(Street Address)

....
(City and State)

TO NEW ADDRESS

....
(Street Address)

....
(City and State)

Also for the membership list for next year's Year Book note change in my business address (or title) as follows, this is / is not my mailing address:

....
(Title)

....
(Company Name)

....
(Address: Street, City and State)

PLEASE FILL IN, DETACH, AND POST TO THE INSTITUTE PROMPTLY

Back Numbers of the Proceedings Available

MEMBERS of the Institute will find that back issues of the Proceedings are becoming increasingly valuable, and scarce. For the benefit of those desiring to complete their file of back numbers there is printed below a list of all complete volumes (bound and unbound) and miscellaneous copies on hand for sale by the Institute.

The contents of each issue can be found in the 1914-1926 Index and in the 1929 Year Book (for the years 1927-28).

BOUND VOLUMES:

Vols. 10 and 14 (1922-1926), $8.75 per volume to members

Vol. 17 (1929), $9.50 to members

UNBOUND VOLUMES:

Vols. 6, 8, 9, 10, 11 and 14 (1918-1920-1921-1922-1923-1926), $6.75 per volume (year) to members

MISCELLANEOUS COPIES:

Vol. 1 (1913) July and December

Vol. 2 (1914) June

Vol. 3 (1915) December

Vol. 4 (1916) June and August

Vol. 5 (1917) April, June, August, October and December.

Vol. 7 (1919) February, April and December

Vol. 12 (1924) August, October and December

Vol. 13 (1925) April, June, August, October and December

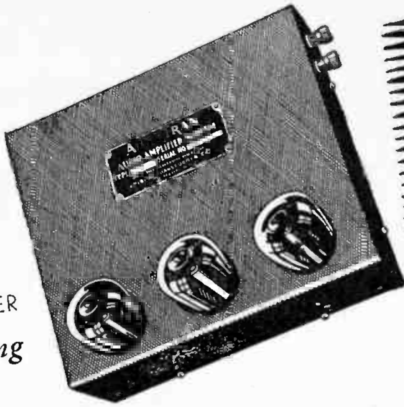
Vol. 15 (1927) April, May, June, July, August, October, November and December

Vol. 17 (1929) April, May, June, July, August, September, November and December

These single copies are priced at $1.13 each to members to the January 1927 issue. Subsequent to that number the price is $0.75 each. Prior to January 1927 the Proceedings was published bimonthly, beginning with the February issue and ending with December. Since January 1927 it has been published monthly.

Make remittances payable to the Institute of Radio Engineers and send orders to:

THE INSTITUTE OF RADIO ENGINEERS
33 West 39th Street
NEW YORK, N. Y.



FULL VOLUME

OR THE MEREST WHISPER

With no distortion along the entire range

The AmerTran Push-Pull Amplifier, Type 2-AP*, is designed for radio listeners who truly appreciate fine music and its reproduction exactly as broadcast. With efficient loud speakers it will furnish ample volume for dancing in a large hall and agreeable rendition in a moderate sized auditorium. Or you can tune down a musical program to a faint, melodious background for an evening by the fireside.

There is no distortion at any volume. The shrill, bird-like treble of the flute has the same rich quality as the somber bass of organ or cello.

The Type 2-AP is a high quality two-stage transformer coupled audio amplifier with a push-pull power stage. It is designed for A. C. operation with a--27 A. C. tube in the first stage followed by standard power tubes in the push-pull stage, and is intended to be connected to the detector of any good receiver and operated from an A. C. power supply system, such as the AmerTran Power Box, Type 21-D.

For complete information on the Type 2-AP Amplifier, write for Bulletin 1075-A.

AMERICAN TRANSFORMER COMPANY
172 Emmet Street, Newark, N. J.

AMERTRAN
TRADE MARK REG. U.S. PAT. OFF.

Quality Radio Products

*Licensed under patents of the Radio Corporation of America and associated companies for radio, amateur, experimental and broadcast reception.

AMERICAN TRANSFORMER CO., 172 Emmet St., Newark, N.J. I. R. E.—5-30

Gentlemen:

Please send me Bulletin 1075-A containing complete information on Type 2-AP Amplifier.

Name.............................. Street..............................

Town.............................. State..............................

EVERYBODY WILL BE THERE

where?

ATLANTIC CITY

when?

June 2nd to 6th

why?

4th Annual RMA Trade Show
and
Joint I.R.E.-RMA Technical Session (June 3rd)

Atlantic City abounds in first class hotels. Visitors to the Trade Show and the I.R.E.-RMA Technical Session can be assured that an average of $10.00 per day will cover living expenses. All railroads are offering special fare and one-half rates for the round trip to Atlantic City.

Make your hotel reservations through the Atlantic City Convention Bureau, Atlantic City, N.J.

WHY KEEP A PROSPECT WAITING 50 SECONDS?

by George Lewis, Vice-President,
Arcturus Radio Tube Company

INTERESTED buyers of radio sets deserve careful treatment. They don't like to wait. And the 30- to 60-second delay caused by the slow starting speed of many tubes often loses sales.

Happily, there is an easy way to avoid this wait—embarrassing to your dealers, irritating to their customers. Just see that your sets are equipped with Arcturus *Blue* Tubes . . . the tubes that bring in programs in 7 seconds by your watch.

Arcturus Tubes have other features, too, that help sell sets and keep them sold after the sale is made. They are famous for clear, humless tone; and their dependability and long life mean minimum servicing.

Consumers judge a radio set by its tubes. Make sure *your* set has the added advantage that only Arcturus Tubes give.

ARCTURUS RADIO TUBE COMPANY, Newark, N.J.

ARCTURUS
Quick Acting
RADIO TUBES

INSURE those AC sets!

No matter how well you may design, manufacture and service those A.C. sets, remember, you are forever *gambling* with one uncertain factor—LINE VOLTAGE.

You have come to take the so-called "110-volt" supply for granted. The light and power companies hasten to assure you that they maintain line voltages constant. You have provided your sets with adjustable taps for "high" and "low" line voltages. No one has complained—as yet.

But nevertheless, radio consumers are now complaining to your dealers. They are going to complain to you. Tube manufacturers are complaining because of excessive replacement claims. And you are going to complain too, when you are called upon to make good on broken-down power packs, let alone the loss of good will and future sales.

Play safe. Until now this meant the installation of a line voltage regulator in the radio set itself. Sets out in the market could not be protected satisfactorily. But now you can protect your outstanding sets quite as well as the sets now being designed. And here's the answer—

Automatic
Line Voltage Regulator
CLAROSTAT

An accessory—not a built-in device—attached instantly, without tools, skill or experience. Simply insert prongs of usual attachment plug into slots of this device. Insert prongs of this device into slots of usual screw plug or convenience outlet. The *Automatic* Voltage Regulator Clarostat is now part of the circuit. Your radio set is assured of uniform and proper working voltage, irrespective of line voltage conditions.

It's *AUTOMATIC.* Not just a plain fixed resistance, which fails to compensate for reduced line voltage. This device provides a greater or less resistance between electric light line and radio set, compensating *automatically* and accurately for line voltage variations. When line voltage is high, the resistance is likewise high, causing necessary voltage drop for safeguarding radio set. When voltage is normal or subnormal, resistance is slight, causing small voltage drop. The usual fixed resistance, contrariwise, remains fixed, and when the line voltage drops, it chokes the radio set as indicated by loss of sensitivity, volume and tone quality.

If you are a MANUFACTURER—recommend the *Automatic* Line Voltage Regulator Clarostat for your sets now in the hands of the trade and the public. And for those sets now going into production, make doubly sure by having them equipped with the Clarostat Line Voltage Ballast as a built-in feature.

If you are a SERVICE MAN—be sure to install the *Automatic* Line Voltage Regulator Clarostat, for every set you install or service. Don't gamble with your clientele. Avoid criticism of your work. And incidentally, make a profitable sale with this accessory.

WRITE for data. Mention the type of set you wish to insure against line voltage dangers, and we shall gladly recommend the proper accessory or built-in equipment.

CLAROSTAT MANUFACTURING COMPANY, INC.

Specialists in Aids to Better Radio

289 North Sixth Street :: Brooklyn, N. Y.

When writing to advertisers mention of the PROCEEDINGS *will be mutually helpful.*

ENGINEERS AVAILABLE

Advertisements on this page are available only to members of the Institute of Radio Engineers. For rates and further information address the Secretary, The Institute of Radio Engineers, 33 West 39th Street, New York, N.Y.

MANUFACTURERS and others seeking radio engineers are invited to address replies to these advertisements at the Box number indicated, care the Institute of Radio Engineers. All replies will be forwarded direct to the advertiser.

TEST ENGINEER, three years' experience inspection, testing and construction and maintenance of radio test equipment, four years' previous experience as commercial operator desires position in charge of factory production or construction and operation of radio communication system. Graduate of radio and high schools. Age 29. Box 21.

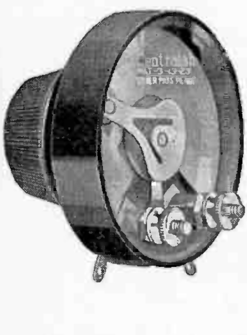
TEST ENGINEER, 3½ years college, six years' responsible work on inspection and test radio receivers. Desires position in charge of quality control of radio manufacturing and factory engineering. Age 30. Box 22.

ENGINEER and inventor, experienced in the installation of broadcast transmitting equipment, operation and instruction in radio, desires domestic or foreign connection as installation engineer of transmitting or sound equipment. Age 40. Box 23.

RADIO ENGINEER, two years college, four years' experience on development, construction, and maintenance of test equipment for radio receivers. Desires work on development and construction of radio testing equipment. Age 23. Box 24.

Volume Controls

Manufactured in three sizes
Standard
Junior
Midget
Also Double Standard
and Double Junior
Special Combination
Wire Wound and
Graphite Control



TO vary the intensity of the faithful reproduction built into radio receivers without introducing noise or distortion, can only be accomplished by a careful and complete consideration of both mechanical and electrical features of the volume control.

Mechanically—The Centralab exclusive and patented rocking disc contact precludes any possibility of wear on the resistance material. This feature adds to the smoothness of operation since the contact shoes ride only on the disc. The shaft and bushing are completely insulated from the current carrying parts—eliminating any hand capacity when volume control is placed in a critical circuit.

Electrically — Centralab engineers have evolved tapers of resistance that produce a smooth and gradual variation of volume. These tapers have been thoroughly tried and tested for each specific application for current carrying capacity and power dissipation.

Centralab volume controls have been specified by leading manufacturers because of their quality and ability to perform a specific duty—Vary the intensity of faithful reproduction—faithfully.

Write for full particulars of specific application.

Centralab
CRL
CENTRAL RADIO LABORATORIES
36 Keefe Ave. Milwaukee, Wis.

A CENTRALAB VOLUME CONTROL IMPROVES THE RADIO SET

PROFESSIONAL ENGINEERING DIRECTORY

For Consultants in Radio and Allied Engineering Fields

THE MAGNAVOX COMPANY

Oakland, Calif. & Chicago, Ill.

PIONEERS AND SPECIALISTS IN THE ART OF SOUND PRODUCTION.

DYNAMIC SPEAKERS SINCE 1911.

RADIO ENGINEERS

Ten dollars will introduce you directly to over 7,000 technical men, executives, and others with important radio interests. For details write to

Advertising Dept., I.R.E.

Electrical Testing Laboratories

Tests of inductances, condensers, transformers, etc. Life and characteristics of radio tubes.

80th Street and East End Avenue
NEW YORK CITY, N. Y.

The J. G. White Engineering Corporation

Engineers—Constructors

Builders of New York Radio Central

43 Exchange Place New York

Radio Engineers

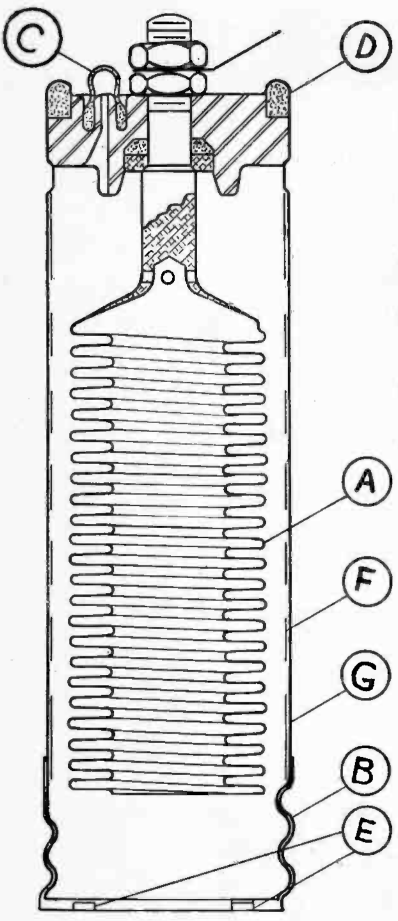
Your card on this professional card page will give you a direct introduction to over 7,000 technical men, executives, and others with important radio interests.

Per Issue—$10.00

Alphabetical Index to Advertisements

Fool Proof Condenser Performance

Compare the 8MFD Sprague Electrolytic with any other condenser. Use it—test it—and judge for yourself its amazing performance. And here are just a few of the reasons why Sprague Electrolytic Condensers can give you better service.



A One piece anode made entirely of pure aluminum; no welded or riveted joints either above or below the electrolyte.

B Screw type socket mounting making for maximum flexibility in receiver design.

C Protected vent eliminating the possibility of damaging the nipple.

D Pressure seal, with no possibility of cutting gasket.

E Locking lugs in socket to prevent condenser shaking loose during shipment.

F Shield, precluding possibility of internal short circuit.

G Individual container allowing space to be utilized with maximum flexibility.

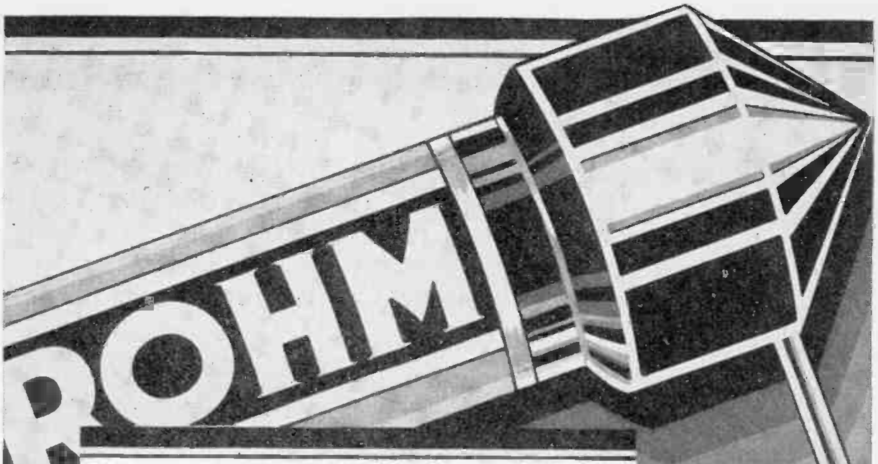
Individual cathodes eliminate all leakage between anodes and allow maximum flexibility in circuit design. Increased life, less leakage and much better shelf characteristics due to anode with edge effect of less than 10% of spiral type. Leakage current guaranteed not to exceed .2 milliamperes per MFD at 400 volts after 5 minutes or .065 milliamperes per MFD at 350 volts after 5 minutes.

And there are the well known paper condensers made by Sprague—made with the same precise skill as the Sprague electrolytic. Types and sizes to fit your every condenser need.

SPRAGUE SPECIALTIES COMPANY
QUINCY, MASSACHUSETTS

SPRAGUE ELECTROLYTIC AND PAPER CONDENSERS
WILL SOLVE YOUR CONDENSER PROBLEMS

SPRAGUE



We make the Resistor *you* are looking for!

All values and all types for all purposes . . . radio, sound pictures, television, photocell work, etc. . . . resistances made according to the Durham policy of greater accuracy, greater dependability and longer life. Data sheets and samples for test sent promptly. Write for the ratings which interest you.

DURHAM METALLIZED

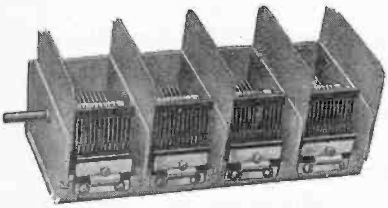
RESISTORS & POWEROHMS

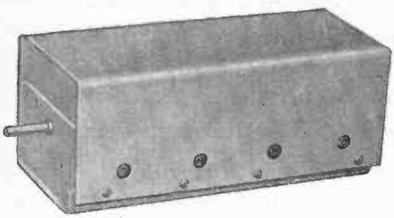
INTERNATIONAL RESISTANCE CO.

2006 Chestnut Street, Philadelphia, Pa.

TRADE MARK

UNITED SCIEN. LAB INC.





COMPARE!

We will be glad to send you complete specifications of this new United Scientific Type S.G. Condenser, but we would rather send you a sample. Then you can test it in your own laboratory. You can compare it with any other condenser on the market and draw your own conclusions.

After all, isn't that the answer?

Write for a Sample, Prices, and More Complete Information

UNITED SCIENTIFIC LABORATORIES, Inc.

115-C Fourth Avenue, New York City

Branch Offices for Your Convenience in

St. Louis
Chicago
Boston
Minneapolis
Cincinnati

RADIO MANUFACTURERS ASSOCIATION RMA MEMBER

Los Angeles
Philadelphia
San Francisco
London, Ontario

When Your Problems —Are Ours

WHEN you invite us to help decide the proper resistor for use in your equipment, the chances are good that you will save time and future expense. Make your resistor problems ours and you have the cheerfully-given advice which comes from more than 39 years' experience in the design and manufacture of Vitrohm Resistors.

It is surprising how frequently difficulties in space, mounting or heat dissipation are difficulties no longer when reference is made to the records of one of the more-than-a-million jobs turned out by Ward Leonard.

You have in Ward Leonard an auxiliary plant, modern, skilled in the development of new resistor requirements, speedy and accurate in production, and capable of meeting your production requirements, however large.

Meet and know the Ward Leonard Sales Engineer serving your territory. His knowledge of the industry in general, and control equipment in particular will interest you. Ward Leonard manufactures a wide variety of products* and operates in many divisions of the electrical industry.

WARD LEONARD ELECTRIC CO.

31 South Street, Mt. Vernon, N.Y.

Resistor Specialists for More Than 39 Years

* Vitrohm (vitreous enamelled) Resistors and Rheostats . . . . Voltage Regulators . . . . Theatre Dimmers . . . . A.C. and D.C. Motor Starters and Controllers . . . . Field Rheostats . . . . Arc and Spot Light Rheostats and Ballasts . . . . Mobile Color Lighting Equipment . . . . Adaptorons . . . . D. C. Battery Charging Equipment . . . . Circuit Breakers

A.H.GREBE & CO., Inc.

RICHMOND HILL, NEW YORK

Grebe radio

SUPER-SYNCHROPHASE

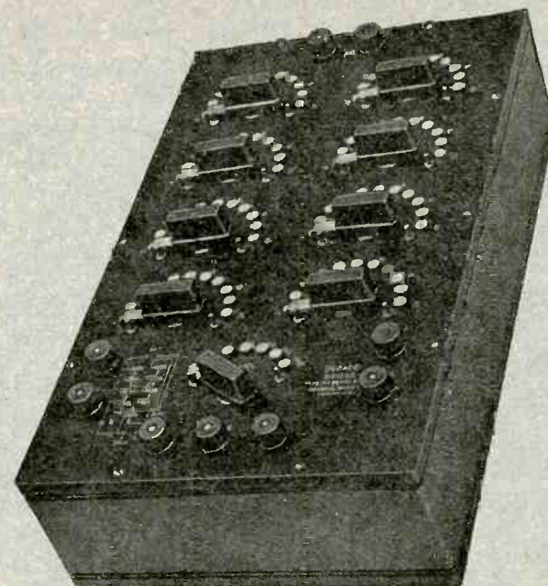
WESTERN BRANCH

443 South San Pedro Street

Los Angeles, California

MAKERS OF QUALITY RADIO SINCE 1909

A GENERAL-PURPOSE BRIDGE



Type 193
Decade Bridge

Price $115.00

THE TYPE 193 Decade Bridge is a general utility bridge designed for measurement of resistance, capacitance, and inductance at audio frequencies. Standards may be either adjustable or fixed, but the former are much to be preferred.

The dial-switch method of adjusting the ratio arms and the resistance compensation arm greatly facilitates making adjustments. Each decade switch has 11 stops (0 and 10) which further add to the convenience of the instrument.

By a suitable choice of the standards and the ratio arms, the bridge may be made direct reading.

GENERAL RADIO COMPANY
CAMBRIDGE A, MASSACHUSETTS

British Branch: 40 Buckingham Gate,
Westminster, London, S.W. 1

GENERAL RADIO INSTRUMENTS

FOR MEASURING ELECTRICAL QUANTITIES AT ALL FREQUENCIES

STANDARD AND SPECIAL ITEMS FOR LABORATORY AND INDUSTRIAL USE

GEORGE BANTA PUBLISHING COMPANY, MENASHA, WISCONSIN