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PROCEEDINGS
of
THE INSTITUTE OF RADIO ENGINEERS

(INCORPORATED)

OFFICERS, COMMITTEES, SUPPLEMENTARY LISTS OF MEMBERS AND ASSOCIATES OF THE INSTITUTE, AND GROWTH OF MEMBERSHIP CHART

THE EFFECT OF A PARALLEL CONDENSER IN THE RECEIVING ANTENNA
LOUIS W. AUSTIN

DIELECTRIC HYSTERESIS AT RADIO FREQUENCIES
E. F. W. ALEXANDERSON

SPECIFICATIONS FOR STEAMSHIP RADIO EQUIPMENT
ROBERT H. MARRIOTT

EDITED BY
ALFRED N. GOLDSMITH, Ph.D.
and the Editing Committee
John L. Hogan, Jr., Chairman, Lloyd Espenchied, Arthur A. Hebert, Louis W. Austin (ex-officio)

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DEARDORFF, RALPH W., Radio Experimenter; Box 21, R. F. D. 5, Phoenix, Ariz.	Oct. 14, 1914
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KNIGHT, MAURICE E., Machinist, American Voting Machine Co.; res., 3 Edwin St., Dorchester, Mass.	July 8, 1914
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LAAGER, CRESTON F. H., Draftsman, Standard Roller Bearing Co.; res., 1029 Belmont Ave., West Philadelphia, Pa.	July 1, 1914
LACHMAN, THEO., Operator and Radio Electrician, U.S. Naval Radio Station, Beaufort, N. C.	Aug. 12, 1914
LANGE, J. ROBERT, Radio Operator, Marconi Wireless Telegraph Co.; res., 1938 Lemmon St., Baltimore, Md.	July 8, 1914
LEE, SAMUEL E., Chief Electrician (Radio), U.S. Flagship "Wyoming," care Postmaster, New York;* res., Key West, Fla.	Aug. 26, 1914
LEHDE, PENDLETON E., Wireless Testing Engineer, Vaccaro Bros. Steamship and R. R. Co.; res., 2223 Magazine St., New Orleans, La.	Oct. 14, 1914
LEMON, LEE, Superintendent, Marconi Telegraph-Cable Co., 42 Broad St., New York;* res., 80 Prospect St., East Orange, N. J.	Sept. 9, 1914
LEVINSON, NATHAN, Shift Engineer, Marconi Wireless Telegraph Co., Kahuku, Oahu, T. H.	Aug. 12, 1914
LINDH, CHARLES, Radio Operator, Mutual Telephone Co., Kaunakakai, Molokai, T. H.	Aug. 26, 1914
LOHMANN, JOHN ANDREW, Plate Printer, Harry Wiltshire; res., 213 West 120th St., New York.	July 1, 1914
LONG, HARVEY H., Radio Operator, Marconi Wireless Telegraph Co., San Francisco, Cal.	Aug. 12, 1914
LOVEJOY, EDWIN W., Operator, Federal Telegraph Co.; res., 1818 Magnolia, Los Angeles, Cal.	July 8, 1914

* Denotes mailing address.

LYNCH, ARTHUR H., Radio Operator, Marconi Wireless Telegraph Co.; res., 118 St. James Pl., Brooklyn, N. Y. — Sept. 30, 1914

LYON, HARRY H., Student, McKinley High School; res., Hyatsville, Md. — June 3, 1914

MACKENZIE, ROY G., Radio Operator, Boston, Station, Marconi Wireless Telegraph Co.; res., 102 High St. Danvers, Mass.* — July 1, 1914

MAHER, EDWARD T., Student; res., 3409 Grove St., Oakland, Cal. — July 8, 1914

MANLEY, LEE L., Radio Electrician, Marconi Wireless Telegraph Co.; res., 788 Park Pl., Brooklyn, N. Y. — July 1, 1914

MARSHALL, LEONARD H., Radio Operator, Marconi Wireless Telegraph Co.; res., 240 Westchester Ave., Port Chester, N. Y. — Aug. 12, 1914

MARQUIS, A. N., JR., Westinghouse Electric Co., (Repair Shop); res., 618 Spring St., Seattle, Wash. — Aug. 26, 1914

MAYER, ARTHUR W., Radio Operator, Marconi Wireless Telegraph Co.; res., 7 Chestnut Sq., Jamaica Plain, Mass. — July 8, 1914

McCAY, DANIEL, Student, Cornell University, 6 South Ave., Ithaca, N. Y.;* res., 45 Lee Ave., Yonkers, N.Y. — July 1, 1914

McCREARY, ARTHUR R., McCreary Moore Co., 508 Hall St., Kansas City, Mo.;* res., 1407 East 35th St., Kansas City, Mo. — June 17, 1914

McGALL, PHILIP K., Radio Experimenter, 341 Gregory Ave., West Orange, N. J. — Oct. 14, 1914

McLELLAN, ARCHIBALD, Engineer, Marconi's Wireless Telegraph Co., care Marconi Trans-Atlantic Station, New Brunswick, N. J. — Oct. 14, 1914

MEYERS, EDWARD A., Telegraph Operator, Postal Telegraph-Cable Co.; res., 2079 Market St., San Francisco, Cal. — Aug. 12, 1914

MONCEAU, JEAN, Navigating Officer, Royal Dutch West India Mail, S.S. "Commerwyne," Amsterdam, Holland. — July 8, 1914

MOORE, ROBERT R., Secretary, Groves Bros. R. E. and Mtg. Co., Kansas City, Mo.; res., 200 East Armour Blvd., Kansas City, Mo.* — July 1, 1914

MORAN, LEON STEELE, Electrical Engineer, Testing Dept., Electric Cable Co.; res., 224 Washington Ave., Bridgeport, Conn. — July 8, 1914

MORSE, GUY E., Operator, Electric Park Radio Station; res., 4238 Harrison St., Kansas City, Mo. — July 8, 1914

MOYER, SAMUEL G., Clerk, Bureau of Navigation, Dept. of Commerce, Washington, D. C.; res., The Savoy, Washington, D. C.* — July 1, 1914

MUIR, JAMES B., JR., Student, University of California; res., 539 38th St., Oakland, Cal. — Oct. 14, 1914

NALLY, EDWARD J., Vice-President and General Manager, Marconi Wireless Telegraph Co., 233 Broadway, New York;* res., Ossining, N. Y. — July 1, 1914

NELSON, FRANCIS A., Operator, Marconi Wireless Telegraph Co., Miami Beach, Fla. — Aug. 26, 1914

* Denotes mailing address.

NICHOLLS, GEO. WM., Assistant to Manager, Boston Division, Marconi Wireless Telegraph Co.; res., 889 Salem St., Maplewood, Mass.	June 3, 1914
NICHOLSON, KNOX W., Student, Associated with Supreme Court, res., 1534 Spring St., Berkeley, Cal.	June 3, 1914
O'NIEL, DONALD H. C., Junior Member, Robert O'Niel Piano Co., St. Louis, Mo.; res., 5740 Bartmer Ave., St. Louis, Mo.*	June 17, 1914
OTT, GEO. A., Radio Electrician, U.S. Revenue Cutter "Pamlico," Newbern, N. C.	Aug. 12, 1914
PAINE, ROGER W., *Ensign, U. S. N.*, U. S. S. "Patterson," care Postmaster, New York.	July 1, 1914
PEARSON, HERBERT B., Hardwood Importer; res., 997 Sterling Pl., Brooklyn, N. Y.	July 1, 1914
PEDERSEN, MARTIN P., Radio Engineer, Poulsen System; res., Rorholmsgade 22", Copenhagen Denmark.	Oct. 14, 1914
PEMBER, HAROLD N., Student, Hartford Public High School; res., 2 Cone St., Hartford, Conn.	Aug. 12, 1914
PENNYPACKER, THOMAS R., Student, Harvard University; res., 52 Mt. Auburn St., Cambridge, Mass.*	July 1, 1914
PETERS, JOHN W., Patent Attorney, 52 William St., New York;* res., Roslyn, L. I., N. Y.	Aug. 12, 1914
PICKEN, WILLIAM J., Engineer, Marconi's Wireless Telegraph Co., Ltd., care Marconi Trans-Atlantic Station, New Brunswick, N. J.	Sept. 30, 1914
PILLSBURY. EDWARD BUTLER, Assistant Traffic Manager, Marconi Wireless Telegraph Co.; res., 313 East 21st St., Brooklyn, N. Y.*	July 1, 1914
POHL, J. A., Port Manager, Marconi Wireless Telegraph Co., Marconi Station, Port Arthur, Tex.	July 1, 1914
PORTER, RALPH H., Bookkeeper, Merchants' National Bank, Salem, Mass.; res., 7 Randall St., Salem, Mass.*	Sept. 9, 1914
POTTS, JEROME, Radio Operator, Tropical Radio Telegraph Co., 17 Battery Pl., New York;* res., 148 Clinton Ave., Brooklyn, N. Y.	Aug. 12, 1914
POWERS, WALTER PALMER, Conducting Electrical Research, University of Pittsburgh, Pittsburgh, Pa.;* res., 234 Craig St., Pittsburgh, Pa.	Aug. 12, 1914
POWNALL, RAYMOND M., Radio Operator, Tropical Radio Telegraph Co., 321 St. Charles St., New Orleans, La.	Aug. 12, 1914
PRENTISS, JOSEPH A., Civil Engineer, Richardson & Hale, care Mr. H. J. Power, 18 Clinton St., Everett, Mass.;* res., 206 Prospect St., Belmont, Mass.	Sept. 30, 1914
PRESTON, JOHN ERNEST, Auditing Dept., Marconi Wireless Telegraph Co.; res., 859 Fulton St., Brooklyn, N. Y.	July 1, 1914
PUMPHREY, WALTER H., U. S. Attorney, Dept. of Justice, Washington, D. C.; res., 1425 Belmont St., Washington, D. C.*	Aug. 12, 1914
PURSSELL, CLARENCE V., Carpenter and Electrician; res., 1257 Morton St., Dorchester, Mass.	June 3, 1914
RAWSON, H. E., Manager, Rawson Ranches, Kuna, Idaho.	July 1, 1914
RECKSIEK, WM. H., JR., Radio Operator, U. S. S. "Minnesota," care Postmaster, New York;* res., 1222 C. St., S. W., Washington, D. C.	Aug. 12, 1914

* Denotes mailing address.

REDFERN, O. R., Chief Operator and Inspector, Great Lakes Division, Marconi Wireless Telegraph Co.; res., 10th St. and 9th Ave., W., Duluth, Minn.*	July 8, 1914
RICHARDSON, KENNETH, Radio Operator, Marconi Wireless Telegraph Co.; res., Box 686, Erie, Pa.	Sept. 30, 1914
RICHMOND, H. B., Statistics Dept., Stone & Webster; res., 12 George St., Medford, Mass.	July 1, 1914
RIES, ELIAS E., Electrical and Mechanical Engineer and Inventor, 116 Nassau St., New York.	Aug. 12, 1914
ROBISON, SAMUEL S., *Capt., U. S. N.*, Assistant Chief of the Bureau of Steam Engineering, Navy Dept., Washington, D. C.	Oct. 14, 1914
RODMAN, HAROLD LEE, Chief Operator, Trans-Pacific Plant, Heeia, Federal Telegraph Co.; res., Heeia, Cahu, T. H. (via Honolulu).	Sept. 30, 1914
ROGATSKY, CARL H., Radio Experimenter; res., 526 86th St., San Diego, Cal.	Sept. 30, 1914
RORKE, ELMO, Radio Instructor, Coast Artillery School, Fort Monroe, Va.	June 3, 1914
SABIN, GLENN C., Electrician, Western Union Telegraph Co., Northampton, Mass.; res., 143 North St., Northampton, Mass.*	July 1, 1914
SALZGEBER, JOHN W., Clerk, Comstock Cheney & Co.; res., Ivoryton, Conn., Box 126.	Aug. 26, 1914
SCHELL, JOHN E., Chief Radio Electrician, Navy Yard, N. Y.; res., 190 Carlton Ave., Brooklyn, N. Y.*	July 1, 1914
SCHMIDT, LAWRENCE R., Operator, Marconi Wireless Telegraph Co.; res., 234 West 111th St., New York.	Aug. 12, 1914
SCHRAM, JACK, JR., Stationery Clerk, Tiffany & Co.; res., 21 Locust St., Brooklyn, N. Y.*	June 3, 1914
SEELEY, ARTHUR PLATT, Switchboard Engineer, The Southern New England Telephone Co.; res., 55 Pearl St., New Haven Conn.	July 1, 1914
SHERMAN, GEORGE C., Treasurer, St. Regis Paper Co.; res., 172 Ten Eyck St., Watertown, N. Y.	Aug. 12, 1914
SHORT, HERBERT M., Chief Inspector, Marconi International Marine Communication Co., Ltd., 29 Cliff St., New York.;* res., 1164 44th St., Brooklyn, N. Y.	Sept. 9, 1914
SKOVMAND, OTTO, Engineer, Poulsen System; res., Christianiagade 10, Copenhagen, Denmark.	Oct. 14, 1914
SLAUGHTER, NUGENT H., Engineer in Charge, High-Power Station, Marconi Wireless Telegraph Co., Honolulu, T. H.	Aug. 12, 1914
SMITH, HARRIS F., Engineer, U. S. Lighthouse Service, Portsmouth, R. I.	Sept. 30, 1914
SMITH, VERNE E., Electrician, Knox Amusement Co.; res., Box 444, Knox, Pa.	July 1, 1914
SPICER, EARL EUGENE, Electrician and Radio Operator, U. S. Revenue Cutter Service; res., 913 8th Ave., Seattle, Wash.	Aug. 26, 1914
SPRAGUE, CLARENCE A., Assistant Examiner, U. S. Patent Office, Washington, D. C.	Sept. 30, 1914
STETSON, DONALD T., Electrical Engineering Student, Minnesota State University; res., 2162 Carroll Ave., St. Paul, Minn.	Sept. 30, 1914

* Denotes mailing address

STEVENSON, VAIL VAUGHN, Division Electrical Engineer, Postal Telegraph-Cable Co., San Francisco, Cal.	Aug. 12, 1914
STEWART, CHAS. H., Radio Experimenter; res., St. David's, Delaware Co., Pa.	July 1, 1914
STONE, CARRINGTON H., Radio Operator, Marconi Wireless Telegraph Co.; res., 230 West Division St., Chicago, Ill.	July 8, 1914
STONE, FRANK M., 7919 Jeannette St., New Orleans, La.	July 8, 1914
STROEBEL, JOHN C., JR., Electrical Engineering Student, Carnegie Institute of Technology, Pittsburgh, Pa.; res., Pleasant Valley, Wheeling, W. Va.*	Aug. 12, 1914
TALLMAN, FRANK G., JR., Student, Cornell University, Ithaca, N. Y.; res., 1102 Broome St., Wilmington, Del.*	Aug. 12, 1914
TOMS, ROBERT WM., Radio Operator, Marconi's Wireless Telegraph Co., England; res., 136 Edgely Road, Stockport, England.*	Aug. 12, 1914
TRAFTON, HAROLD A., Appraisal Work, N. J. Neall; res., 39 Hancock St., Dorchester, Mass.	Aug. 12, 1914
TUSKA, CLARENCE D., Secretary, American Radio Relay League; res., 136 Oakland Terrace, Hartford, Ct.	July 1, 1914
VOGEL, PHILIP J., Operator, Radio Telegraph Dept., American Hawaiian S. S. Co., 8 Bridge St., New York;* res., 825 East 165th St., New York.	Sept. 9, 1914
WATKINS, JAMES O., Engineer, Federal Telegraph Co., 1004 Merchants' Exchange' Bldg., San Francisco, Cal.	July 8, 1914
WATSON, CLIFTON H., Radio Engineer, Northwestern Electric Co., Condit Plant, Underwood, Wash.	Aug. 26, 1914
WATTS, JOSEPH H., Director of Radio Installations, Government of Guatemala, Guatemala City, C. A.	Sept. 9, 1914
WAY, DONALD D., Radio Experimenter; res., 214 West 92nd St., New York.	Sept. 9, 1914
WEBB, J. S., Student, Valparaiso University; res., 757 Greenwich St., Valparaiso, Ind.	Aug. 26, 1914
WEISS, JACOB, Organist, 5 Adams St., Port Washington, L. I., N. Y.	July 1, 1914
WILLIS, SYDNEY JOHN, Assistant Engineer, Marconi's Wireless Telegraph Co., Ltd.; res., 41 Bloomfield Road, Chelmsford, England.	July 1, 1914
WISHAAR, WM. P., 2nd Lieut. U. S. Revenue Cutter Service, care U. S. R. C. "Seminole," Wilmington, N. C.	Sept. 9, 1914
WOODCOCK, NORMAN A., Radio Operator, Marconi Wireless Telegraph Co., Merchants' Exchange Bldg., San Francisco, Cal.	July 8, 1914
ZIMMERMAN, HERMAN, JR., Radio Operator, Tropical Radio Telegraph Co.; res., 346 East 139th St., New York.	July 1, 1914

* Denotes mailing address.

SUMMARY OF MEMBERSHIP

October 15, 1914.

MEMBERS	93
ASSOCIATES	523
Total	616

It is requested that *changes of address* be forwarded promptly to:

THE SECRETARY, INSTITUTE OF RADIO ENGINEERS,

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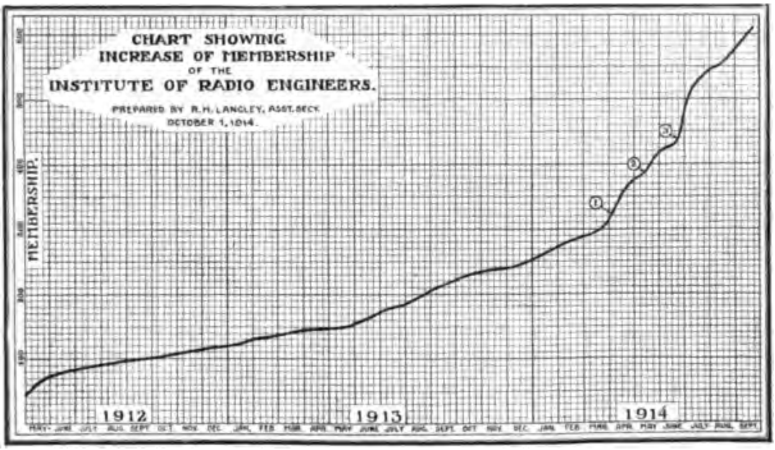


Thru the kindness of Mr. Ralph H. Langley, Assistant Secretary of the Institute, the Editor is enabled to present to the membership the above chart. This interesting curve shows the increase in membership of the Institute of Radio Engineers between May, 1912 and September, 1914. Since the preparation of this chart there has been a further considerable increase in membership. Attent'on is called to the accelerated rate of increase in membership directly above each of the points 1, 2, and 3 of the chart. At each of the points indicated by these figures, systematic efforts to increase the membership were made by the Board of Direction. The results were gratifying, and lead the Board to expect still greater increases in membership so soon as the advantages of participation in the Institute activities become even better known to the radio fraternity.

THE EFFECT OF A PARALLEL CONDENSER IN THE RECEIVING ANTENNA.*

By

Louis W. Austin.

President of the Institute.

It is a common practice to make use of a variable condenser in parallel with all or a portion of the inductance of the receiving antenna, for the purpose ot increasing the wave length to which the antenna is tuned. This method is very convenient, inasmuch as it does away with the necessity of small inductance steps, and also reduces the total amount of inductance required. It was believed at one time that it was possible in this way to increase the amount of energy delivered to the detector circuit above that obtainable by pure inductive tuning.

The comparison of receiving sets in which the parallel condenser is used, with those using inductive tuning, generally showed that the former were inferior to the latter in efficiency. For this reason an examination was made of the effect of replacing inductance by various amounts of parallel capacity.

The apparatus used consisted of an artificial antenna circuit containing a capacity representing the antenna, the receiving set under test, a resistance of 6 ohms to represent the antenna resistance, and a small coil to which was loosely coupled a buzzer driven wave meter adjusted to the wave length and sending decrement desired. The receiving set, which was originally designed for pure inductive tuning, was provided with a tuned secondary circuit consisting of variable inductance and variable capacity, with the iron pyrites detector connected in parallel to the capacity in the usual way. For the purpose of making quantitative comparisons the telephones were replaced by a sensitive D'Arsonval galvanometer of 2,000 ohms resistance.

The deflection was first measured using pure inductive tuning, the coupling being carefully adjusted to give the maximum

*Presented before the Institute of Radio Engineers, New York, March 4, 1914.

galvanometer deflection. A variable air condenser was then placed in parallel with the primary of the receiving set, and observations taken on various combinations of inductance and parallel capacity, the coupling between primary and secondary being adjusted in each case to give the maximum possible deflection.

Two such series of observations are shown in Tables I and II. Table I represents an antenna of small capacity, 0.0007 microfarad; while in Table II the antenna is considerably larger, and of 0.002 microfarad capacity. The tables show clearly the decrease in receiving efficiency when inductance is replaced by the parallel condenser. As is to be expected, more capacity can be used in the case of the larger antenna without materially decreasing the intensity of the received signals. In both cases, replacing half of the inductance by capacity reduces the deflection by approximately one third.

A number of other sets of observations were made, in some of which the artificial antenna was excited by sustained oscillations, and in some of which real antennae were used instead of artificial. In all cases, however, the influence of the parallel capacity was substantially the same as in the cases here given.

SUMMARY: Tuning inductances placed in artificial and actual antennae are shunted by a tuning condenser. In all cases the introduction of this capacity is found to reduce the strength of received signals.

TABLE I.

Antenna Capacity = 0.0007 microfarad

λ = 2000 m. δ_1 = 0.10

Parallel Capacity microfarad	Antenna Inductance microhenrys	Deflection mm.
0	1330	230
0.00016	1180	210
.00032	1050	195
.00064	840	180
.00100	820	160
.00132	610	140
.00165	540	125
.00200	480	105

TABLE II.

Antenna Capacity = 0.002 microfarad

λ = 3000 m. δ_1 = 0.10

Parallel Capacity microfarad	Antenna Inductance microhenrys	Deflection mm.
0	1100	110
0.00034	980	105
.00073	874	95
.00094	830	92
.00147	720	90
.00224	620	74
.00314	515	56
.00422	415	42

DISCUSSION.

John Stone Stone: This paper discusses not only an interesting, but essentially a practical question.

In a very large number of instances the decrement δ_1, of the wave trains to be received is less than δ_2, that of the receiving aerial circuit when tuned by an auxiliary inductance or aerial loading coil to receive them. In such cases, there can be no doubt that the substitution of a condenser in parallel to the primary of the receiving transformer for the auxiliary aerial tuning inductance in series therewith, would diminish the rate of energy reception at the detector in the secondary circuit. In such a case the substitution of the parallel capacity for the series inductance would serve to increase the disparity between the decrement of the wave to be received and the decrement of the receiving aerial circuit. Theoretical considerations and indeed some of my own experiments lead me to the conclusion that, other things being equal, the best condition for receiving a damped train of waves is reached when the decrement of the receiving aerial circuit is equal to the decrement of the received wave trains.

There is another consideration to be kept in mind in drawing deductions from the tests outlined in this paper. When a parallel capacity is substituted for a series inductance, the coupling between the aerial circuit and the detector circuit is automatically altered. To maintain this coupling the same in the two cases, the mutual inductance between the two circuits would have to be simultaneously reduced. Thus, if L_1 is the inductance of the primary of the transformer, L_2 the inductance of the secondary, L_{11} the auxiliary inductance in the aerial, L_{22} the auxiliary inductance in the secondary and M the mutual inductance between the circuits, it would be necessary to reduce M in the case of the parallel capacity in the ratio $\sqrt{\dfrac{L_1}{L_1 + L_{11}}}$

The apparent resistance and reactance to alternating currents of a system consisting of a condenser in parallel to a coil is:—

$$R' = \frac{R}{R^2 C^2 \omega^2 + (C L \omega^2 - 1)^2}$$

and

$$X' = -L\omega \frac{R^2 \frac{C}{L} + C L \omega^2 - 1}{R^2 C^2 \omega^2 + (C L \omega^2 - 1)^2}$$

where R, C, and L are respectively the resistance capacity and inductances of the loop and ω is $2 \pi n$, where n is the frequency of the current. If ω_0 is the periodicity to which the loop is itself reasonant when isolated, so that $\omega_0 = \dfrac{1}{\sqrt{C L}}$ and if the periodicity of the impressed force be m times this, then:—

$$R' = \frac{R}{m^2 R^2 \frac{C}{L} + (m^2 - 1)^2}$$

and

$$X' = -L m \omega_0 \frac{R^2 \frac{C}{L} + m^2 - 1}{m^2 R^2 \frac{C}{L} + (m^2 - 1)^?}$$

These are the two quantities which have to be considered in computing the decrement in the case of a condenser in parallel with an inductance in an aerial. Of course, these expressions only apply with complete accuracy in the case of sustained oscillations. But they are approximately correct in the case of damped oscillations except where the decrement is quite large and I have found them to be of considerable utility in the case of the damped trains of waves used in commercial practice.

In the case where the coil of the loop circuit is the primary of a transformer loosely coupled to a detector circuit tuned to the periodicity $\omega = m\omega_0$ of the received waves, the L of the above expression remains unchanged but the R must be increased by the addition of the amount $\frac{M^2 m^2 \omega_0^2}{R}$.

John L. Hogan, Jr.: Dr. Austin's paper opens a field for further investigation which should prove of value. I have no data at hand which either confirms or contradicts his results, but would suggest that in using the capacity-shunted primary I have found what appear to be two distinct cases which in general give opposite actions. When the wave length received is much greater than the natural wave length of the antenna, the distributed inductance of the aerial may be neglected and its capacity can be considered simply as a shunt to the lumped capacity in parallel to the lumped primary inductance. When the received wave is of the same order as the natural wave length of the antenna in question, it appears to be necessary to tune the antenna itself, independently of the capacity-shunted primary, to the wave length desired. This tuning is accomplished by use of a variable loading inductance in series with the aerial, above the upper point of connection to the shunting condenser.

My experiments indicate that relative efficiencies with and without shunting condenser depend not only upon the ratio of incoming wave length to receiving antenna natural wave length (and the mode of connection which this ratio indicates as the better), but also upon the decrement of the received wave as compared to that of the receiving circuit as a whole. I hope that there will be forthcoming additional data of tests in which there is varied not only the ratio of primary inductance to capacity but also the other quantities of which I have spoken.

DIELECTRIC HYSTERESIS AT RADIO FREQUENCIES.*

By

E. F. W. Alexanderson.

The investigation of dielectric hysteresis at high frequency, which I have taken as a subject for this paper, has been carried out in order to get data of value to the electrical industry, but the phenomena involved have a still more intimate bearing on the construction of apparatus used in radio telegraphy.†

TRANSFORMER DESIGN.

The design of the high tension transformer, which has been used in the dielectric tests, involved a number of unexpected difficulties, and several models were discarded before one which could be satisfactorily operated was produced. The use of an iron core transformer was not seriously considered for high voltages, because the insulation difficulties, which are great enough without any iron core, would obviously be increased. It is not implied that an iron core transformer may not be found valuable for certain purposes. For instance it may be desired to design a transformer for moderate voltages with substantially the same characteristics as an ordinary low frequency transformer that has a constant transformation ratio regardless of the frequency. However, for the present purpose, where high voltages were desired, no attempts were made to realize such conditions, inasmuch as constant potential characteristics would not be of great value in the measurements of losses. On the other hand it was important to use an apparatus the inherent losses of which were as low as possible, in order to attain great accuracy in the measurements of small quantities of dissipated energy.

In designing the transformer, the feasible alternatives of construction were either the open air type or the oil type. Of these, the open air type was found to be the more practical, partly on account of an inherently greater facility in re-arranging the various coils in order to adapt the transformer for use at dif-

*Presented before the Institute of Radio Engineers, New York, November, 1913.

†With reference to the measurements of dielectric hysteresis, the author wishes to acknowledge the assistance of Mr. S. P. Nixdorff.

ferent voltages and frequencies, and partly because of dielectric losses in the oil itself which would have been so considerable at high voltages that the accuracy of the energy measurements would have been much impaired.

The first transformer which was made consisted of a number of coils designed so as to have minimum internal capacity between the layers of the windings and between the various coils. The insulation losses to be expected are naturally reduced if the internal capacity is kept down to a minimum. Altho the proportioning of the coils was carried as far as could reasonably be expected in this direction, it was found that the insulation losses were excessive. The insulation between the layers of the winding was varnished cambric, and each coil was supported on a frame of fiber. The greatest losses seemed to occur in the fiber spool. It was found that the transformer could be operated only for a short time at a maximum permissible frequency of 40,000 cycles and at about 25,000 volts before it became so hot that it was necessary to interrupt the test. Consequently a new set of coils was made of the same general type, but without the fiber frame and simply taped with cotton. These coils were used in a number of tests at frequencies up to 30,000 cycles. However, it was found that even the varnished cambric insulation between the layers of the winding caused excessive losses. Considerable trouble was experienced from damage caused by corona discharge at high voltages. It was then attempted again to make a fireproof coil, but of somewhat different proportions, by covering the coils with asbestos tape. This proved to be an entire failure, because the heating of the asbestos was excessive even at moderate voltages, and the energy consumption was so great that high voltages could not be obtained at all.

The type of transformer that finally proved successful consists of a considerable number of thin, flat coils wound with wire having a braided cotton covering, but without any further insulation or spacing between layers. The average diameter of the coils is about one foot (30 cm.) and there are 84 turns per coil, each consisting of four wires side by side, the wires being arranged in 21 layers. A voltage of 100,000 can be generated by 18 of these coils in series. Furthermore, it appears that the insulation losses have been entirely eliminated, at least as far as it has been possible to determine them by measurement, and that the losses of the transformer, outside of the I^2R losses, seem to be only the dielectric losses in the air. The coils are insulated as described by nothing but dry cotton, and they are naturally

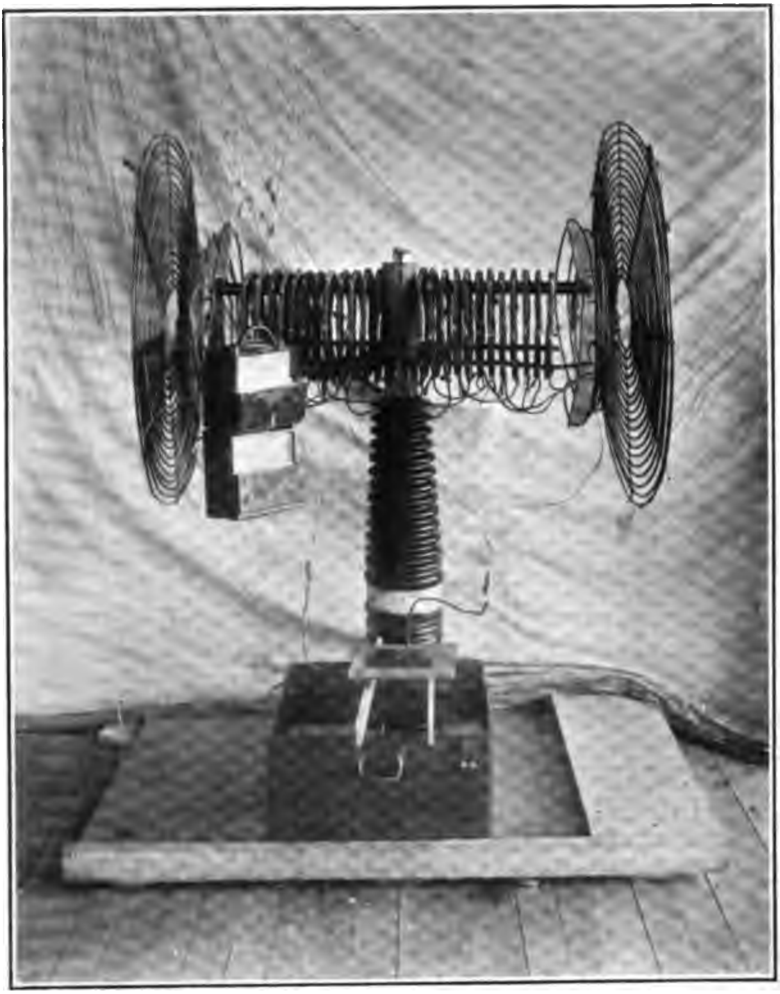


FIGURE 1—Transformer for 100,000 Volts at 100,000 Cycles, Used in Measurements.

susceptible to damage by corona (brush) discharges. It was, therefore, particularly important to construct the transformer in such a way as to protect the coils from exposure to excessive dielectric strains. This has been done by mounting the coils between two end terminals, each sufficiently large entirely to shield the coils from excessive electric strains and to create an electric field of uniform gradient within which the coils are supported. Inasmuch as these terminals or shields are cut by the magnetic field of the transformer, they could not be constructed of solid plates in which eddy currents would be induced, thereby causing serious losses. A convenient structure designed to avoid such losses was made up in the form of a spiral of heavy copper wire with free ends, wound on a wooden frame support. The profile of the frame had an outline with rounded corners, thus avoiding localized dielectric strains in the air. The electrostatic capacity effects produced by these terminal shields is considerable at the high voltages and frequencies used; and it was found, both by calculation and by test, that the capacity of the air circuit would absorb about 200 kilovolt-amperes (K.V.A.) at 100,000 cycles and 100,000 volts. The electrostatic capacity of the terminals was therefore of great importance in connection with the tuning which is absolutely necessary to build up high voltages.

Consequently the number of turns in the coils was so selected as to give inductances fulfilling the requirements for tuning without the addition of an additional external capacity. Any object connected to this apparatus, even a piece of wire attached to the terminals, adds to the electrostatic capacity, and whenever any measurements were made, the added capacity was compensated for by reducing the number of coils in the circuit so as to tune properly at the new voltage and frequency. The assembled apparatus is shown in Figure 1. The transformer coils are mounted on the horizontal supports, which are attached to the top of the large vertical corrugated insulator. The rounded end shield, together with the larger supplementary shields, are clearly seen. The ammeters are suspended by insulating cords in the foreground. In the lower portion of the illustration, a sample under test, between the terminal electrodes, is resting on the top of the oil tank.

If the input (in watts) supplied to the apparatus be measured with the transformers, connecting wire, and necessary instruments in circuit as well as with the sample dielectric properly placed and then if the sample be removed and the input again measured at the same voltage and frequency as before, the difference between the two inputs is the dielectric loss in the sample. In order that these measurements should be accurate, it is evidently important that the losses in the transformer and its accessories should be kept as small as possible compared with those in the sample. This was actually the case in the measurements that have been made, the total losses in the apparatus being only a small fraction of the total energy that was measured.

ENERGY MEASUREMENTS.

The method used for measuring the energy in the radio frequency circuit is in principle, the same as the one described in a paper by the author, delivered before the American Institute of Electrical Engineers on "CORE LOSS IN IRON AT HIGH FREQUENCY." The method is based on the use of both voltmeters and ammeters, because accurate wattmeters for such high frequencies have not been developed. The method depends further on a well-known characteristic of alternating current circuits in which sinusoidal currents are flowing. The impedance can be resolved into an "energy component" and a "wattless component," and the wattless component can be completely neutralized by a suitable choice of inductance and capacity. If the impedance of such a circuit is measured, and the ratio of inductance to capacity, varied, various values of the impedance can be obtained and plotted as a curve. This curve passes thru a point of minimum impedance for which the inductance and capacity neutralize each other. At that point, the product of volts and amperes represent the energy component or the equivalent resistance of the circuit. This is the condition of unity power factor.

The apparatus which is used for these measurements is adjusted so as to determine this minimum point in the simplest way, without the necessity of plotting the whole curve. Thus, it is possible to make measurements of energy wherein the watts are obtained directly from the product from the volts and amperes, which latter quantities are being observed. The adjustment which is needed to find this minimum point is made by selecting an inductance which is nearly right, and then finding the exact point of minimum impedance by a slight variation of the frequency. The measurement requires simultaneous observation of a voltmeter and an ammeter; and the condition to be looked for is that at which the ratio between the voltmeter reading and the ammeter reading is a minimum. In order to facilitate this observation without recourse to calculation, the

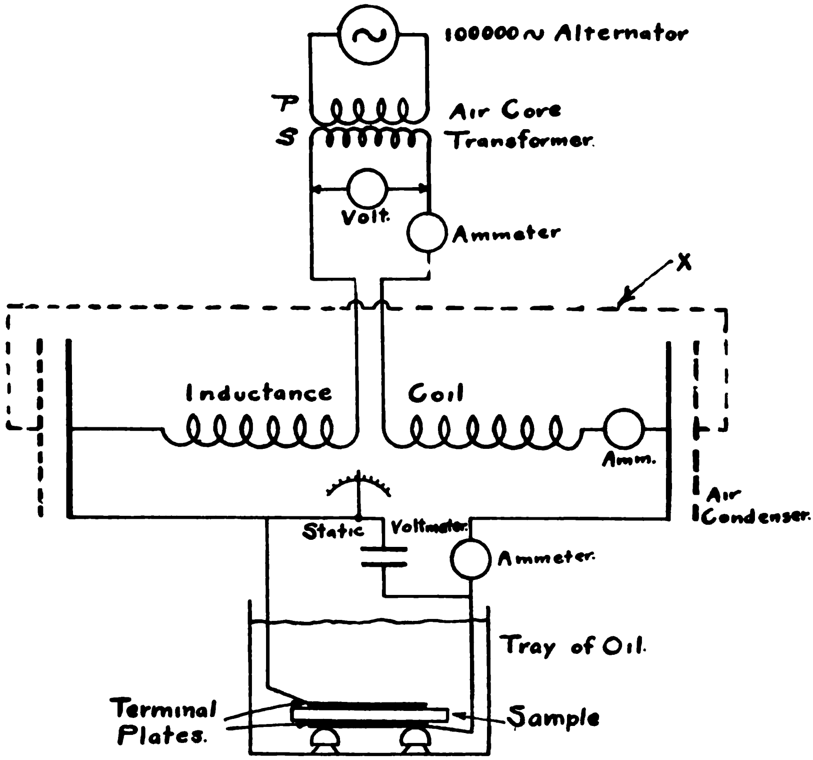


FIGURE 2—Diagram of Connections of Transformer for 100,000 Volts at 100,000 Cycles.

circuit is so adjusted that the voltage remains practically constant while the current goes thru a sharp maximum. It is also possible to arrange the circuits so as to keep the current practically constant while the voltage goes thru a sharp minimum. In other words, the measurements can be made conveniently either on constant potential or on a constant current.

The diagram of connection for a typical arrangement is shown in Figure 2.* The shields or terminals which are used to protect the windings from electrostatic strains are at the same time used as the plates of an air condenser which is needed to create

*The apparatus used is practically a long coil having distributed capacity and inductance thruout its length, and added end capacities. A stationary wave is produced on this coil by exciting it inductively at its central point from a radio frequency Alexanderson alternator. The coil in question is the long horizontal row of flat coils, and the added end capacities referred to are the terminal circular shields.

The stationary wave produced has maxima of potential at the outer ends of the terminal shields and zero potential at the center of the coil S resonance. If a measurement is made wherein the sample is subjected to a difference of potential, it is convenient to connect the apparatus so as to produce a positive and negative difference of potential at the ends of the transformer secondary with a grounded neutral point. In this case, the energy is introduced at the middle of the high tension coil of the transformer by introducing the energy thru a low tension transformer arranged with a variable ratio of transformation. The energy measurements are made at the point at which the current is led into the high tension coil. The only instruments needed are a hot wire voltmeter and ammeter. It is sometimes convenient to have a static voltmeter connected across the high tension terminals to indicate the voltage impressed on the sample, but it is to be noted that the indications of a static voltmeter sometimes are unreliable, because at high frequencies corona and brush discharges appear at comparatively low voltages. The use of the static voltmeter is not necessary if the inductance of the high tension coil is known, because the voltage can be obtained by multiplying the current by the reactance due to the inductance. It was actually found necessary to use this method in the measurements at the higher potentials. The inductance of the coil was found by calculation, and also by measurement at the lower potentials. This was necessary because at higher potentials the static meters that were available broke down and arced over.

DIELECTRIC STRENGTH OF AIR.

The phenomena which were observed when the high tension oscillation transformer was operated at a high potential were such as to suggest the immediate conclusion that the dielectric constants of the air differ entirely at radio frequencies from those that have been observed at ordinary frequencies. A further analysis has led to a modification of those conclusions, at least in part; and there are several indications that all the abnormal phenomena at very high frequencies can be explained as secondary effects. A theoretically ideal condition may be supposed for which air would have exactly the same characteristics at radio frequencies as it has at audio frequencies. Whether this is the

whereby it is inductively coupled to coil P and the alternator. In order to produce this stationary wave, it is necessary that the inductance of the long coil, together with its distributed and end capacities, shall cause resonance at the given frequency.

The distributed capacity of the long coil and of the end shields is indicated by the dotted line (X) of Figure 2. This capacity is, of course, only present in effect; and is not actually definitely connected in setting up the apparatus.—(EDITOR'S NOTE.)

case or not, the fact remains that for all practical purposes the phenomena at very high frequencies are radically novel, and any apparatus which is to be subjected to such high frequencies must be quite specially designed. Constants obtained by observation must be known for the materials used, as well as the proper proportioning of parts that are to be used in the radio frequency circuit. For instance, at 100,000 cycles, a small wire is surrounded by so much corona discharge even at a potential difference relative to ground of 15,000 volts, that such potentials can be handled without excessive loss only when observing great precautions. Thus, we must use a cable of at least the thickness of a lead pencil and protect all projecting corners by shields of tin foil. On the other hand, we find practically the same constants for the dielectric strength of air as have been found for ordinary frequencies if the measurements are based on the arc-over distance between spheres of polished brass. The arc-over distance for a pair of spheres of 5 inches (12.9 cm.) diameter was found to be 3 inches at 100,000 volts and 100,000 cycles, and no corona was noticed on the spheres before the arc took place. The difficulty in arranging these measurements consisted in producing this potential difference and conducting it to the spheres without excessive static discharge from the terminals and leads. This could be accomplished only by placing the spheres within the uniform electrostatic field that is created between the transformer terminals or end shields which are used to protect the coils on which the potential is generated. This is obviously an artificial condition and it is safe to say that, for practical purposes, it is not possible to conduct a current, even for short distances, at a potential difference approaching 100,000 volts at such radio frequencies.

DIELECTRIC LOSSES IN INSULATION.

In measuring the losses in solid dielectrics, it was necessary for the reasons given above to immerse the sample under test in oil. The attempts to make measurements in air failed because the air space between the terminals and the sample gave rise to such an excessive loss of energy from corona discharge that the sample would crack or burn, because of the heating, at a much lower potential than that corresponding to the true dielectric strength of the material. Commercial insulation, which successfully resisted 100,000 volts at any ordinary frequency, cracked after being subjected for about a minute to 15,000 volts at 100,000 cycles, because of the heat of the corona produced at the metallic terminals. Tho immersion of the sample in oil makes it possible to measure the losses in the material itself without interference by secondary phenomena, it must be remembered that in practice insulators of existing designs have no such protection, and may be subjected to the local heating caused by corona. A test of commercial insulators under oil will, therefore, not give fair indications of their values, even tho the dielectric characteristics of the material itself might, as determined by such a test, be apparently quite satisfactory.

Even when measurements are made under oil, the insulator is apt to break down because of deterioration caused by the heat generated in dielectric hysteresis, rather than because of dielectric strain. The same effect is found to occur when oil is used and the arc-over occurs at much lower voltages than those corresponding to ordinary frequencies. This is another instance where the apparently different characteristics are dependent for their difference on secondary phenomena. It is probable that under theoretically perfect conditions the same dielectric strength would be found at high frequencies as at low frequencies, and in oil and solid dielectrics as well as in air. This would be the case if the incidental phenomena of corona and heating could be eliminated. In order to be able to apply systematic and scientific methods to the design of radio frequency circuits, the author has made a series of measurements of dielectric losses for different insulation materials. These results are presented on the curve sheets in order to give the designers data for calculating the insulation losses in each part of a complete structure designed for use at such very high frequencies.

All the measurements have been made on samples 0.6 cm. (0.25 inch) thick, and with an area of 200 sq. cm. (30 square inches). The samples were in every case immersed in oil for reasons that have been explained. The insulation materials which were investigated are mica, glass, paper, varnished cambric, and asbestos. A general comparison between the characteristics of these materials is given by the curves of Figure 3 to Figure 7 inclusive. Figure 3 gives a comparison between the dielectric permittivities of the materials that were measured. This information is given by plotting the amperes of displacement current that would flow through a centimeter cube under a potential difference of 10,000 volts against the frequency. Figure 4 gives the watts loss in a centimeter cube for 10,000 volts at different frequencies. For the sake of comparison the losses of each of the materials, among which mica gives the lowest values and

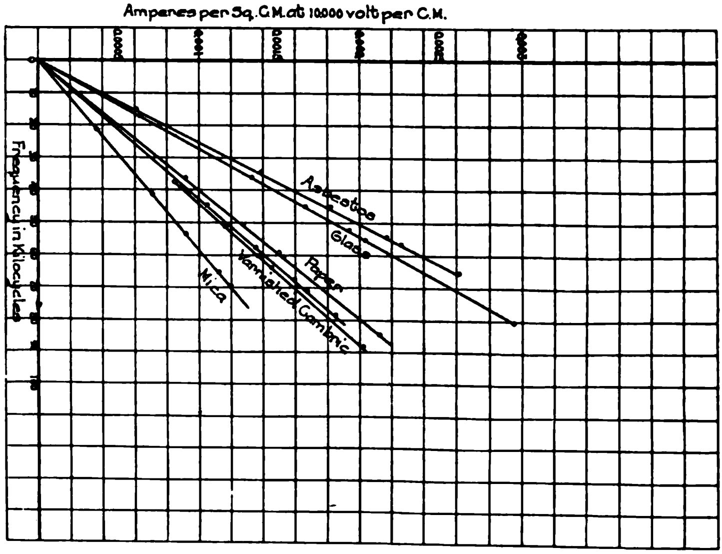


Fig. 3
Dielectric Permitivity

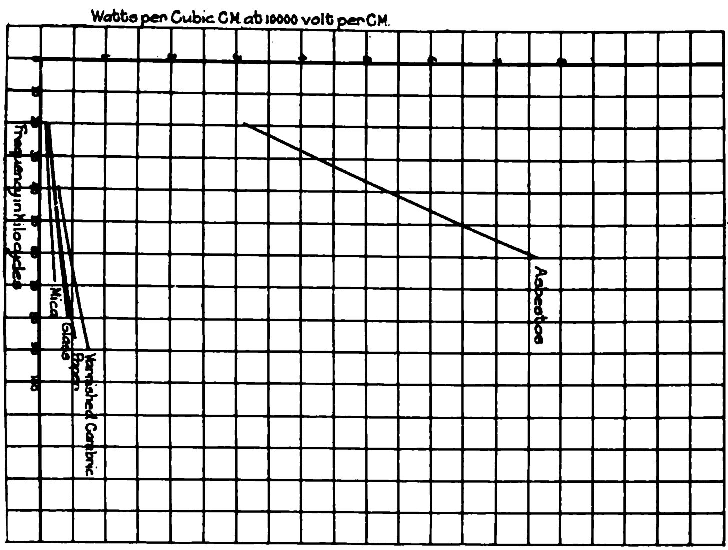


Fig. 4
Comparison of Dielectric Losses
in Different Materials

asbestos the highest, are plotted on the same curve sheet. It is noticeable from this comparison that asbestos has a loss which is so far the greatest as to make it appear to be in a different class. For a closer comparison of the ordinary insulation materials; namely, mica, glass, paper, and varnished cambric, the losses per centimeter cube are shown on Figure 5. On Figure 5 is also given the power factor of each of these materials at the different frequencies. The power factor is the ratio between the watts loss and the volt-amperes absorbed.

It was found, in examining this data, that the figure for the power factor gives the most important and characteristic information of the insulation materials so far as dielectric losses are concerned. As seen from the curves the power factor is substantially constant at all frequencies and all voltages. This fact naturally leads to some interesting speculations as to the real nature of the dielectric losses. The dielectric losses are usually called dielectric hysteresis, but the question has been raised whether this is an appropriate name; and the data for dielectric losses has, by several investigators, been given in a form that would indicate that the nature of the losses is such as would be presented by a resistance in series with the capacity, while others have indicated it as a shunt resistance. A series resistance would give a power factor increasing in proportion to the frequency and a shunt resistance a power factor decreasing with the frequency.

The data obtained shows a power factor that increased slightly with the frequency for glass, mica, and paper; whereas the power factor for asbestos decreases. If we assume that the losses consist of a true dielectric hysteresis as well as series resistance and shunt resistance, it appears that that dielectric hysteresis, which is characterized by a constant loss per cycle, and consequently a constant power factor, is by far the predominant portion. In addition to this, it would appear that mica, glass, and paper have a slight series resistance and that asbestos has a shunt resistance, which is large enough to be slightly predominant over the series resistance. The losses in all the insulation materials are dependent upon the temperature; and a variation in losses due to this cause is apt to introduce differences considerably greater than the actual changes in power factor due to a series resistance or a shunt resistance. It can therefore be said that for practical purposes, the losses may be considered as if they were due to a true hysteresis, at a constant power factor, at all frequencies and all voltages. After the general data has been obtained for each sample, the test was carried further to the point of break-

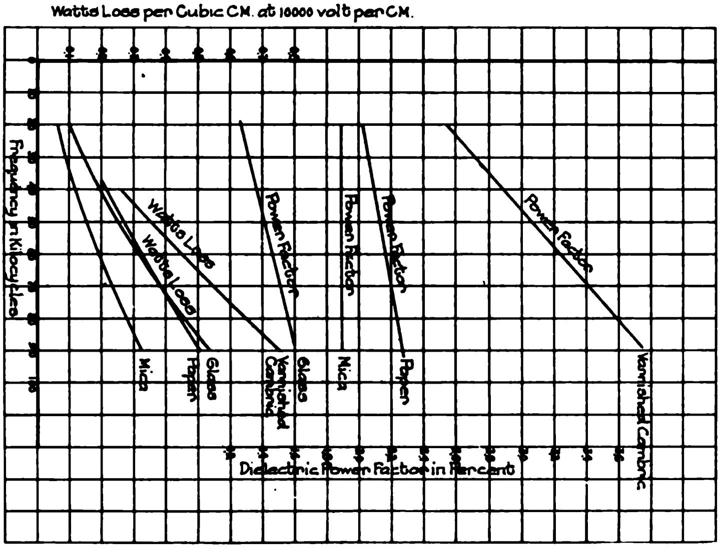


Fig 5
Losses per Unit Volume and Dielectric Power Factor

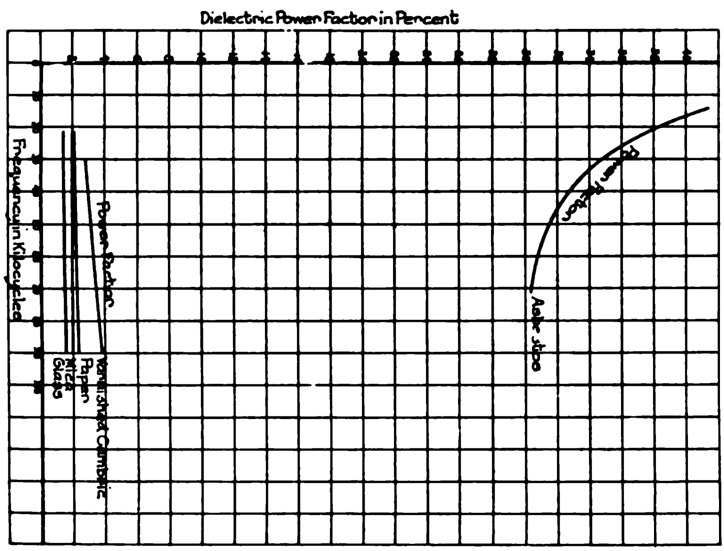


Fig 6
Comparison of Dielectric Power Factor in Different Materials

down of the insulation. It is found that in each case, before the actual breakdown, a certain rise occurs in the power factor, and a slight decrease in the dielectric capacity. This rise of power factor is due to the increased heating, which becomes cumulative when the temperature has reached a certain limit. A set of average curves for the increase of power factor before the breakdown is shown in Figure 7 for the different materials. These curves show that the different materials, regardless of their inherent power factor, break down after the power factor has reached substantially the same value. The limits of power factor, given by the curves of Figure 7, therefore depend more upon the method of cooling of the particular samples that were used than on any inherent characteristic of the material. To illustrate the change in the power factor, the curves are plotted for the actual volts applied to a sample 0.6 cm. thick. The results can be duplicated only if the sample under test is cooled in the same way.

Figures 8 to 12 inclusive give the results of the measurements from which the above conclusions are drawn. The curves are plotted for each set of measurements, so that the reader will have the opportunity to form an opinion of the magnitude of the variations, which are due to voltage and frequency values, and also of those variations that were incidental to the experimental procedure which were due to rise of temperature. The shape of the power factor curve for each set of measurements is not sufficiently continuous to allow any definite conclusions to be drawn as to the law of variation of power factor with the frequency; nevertheless the assembled set of data indicate a general shape of the curves quite clearly.

With regard to the losses in mica, it should be noted that the samples used were of commercial built-up mica. Tests have since been made of clear mica for condensers and it was found that there is a wide variation of losses depending upon the grade of material. Measurements of power factor in various grades of mica used commercially for insulation have shown variations from 0.5 per cent. power factor to 7 per cent. power factor. Most commercial grades of mica fall between 1 per cent. power factor and 3.5 per cent. power factor, and it may be assumed that such mica as might be selected for condensers should have a loss of not more than that corresponding to 1 per cent. power factor.

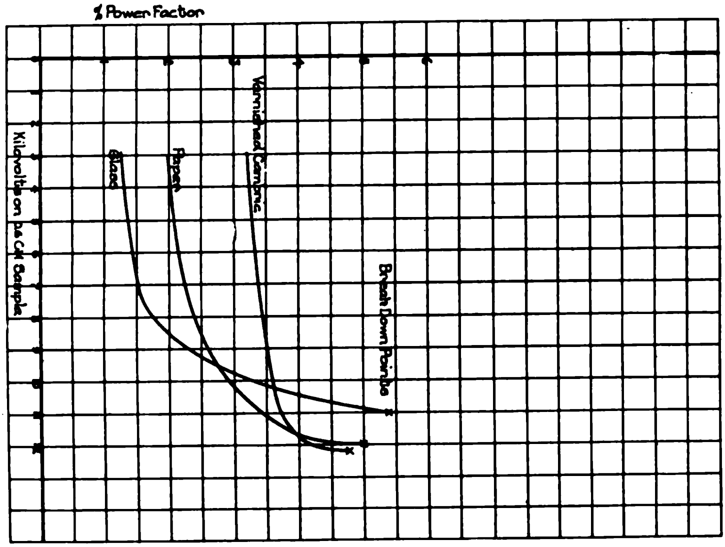


Fig. 7.
Rise of Dielectric Power Factor
Before Break Down

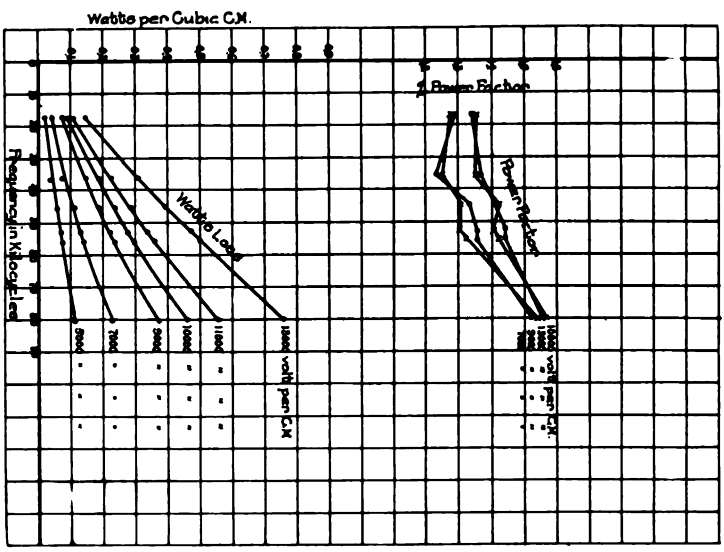


Fig. 8
Results of Measurements
2 Sheets of Glass - Total Thickness 0.89 CM.

It has usually been assumed that air has no dielectric hysteresis whatever. While this may be so in a theoretical sense, the measurements made by the author for the purpose of determining the dielectric losses in air indicate that even the most perfect air condensers which it has been possible to establish, have losses which are easily measurable, and within the range of the apparatus used for this purpose. The losses that have been measured in different air condensers vary considerably in magnitude, and they depend principally on the sharpness of the corners and edges. For instance, if sheets of tinfoil about 6-inch square (15 cm.) are suspended at about 2-inch (5 cm.) distance, they show a loss as high as 1 per cent. Round copper plates of about $\frac{1}{32}$ inch (0.8 mm.) thickness and 2 feet (60 cm.) in diameter suspended at 6-foot (1.8 m.) distance from each other show a loss of about 0.4 per cent. The end shields of the high tension transformer, which are shaped so as to avoid, as far as possible, any local dielectric strains, show a loss of 0.2 per cent.; and a pair of brass spheres suspended at 0.5 inch (1.3 cm.) distance also show 0.2 per cent. A part of this measured loss may be due to incipient corona which cannot be detected, and a part of it may be due to actual dielectric hysteresis in the air space. However, it is certain that a part of it is due to radiation into space. This was proven conclusively by some measurements on the end shields of a transformer when in one case for which these losses appeared to be unusually high. This was found to be due to a fine wire which was suspended about 5 feet (1.5 m.) above the apparatus, but entirely disconnected. It may be possible to design an apparatus so as to separate and measure these losses. The radiation losses could be eliminated by enclosing the whole apparatus in which the high voltages are generated in a metal cage constructed so that no losses could occur due to the short circuits cut by the varying magnetic flux; and the losses due to incipient corona could probably be eliminated by comparing the losses in air circuits of different lengths but with the same voltage gradient at the terminals.

A demonstration which is both unexpected and striking to the effect that the fundamental loss which has been found at low frequency remains applicable at extremely high frequencies, is found in the measurements of energy loss due to corona around a small wire. The measurements were made on two wires, each 40 inches (1 m.) long, suspended free in air at a distance apart of 2 feet (60 cm.). The wires were 0.01 inch (0.4 mm.) in diam-

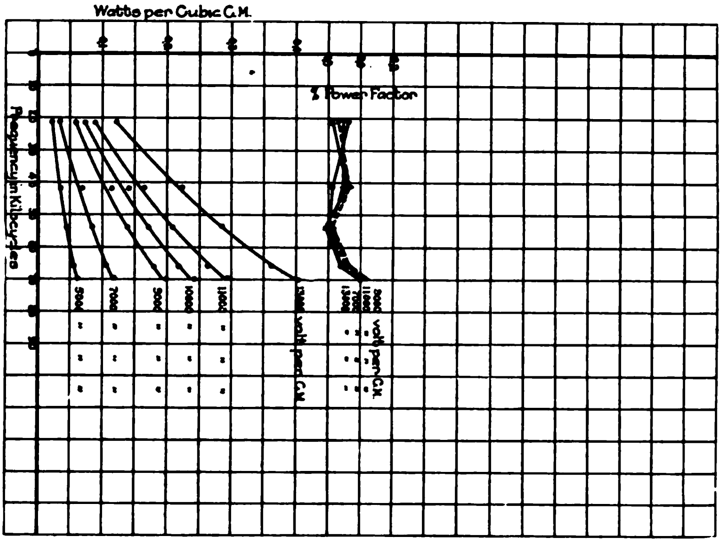


Fig. 9
Results of Measurements
4 Sheets of Mica – Total Thickness 0.56

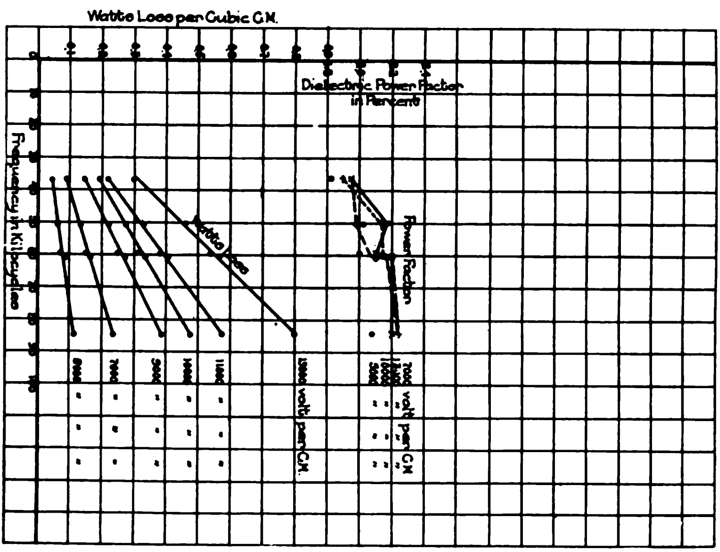


Fig. 10
Results of Measurements
28 Sheets of Paper – Total Thickness 0.5 C.M.

eter. The measurable corona loss was first evident at 15,000 volts difference of potential; and increased very rapidly so that at 27,000 volts, the energy absorption was nearly 0.5 kilowatt. It is the quantitative magnitude which is surprising in this case; and it is difficult to imagine that this large amount of energy is radiated from such fine wires without bringing them to incandescence. However, there appeared to be no evidence of heating on the wire itself, and the wires were surrounded by the blue flame of the corona, which was well visible even in bright daylight. The most interesting feature of these results is the fact that they agree remarkably well with the laws of the corona as developed theoretically by Mr. F. W. Peek, Jr., and given in a paper* for the American Institute of Electrical Engineers in 1911. Both the point at which the corona begins, and the shape of the sharply rising curve of losses at increased voltages are in agreement with calculations. An agreement has thus been found between phenomena occurring at low frequencies and at radio frequencies, not only as to arc-over distances between spheres of polished metal but also for the measurement of corona loss on wires. This justifies confidence in such theoretical assumptions as may be necessary in order to determine by calculation the losses under various conditions that are not conveniently subjected to laboratory measurements. In view of this, I believe that calculations for a number of phenomena, which are at present uncertain in nature, can be made on a semi-theoretical basis, thereby furnishing practical data for the design of insulators and conductors which are to be subjected to very high frequencies.

In the first attempts to make measurements of corona losses on wires, as was previously mentioned, some difficulty was found in suspending the wires. If a cotton string was used, it soon caught fire and burnt off because of the heating caused by the corona flame. It was then attempted to use a small porcelain insulator suspended by a cotton string. In this case, there appears to be an excessive corona discharge between the wire and the insulator at voltages lower than that of the appearance of corona on the wire itself, and the insulator eventually heats up sufficiently to break it into loose pieces. The heating of the insulator itself would, of course, interfere with the accuracy of the measurements that were to be made. As a practical method of suspending the wires without introducing extra losses, they

*"The Law of Corona and the Dielectric Strength of Air," F. W. Peek, Jr., Proc. A. I. E. E., Vol. XXX, Part 1, Page 1485.

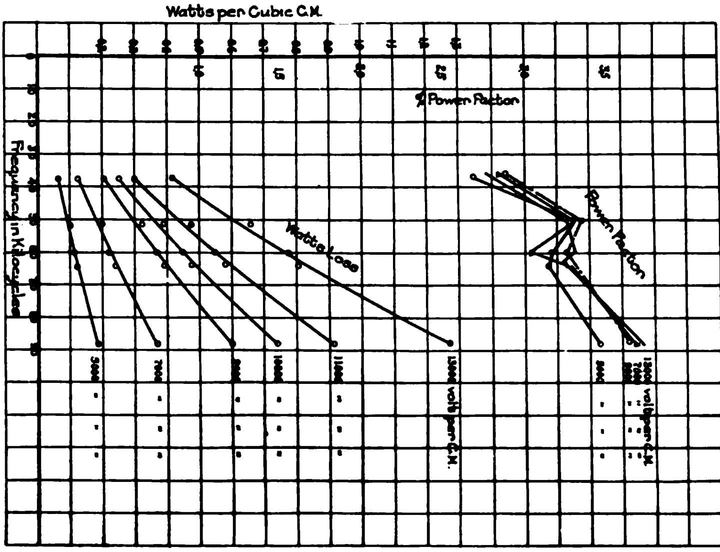


Fig. 11
Results of Measurements
13 Sheets of Varnished Cambric
Total Thickness .088 C.M.

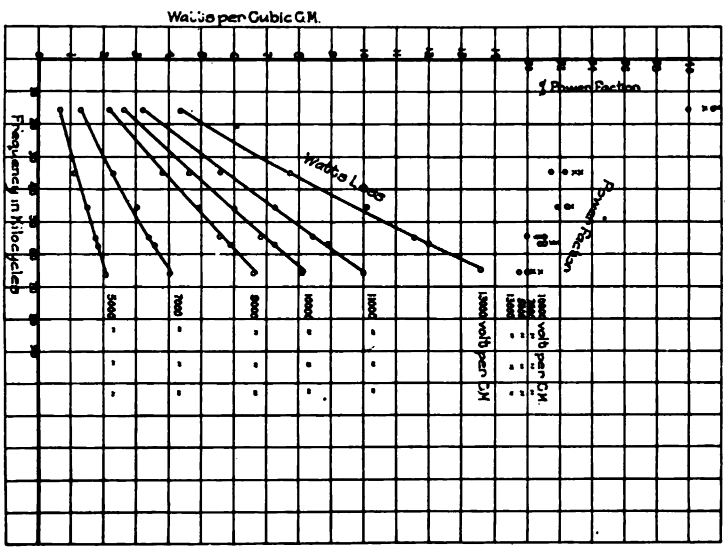
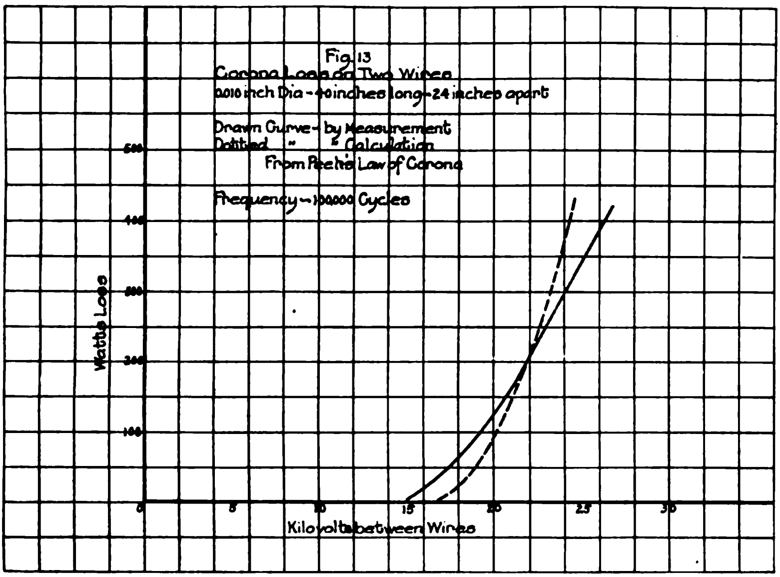


Fig. 12
Results of Measurements
8 Sheets of Asbestos—Total Thickness 0.6 C.M.

were tied to a cotton string, and the joint wrapped with tinfoil to a considerable thickness and in such a shape that the point where the wire touched the metal was surrounded by a bell shaped shield of tinfoil. In this way the corona discharge from the terminals was not only reduced but also kept away from the joint between the wire and the metal. While it is in practice necessary to use insulators in supporting wires there can be no doubt that the success of the apparatus depends greatly upon the design of the insulators and the effectiveness with which losses due to local heating are avoided. The excessive corona losses at the point where the metal touches the insulator can



easily be explained from a consideration of the dielectric characteristics of the materials. We may, for instance, assume that the insulator has a dielectric constant five times as high as the air, and that the layer of air between the metal and the insulator is not of sufficient thickness to change the distribution of the electric field in the insulator. If the wire were totally embedded in the dielectric the higher permittivity of the insulator would cause five times as great a current to flow from the wire into the dielectric as would flow if the wire were suspended in air, but the distribution of potential in the insulator would be the same as the distribution of potential when the wire is totally surrounded by air. If, however, there is a small layer of air between the wire and the insulator, the current flowing thru this layer of air is five times as great as it would have been if the insulator had not been present, and consequently the potential gradient in this layer of air becomes five times as great. In this case it is to be expected that corona would appear locally at a voltage only one-fifth as great as the voltage that would produce corona if the wire were suspended freely in air. The measurements of corona losses in a 10 mil (0.4 mm.) wire, as well as theoretical considerations, indicate that corona should commence at 15,000 volts between such wires suspended at a considerable distance. In other words, corona begins when each wire has a difference of potential of 7,500 between it and the surrounding air. If such a wire be brought close to a large insulator, which has a permittivity five times that of air, it is to be expected that corona would appear at a voltage one-fifth as great as before, that is at 3,000 volts potential difference (or 1,500 volts above ground potential, provided that one side of the insulator is grounded). This agrees substantially with the results of observation, and tho it may be desirable to collect more empirical data on this point, it should be possible to extend this line of reasoning to phenomena which cannot be subjected to measurements, thereby gaining a quantitative knowledge of many phenomena which have an important bearing on the proper functioning of the very high frequency circuit.

TABLE 1.

REPRESENTATIVE VALUES OF DIELECTRIC LOSSES.

	Power Factor per cent.	Watts Loss per cm. cube at 10,000 volts per cm.; per kilocycle.
Clear Mica for Condensers,	1.0	0.0016
Built-up Mica,	1.9	0.003
Mica,	1.9	0.003
Glass,	1.4	0.005
Paper,	2.2	0.0055
Varnished Cambric,	3.3	0.0080
Asbestos,	3.0	0.13

(September 14, 1914.)

SUMMARY: The development of a transformer for 100,000 volts at 100,000 cycles is described in detail. The successful construction is given. The necessary even potential gradient along the high tension secondary of the transformer is provided by special end shields. The dielectric strength of air is determined at radio frequencies, and the novel behavior of air at these frequencies is described. The methods of measurement of dielectric losses

of various materials are given. The materials tested show that the predominant loss is constant per cycle (i. e., it gives rise to a constant power factor). Mica, glass and paper show also a slight equivalent series resistance (corresponding to a power factor increasing with the frequency); asbestos a shunt resistance. The break-down conditions of the various dielectrics were studied. The dielectric hysteresis of air is measured, and it is found that radio frequency corona as well as arc-over distance are subject to the same laws as at audio frequencies.

DISCUSSION.

Robert H. Marriott (*Chairman*): On behalf of The Institute of Radio Engineers, I wish to thank Mr. Alexanderson for presenting this paper before us. It is of great value to workers in the radio field.

H. E. Hallborg: There are three recent papers; one by Fortescue read before the American Institute of Electrical Engineers, and those by Dr. Austin and Mr. Alexanderson read before the Institute of Radio Engineers, which mark three milestones in our emancipation from insulation difficulties. These papers should certainly be read by all radio engineers.

Our methods in the past have been empirical in the extreme. If we found that one foot of insulation would not withstand 100,000 volts, we simply added an additional foot of insulation. The effect might well be the opposite of that desired. It is very important in such problems to consider the stresses in the dielectric (that is, the electric field intensity). There is no doubt that these problems will eventually be worked out in the same systematic fashion as that in which problems involving the magnetic circuit containing iron are now handled.

The total dielectric field is represented by the product C times E (C, of course, is capacity and E voltage). Fortunately for most insulators, the value of C is small, so that in spite of the application of a high voltage the total dielectric field remains such that the dielectric flux per unit area is very low, and the danger of failure therefore remote. When, however, the value of C becomes appreciable, as in a condenser, then the application of even a moderate voltage sets up a dense field and the flux per unit area becomes high. Hence, it is readily seen that it is by no means a just test to compare insulation by voltage test alone since there may be a vast difference in field intensity, and the insulation that is found to be the poorer by this test may really be the better when densities are taken into account. We compare samples of transformer iron for losses at equal densities; why not dielectrics? I believe that the time is coming when we will assign a particular density to a particular frequency range for all radio dielectrics at least.

I have had occasion to make some measurements following the method outlined by Dr. Austin in a somewhat modified form, adapted to commercial practice. The energy in a circuit containing an air condenser was compared with that in a circuit containing a condenser having the dielectric under test, the circuit being otherwise the same. In making these measurements, the percentage current absorption per square inch of dielectric cross section could be determined, and thus the most desirable insulator selected for the purpose at hand. Measurements were made using a quenched spark set, and at a frequency of 500,000 cycles. The difference in the losses in what are ordinarily considered good insulators was found to be enormous by these tests. Indeed, most of the so-called "good insulators" were worthless when used at radio frequencies.

Insulating oils were also found to possess substantial dielectric hysteresis. This varied markedly with the sample tested, the measurements yielding results differing by as much as ten to one. Some of the losses are probably due to water in the oil, but another component is probably due to some inherent quality of the oil.

Insulators of glass, which would satisfactorily withstand a certain voltage in air without rupture, I found would break down in oil, probably because of the concentration of the brushing along the glass surface. When in oil, the brushing is concentrated along the edges of the conductors carrying the applied potential difference; which results in excessive heating at these points, and consequent breakdown of the glass. The failure of glass plate condensers immersed in oil is exactly proportional to the relative hysteresis losses of the oils; the greater the loss in the oil, the lower the rupture voltage of the glass plate condenser. This is probably due to unequal expansion in the glass caused by dielectric saturation of the oil which starts heavy brushing at the edge of the foil, as failure is usually in the form of a crack, seldom a straight puncture.

In working with electrostatic voltmeters, I have experienced considerable trouble. One instrument gave unreliable results because its capacity changed the constants of the circuit in which it was connected. This instrument was very unsuitable; in fact, it gave half scale deflection when used on high frequencies with only one lead connected.

I should like to consider the matter of using iron in radio coils, and oscillation transformers as mentioned and proposed by Mr. Alexanderson. I remember trying this experiment some years ago when a bundle of good quality transformer iron was inserted in an aerial loading coil operating at a frequency of 200,000 cycles. The inductance value naturally increased greatly; but on retuning the circuit by changing only the number of turns in the loading coil, I found that the tuning had become very broad and the radiation considerably lower because of the increase in damping resulting from the insertion of the iron. I would also quote as an objection to the use of iron cores the fact that the voltage per turn would run so high that the smaller size of coil for a given inductance would be counteracted by the fact that a solid insulation would be necessary between turns, thus producing more of the losses that Mr. Alexanderson has just been telling us about.

Ralph H. Langley: Has fatigue of the dielectric been noticed; that is, have the losses been noticed to increase with time? In other words, was the power factor of the circuit a function of the time?

E. F. W. Alexanderson: As regards the electrostatic voltmeter, I may say that I have had experiences similar to those of Mr. Hallborg. There are two types of electrostatic voltmeter. In one of these types, the distance between the plates is fixed but the opposing area variable. This is the Kelvin interleaving plate electrometer. Such electrometers are very unreliable partly because of the large corona losses and partly because of the high, and markedly variable, capacity. The second type of meter has constant area between the plates but variable separation. These are found to be fairly satisfactory.

In testing the oil, it was found that the loss was 0.7 per cent. per cubic inch at 20,000 volts per inch stress. It was not possible to increase this stress beyond the value given, because thereafter the losses increased very rapidly, the oil began to boil, and breakdown followed. It will be seen that the eventual breakdown was thus due to heating, and this may be called a sort of fatigue. The oil does not seem to break down immediately, but may after a considerable time lag. This may be due to the continued storage of heat in the dielectric, which is therefore weakened. It is difficult to differentiate between the fatigue which is due to heating and that which may be due to other effects.

H. S. Osborne: With reference to the subject under discussion this evening, the recent work of Professor Ryan of Leland Stanford University, may be of interest. He has been looking for an explanation of some of the curious insulator breakdowns which occur on high voltage transmission lines. He experimented with about 100,000 cycles at 30,000 volts. In making tests with small porcelain knobs, which at ordinary frequencies flash over at perhaps 10,000 volts and cannot be punctured, it was found that 100,000 cycles and 30,000 volts did not cause a flash over, but gradually punctured the knob by burning a minute hole thru it. A 60,000 volt line insulator was also tested. Altho this insulator did not break down at the usual power frequencies and flashed over at about 200,000 volts, when subjected to the radio frequency, a small hole was burned thru the insulator from the groove to the pin.

E. F. W. Alexanderson: Such tests must be of considerable interest to radio men. We have made similar tests of high voltage insulators, using a relatively fine wire for localizing the heating at some point of the insulator.

Alfred N. Goldsmith: In connection with values of the power factor given by Mr. Alexanderson, it is interesting to compare them with similar results obtained by Max Wien in May, 1909. In working with air, Wien used compressed air condensers, the separation of the metal tubes being 3 mm., the pressure 20 atmospheres, the capacity 0.0017 microfarad, and the breakdown voltage 40,000. The condenser was charged quickly by an induction coil in these measurements. The decrements were always carefully obtained from the same points of the resonance curve. In order to avoid the spark decrement and to check up the measurements, the impulse excitation method of energizing the condenser circuit was also tried. In order to test the oil as a dielectric, thoroly dried paraffin oil was poured into one of the air condensers. The breakdown voltage then became 30,000. The glass condensers tested were Leyden jars, which showed considerable corona even at 9,000 volts. They could be run as high as about 25,000 volts. The brush losses were separated with these jars by testing them again when immersed in oil. In all these measurements, the frequency was of the order of magnitude of 1,000,000 cycles. I have obtained the value of the power factor from Wien's values of the decrement by the usual equation:

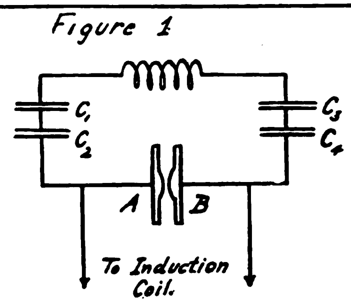
(Decrement) $= \pi$ (Power Factor).

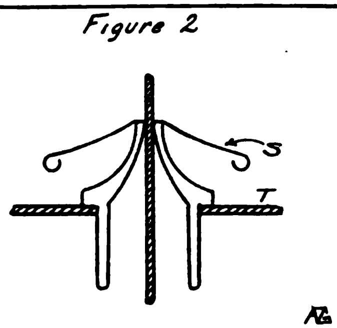
The following table gives a comparison of the results:—

Material	Power Factor (Wien) Less than	Power Factor (Alexanderson)	Testing Voltage (Wien)	Testing Voltage (Alexanderson)
Air,	0.03%	0.2%	40,000	100,000
Oil,	0.06%	0.6%	30,000	20,000
Glass,	0.05%	1.4%	9,000—25,000	10,000

Wien calls attention to the fact that the increased corona and hysteresis losses apparently increase the spark decrement at high potential very markedly. Most of the earlier investigators were not aware of this, and their values for the spark decrement at high potentials are much too large, and of no value.

The methods used by Wien in experimenting at frequencies of about 2,000,000 cycles and voltages up to 140,000 may be of interest. The circuit arrangement is shown in Figure 1. The





inductance, L, consisted of 0.5 cm. copper wire wound into a helix 40 cm. long and 50 cm. in diameter. This helix was hung on dry wood supports by silk threads. At the highest voltages used, the leads to the condenser began to brush. To prevent this, they were covered with wax to the necessary extent. The condensers C_1, C_2, C_3 and C_4 were compressed air condensers each capable of withstanding 40,000 volts. A and B are the sparking electrodes, which are of large size. They consist of brass plates 22 cm. in diameter, in the center of the plate a rounded piece of zinc 0.45 cm. high being soldered. Such large electrodes are needed if low decrements are to be obtained at high voltages. It was found that the spark decrement decreased from 0.039 at 31,400 volts to 0.018 at 136,000 volts.

An ordinary inductively coupled set was then arranged. The induction coil supplied 13.4 watts to the condensers (7 discharges per second). When working at 150 meters and 72,000 volts, with a properly arranged secondary, the efficiency from induction coil to secondary circuit was 82 per cent. This result is surprising to those who have believed that the efficiency of such ordinary spark sets is limited to 10 or 15 per cent. It may be mentioned that the highest efficiency claimed by the Telefunken Company for a quenched spark set from transformer to antenna is 84 per cent.

The means which Mr. Alexanderson has used for preventing a concentration of the electric field; namely, enlarging the conducting surface and extending it away from the point at which the brushing tends to occur, has been used by the Telefunken Company in the Rendahl deck leading-in insulator, a cross section of which is shown in Figure 2. Here S is a metal shield which extends over the conducting deck, T, and thereby produces a more even electric field, thus avoiding an excessive load at any point of the insulator.

The problem of insulation at radio frequencies and even moderate voltages will surely become of increasing importance, particularly when such devices as the Goldschmidt alternator and the Arco frequency transformers, both of which must be constructed of reasonable dimensions, become more commonly used.

H. E. Hallborg: In making tests on the ability of insulators to withstand high voltages at radio frequencies, it is necessary to continue the test over a period of time which will be sufficient to show any effects which may result from the gradual accumulation of heat. The true heating effects will not appear in a few seconds, tho in condensers the hysteresis effects will show more quickly than in insulators generally. Tests made on an ordinary molded insulator show that, altho the insulator may behave well for the first few minutes, if the test is extended over five or ten minutes, the insulator may fail completely. One sample of molded insulator, for instance, finally curled up and rolled off the table. It is evident, therefore, that in testing the characteristics of insulators at radio frequencies the time element must not be neglected.

J. L. Hogan, Jr.: The data given by Mr. Alexanderson, especially when confirmed by further experiment, will prove of great value to radio designers. The need of more intelligent planning of insulators than is practiced in some quarters is well shown by the many instances of failure under high frequencies after stringent low frequency tests have been passed satisfactorily. The experiences of the Federal Telegraph Company, which often have been duplications of the effects described by other speakers this evening, show the absolute necessity of considering the form of the static field surrounding conductors which are to be kept apart. Several A. I. E. E. papers have treated these matters recently, and I cannot urge too strongly that all radio engineers familiarize themselves with the principles involved, with especial attention to the important work described in the last A. I. E. E. paper of Mr. Fortescue (in the Proceedings of the American Institute of Electrical Engineers, 1913, Vol. XXXII, Part 1, page 759).

Guy Hill: Has Mr. Alexanderson tried measuring the insulation losses in air by putting the insulating material between spheres, instead of immersing it in oil?

E. F. W. Alexanderson: This was not attempted. If the metal electrodes touch the insulating material the results are apt to be vitiated because of the local concentration of the field and the resulting heating; that is, a redistribution of the electric gradient occurs. In air, we should also get corona effects which would materially affect the results. Altho the air might be strong enough normally, the concentration of the field might cause a breakdown.

Robert H. Marriott: In connection with the subject of insulation, I should like to refer to a paper by Stanley M. Hills. (Proceedings of The Institute of Radio Engineers, Vol. I, Number 1, page 14.)

Lester Israel: What material was finally used for supporting the transformer coils?

E. F. W. Alexanderson: Cotton tape was used for separating the turns of the pancake sections of the transformer. Each of the pancakes was held together by a radial application of tape at several points of the inner and outer circumferences. The coils thus formed were rather loose, but satisfactory in practice. They were merely hung on a wooden stick. It was necessary to limit the drop of potential along this stick else burning occurred on the wooden surface.

An Auditor: Were the transformer shields wound on an insulating material?

E. F. W. Alexanderson: These spiral shields were supported on wooden templates which did not extend outside of the shields. It is necessary that the wood used in such work be well treated.

A motion was made, seconded and passed that the thanks of The Institute of Radio Engineers be extended to Mr. Alexanderson.

SPECIFICATIONS FOR STEAMSHIP RADIO EQUIPMENT*.

By

Robert H. Marriott, B. Sc.
Past-President of the Institute.

I have repeatedly argued before you that steamships are not so well equipped with radio apparatus as they should be, that the apparatus in use is not so powerful, efficient or reliable as it should be from the standpoint of commercial and distress requirements taken in conjunction with the present knowledge and available apparatus.

I have particularly tried to point out that it is absurd to give a steamship a comparatively strong voice for ordinary conditions and a hoarse stuttering whisper for use under conditions of extreme distress, when a good strong voice for both ordinary and distress conditions is easily obtainable. Vessels are said to sail as long as five days in some parts of the ocean without being able to carry on communication because of the great average distance of ships and small radio range.

I have endeavored to bring these points to the attention of all concerned, and have continually described the kind of apparatus I believe should be used. For a time I tried to explain verbally what I believed could be reasonably obtained at the present time.

A little more than a year ago, I put my ideas of what should be used as radio equipment on board vessels into the form of a set of specifications, and in June, 1913, a number of these specifications were struck off. And it is these revised specifications, with some slight modifications and explanations, that I am presenting to-night for your discussion. In making these specifications, I tried to put myself in the position of steamship owners who desired to secure as satisfactory equipment as could be obtained at a reasonable price at the present point in radio development; and to make the specifications such that when

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sent out to all manufacturers of radio apparatus, apparatus conforming to the present status of radio development would be offered. This practice of sending out specifications has been adopted by the United States Navy to a considerable extent; and it is probably due to this, in a general way, that we have quite high class radio apparatus manufactured in the United States. Should this practice be followed by the steamship companies, it would probably result in still further development. It certainly would result in the steamship companies obtaining far better apparatus than they have at present. In making up these specifications the United States Navy 16 R 1 specifications were used partly as a guide.

The apparatus described is similar to apparatus which has been furnished to the United States Navy, but in this case it is considered to be manufactured in large quantities; thus making it very much less expensive. Probably 75 per cent. of the past cost of such apparatus has been due to the very small quantity manufactured at a time, to new features developed each time, and to inefficient factory methods. That is, the apparatus produced would probably be classified as "special apparatus," inefficiently manufactured.

The following specifications call for apparatus which, to a large extent, is not special; because the various designers of similar apparatus know how it can be made without further designs or cut-and-try methods, and the quantity (125 sets) makes it possible to have the order filled by an efficient manufacturing firm.

The proposition is not idealistic in an impractical sense. With but one or two minor exceptions it only calls for what has been manufactured, tried, and is in use. It is simply a proposition to replace known poor apparatus by known better apparatus.

There is at least one group of steamship companies that control together about 125 vessels, and this group could arrange to order the same kind of apparatus at the same time (i. e., 125 sets); and thus obtain good apparatus at lower cost.

As to patents, there are said to be ways of avoiding infringement of them in cases in which the courts have rendered decisions. Furthermore, some unfavorable decisions may be reversed, and some of the patents expire before long.

SPECIFICATIONS FOR RADIO EQUIPMENT.

1. The purpose of this specification is to obtain steamship radio equipment, with which ample, correct, and prompt radio

service may be maintained, under normal and distress conditions, with provisions for emergency-lighting power.

2. Bids are to include detailed specifications (in English), photographs, drawings, and diagrams; delivery and price.

3. It is desired that the bids be received at this office prior to .... Bids received after that date may or may not be considered.

4. Simplicity and good workmanship, without expensive construction or ornamentation, are desired. (This is an effective method of keeping down cost.)

5. All work to be done to drawings, templates, jigs and gauges, in order that strict interchangeability be insured for all parts, both fixed and moving.

6. All parts to be exposed to view, simple, compact and accessible, so far as practicable. (I find that the practice of hiding cheap and inefficient parts in handsome and expensive cases is somewhat general, and should be discouraged.)

7. Apparatus to retain its efficiency, power and appearance, with minimum cleaning, under the atmospheric conditions between the latitudes 45° North and 45° South during all seasons of the year.

8. All parts and units which cannot be easily and quickly repaired with material commonly available on shipboard, and which are liable to need repairs, and are essential to the use of the station, are to be furnished in duplicate (or in such quantities as will insure the continuous working of the station between ports where these parts are available). (Each set to include, at least, a spare armature, spare field coils, high tension condensers, telephones, and transformer secondary sections, or spare transformer if the windings are not removable.)

8A. As certainty of communication without delay is required under distress conditions, it may be found that a spare motor generator should be included.

Motor generators in the quantity these specifications would thus include (i. e. about 250), probably would be had for 250 dollars each from the maker.

9. Apparatus to produce as little noise and vibration as practicable, and not to get out of adjustment because of the ship's vibration.

10. So far as practicable, equipment to occupy as little table space as possible, and be arranged for installation on or above the operating table.

11. Other things being equal, self-contained sets, requiring minimum installation labor, will be given preference.

12. Parts and units to be permanently marked or by name plate; with name, type, style, serial number, volts, amperes, watts, cycles, resistance, inductance capacity, r.p.m., etc., according to the best practice.

13. In so far as practicable, all high-tension insulators are to be of glazed wet process porcelain, low tension insulation, according to New York Board of Underwriters' rules; and the receiver insulation is to be of hard rubber. The insulation is to receive special attention, and to be tested for fatigue, and resistance to moisture.

14. All mechanical supports to be, in so far as practicable, of metal not materially affected by atmospheric conditions.

15. Radio frequency conductors, as a rule, to be of copper or triple-plated with silver.

16. All contacts, both fixed and variable, to have a resistance of less than 0.01 ohm, and to work without sparking or heating, and with minimum mechanical and electrical deterioration.

17. Contacts to be soldered where practicable, using non-corrosive soldering flux.

18. Instruments to be capable of indicating 25 per cent. higher than it is expected it will be necessary for them to indicate.

19. Each equipment to include a cabinet, with hinged door, and locks with two keys, containing all tools necessary for maintenance of the equipment, and a bound book of type-written or printed instructions, with drawings and diagrams showing the construction of the equipment in full detail and methods for locating and repairing faults. Cabinet to be arranged for fastening to the wall. The door of the cabinet to be partly of glass, arranged to hold the operator's licenses in such a way that they may be read thru the glass.

20. Auxiliary equipment is to include an auxiliary source of power (Edison storage battery), independent of the ship's main power, capable of supplying the transmitter for six hours' continuous sending using Continental Morse at full rated power. Also the necessary fuses, under-load circuit breakers, resistances, switches, etc., necessary properly to charge the battery from the ship's mains at any line voltage, from 90 to 120 volts, these to be mounted on the switchboard. Also trays, distilled water tank, filling device and hydrometer. Separate bids may be made on storage cell compartment, suitable for installation in

the operating room. In addition to supplying the transmitter for six hours' continuous sending, the storage battery is to be capable of supplying 500 watts for six hours, for l ghting purposes.

20A. The Edison storage battery is specified because the Edison battery seems to be so far beyond any other auxiliary for this purpose that it should be named specifically.

The right kind of auxiliary is one which can be brought into service immediately and which will give at least as much power and range as could be obtained by the use of power from the engine room; that is, the ship should be able to send as far in times of distress as under ordinary conditions (or farther). For this purpose, I have considered a number of kinds of auxiliary power which are mentioned briefly:

1. STEAM ENGINE.

For a steam engine to be ready for immediate service would require the proper working steam pressure at all times whether or not there was a fire under the main boiler. To install a steam engine in a location such that the operator could start it quickly and not be interfered with by its noise, is a problem.

2. GASOLINE ENGINE.

These are commonly considered as uncertain as to the time required to start them, and they usually make considerable noise. Also, the present law does not permit carrying of gasoline on board steamships.

3. OIL ENGINE.

These have a reputation of being more or less uncertain as to the time required to start them. Furthermore, they make some noise, and it is a question as to where they should be located so as to be readily accessible in an emergency.

4. MANUALLY DRIVEN GENERATORS.

Generators with crank gear to be turned by members of the crew have been suggested, but generators which would furnish sufficient power would probably require a number of people to turn them and considerable space for these people; and it is quite possible that members of the crew might not be obtainable or controllable in times of distress.

5. STORAGE BATTERIES.

Storage batteries make very little noise, practically none, because they can be installed in cabinets which will muffle what little noise they do make. These cabinets can be in the operating room, ventilated to the outside. Or possibly, in some cases, they might be just outside the operating room. They can be brought into use in less than a second by providing a double throw switch which, when simply thrown from one position to the other, disconnects the engine room leads and connects the storage battery leads. Any form of storage battery is probably far more desirable than any present form of engine. However, lead storage batteries have a number of drawbacks. Some of the objections to lead storage batteries are as follows:

LEAD STORAGE BATTERIES.

First. The acid they contain, if spilled, which is frequently the case, is injurious to other apparatus, and furnishings. The gases from a lead battery are detrimental to certain materials. For instance, ropes on life boat davits are rotted thereby. This occurred on a United States warship recently.

Second. They may be seriously damaged by over-discharging, over-charging, evaporation of electrolyte, use of impure water or of salt water.

Third. They require continuous careful attention on the part of operators and inspectors. The attention they receive from operators is uncertain and varies as the operators change.

Fourth. Their condition (that is, as to how long they will operate) is usually something which it takes considerable time for the inspector to determine.

Fifth. Even when reasonably well cared for, their length of life at the rated output is not very great. If a lead battery is placed on a rocking base, the plates may be broken, and the separators damaged. The active material is particularly likely to be jarred out of place, or washed out by the splashing electrolyte.

EDISON STORAGE BATTERIES. (IRON AND NICKEL.)

The Edison storage battery is apparently quite different from lead storage batteries mainly in that it seems to be practically fool-proof. When I first read the Edison storage battery literature, I doubted some of their statements, but later investigations, which have now lasted over a period of about two years, have lead me to believe that their claims are true; and if anything, that they have underrated their battery (particularly in the matter of ampere-hour capacity when it is applied to this auxiliary use). I have repeatedly tested a battery of 100 Edison cells. By courtesy of the College of the City of New York and Dr. A. N. Goldsmith, these cells were installed in the Radio Laboratory of the College of the City of New York, and a number of tests have been made on them during the past year.

Practically the only argument that has been advanced against the Edison battery is that its efficiency for individual charge and discharge is not as high as that of the lead cells. That is, for a given number of ampere hours supplied to a *new* lead cell or an Edison battery, more ampere hours can be gotten out of the lead cell. However, it is recommended that the lead cell be charged and discharged at least once every two weeks to keep it in good condition. This is a serious waste of power and attention. The Edison cell can be left standing indefinitely without attention. Moreover, lack of efficiency is negligible for the purpose of an auxiliary source of power for radio apparatus because for that purpose the battery is so seldom used that its watt-hour efficiency is not material. According to the rules the battery is for use only in times of emergency.

The Edison battery costs more than the lead battery but it undoubtedly will last very much longer and cost less for maintenance; and it is claimed that in the long run the Edison battery would be found to cost *less*. The auxiliary source of power will probably never be satisfactory and will cause the steamship companies more or less trouble until that auxiliary source of power conforms to the fundamentals; namely, *full power*, *instant service* and *reliability*, and I believe the Edison storage battery properly installed meets these fundamental requirements. In August, 1910, a set of Edison batteries were put into quite steady service at the Brooklyn Navy Yard, and they are still completely satisfactory, I am told.

21. TRANSMITTER. All apparatus used in transforming the energy drawn from the ship's mains or storage battery into radio energy in the antenna.

(This is so worded as to include blowers, motors, resistance, etc., which may be necessary adjuncts to the radio transmitter.)

22. Rating of transmitters to be in terms of the energy developed in the antenna (watts in the antenna). Efficiency to be in terms of the ratio of energy in the antenna to the energy drawn from the ship's mains or storage battery by the transmitter.

(At present the rating of commercial transmitters is, to say the least, chaotic. Some of them are rated in terms of watts in the primary of the transformer, but some apparently must have been rated in terms of the energy in the engine driving the ship's dynamo, or possibly in terms of the energy in the coal bunker.)

23. Tests for rating to be made on an approved artificial antenna, having a capacity of 0.001 microfarads (compressed air dielectric), inductance of 40 microhenrys and resistance of 6 ohms.

24. The energy in the artificial antenna to be at least 1200 watts on all wave lengths from 450 to 600 meters, and as much energy as practicable from 300 to 450 meters.

(It is thought that if the manufacturers' experts can get 1200 watts in the artificial antenna, the operators will be able to get about 1 kilowatt in the antenna a greater part of the time.)

25. The transmitting circuit supplied with each set when adjusted to the artificial antenna shall be capable of continuous six-hour telegraphic operation, without any sparking, breakdown or injurious strain on any part of the apparatus, at the full rated output thruout the entire range of wave lengths.

26. The transmitting power required from engine room or storage battery is not to exceed 3 kilowatts.

27. Transmitting couplers to be calibrated for coupling and wave lengths. At least one of the coupler circuits to be calibrated in wave lengths. Couplings and wave lengths to be continuously variable between 300 and 600 meters.

28. Transmitter to be so arranged that the operator can conveniently change to any one of four wave lengths between 300 and 600 meters in 10 seconds, antenna energy to be within 25 per cent. of full power as rated for that wave length.

29. Other things being equal, constructions in which the exciting and radiating circuits can be simultaneously and rapidly adjusted to any wave length within the required range, without requiring the operator to leave his seat, are desired.

30. Transmitters to be capable also of sending on wave lengths from 1,600 to at least 2,000 meters on antennae having a capacity of 0.0007 microfarads, and inductance of 55 microhenrys.

31. Each transmitter to include a suitable adjustable capacity, to be used in series with antenna, to bring the wave length down to 300 meters, where the antenna may have any capacity between 0.0007 and 0.0025 microfarads.

32. All transmitters to be capable of giving pure notes at any sound frequency from 800 to 1,200 periods. Of these transmitters, 50 to radiate maximum power at 800 periods per second (sound frequency), 25 to radiate maximum power at 1,000

periods per second (sound frequency), 50 to radiate maximum power at 1,200 periods per second (sound frequency).

Should the total amount be between 100 and 125 sets, the decrease is to be made from the 25 sets.

32A. As 125 ships is probably the largest number under the American flag that is controlled by one group of steamship interest, this number is used in these specifications. In order to get such equipment as is herein specified at not too great a cost it is probably necessary that the equipments be manufactured in quantities of 25 or more. In such quantities the work should be an excellent manufacturing proposition. The set that will put 1,200 watts in the antenna should cost but a small percentage more than one that will put 600 watts in the antenna, because the development charges and overhead cost should be about the same for a quantity of 1,200 watt transmitters as for 600 watt transmitters, and no additional patent charges should be made for the 1,200 watts size as the same patents apply for either size.

Different audio frequencies are specified to provide against interference due to similarity of sound and also to permit of audio or group tuning.

33. The design shall be such that the adjustments for obtaining a uniformly clear, pure, musical note shall not be critical, but of wide range.

34. Transmitters to radiate at least 95 per cent. of the energy in a single wave having a logarithmic decrement of less than 0.2 under all required conditions.

35. Transmitters to give full rated power and efficiency when supplied with current from the ship's mains or storage battery, at any voltage between 90 and 130.

36. Transmitter to make as little noise as is practicable with a quenched gap transmitter. Other things being equal, a muffler around the condenser may be desirable.

37. The energy in the antenna to be easi y variable in at least five steps from the rated energy to 50 watts, preferably with a corresponding decrease in the input from the ship's mains or storage battery. Minimum transformer input not to exceed 500 watts.

(I have said 1,200 watts in the antenna as shown by trial test. This sounds large but I do not believe it is too large when we consider that we should have a factor of safety. Firstly, I believe operators seldom have the transmitter in proper adjustment to give full power; secondly, transmitters may depreciate so as to reduce the power radiated; thirdly, even 1,200 watts may not work 100 miles when atmospherics are strong; fourthly, ranges may vary even irrespective of atmospherics.

A power of 1,200 watts, or even 600 watts, on a winter night would probably cause interference over a distance far greater than it is desired to send. Therefore it is desirable that the operator cut down the radiated energy at such times and this should be made easy so that he will not neglect to do it. Loosening the transmitter coupling is probably the easiest and quickest way. For example, one coupler coil may be hinged so that it may be easily swung at right angles to the other.)

38. Low tension control devices and instruments, except the transmitting key, receiving controls, and push button for motor starter, to be mounted on the switchboard.

39. Transmitting instruments to include D. C. volt and ammeter for use in the line and storage battery circuits, A. C. volt and ammeter for the dynamo circuit, and ammeter for the antenna circuit.

40. Low tension power wiring to be encased in grounded metal covering; covering preferably mechanically stronger than lead; e. g. lead covered wire in conduits.

41. The motor starter to be arranged for automatically starting and stopping from push button control at the operating table.

42. The switchboard panel to be black, enameled, polished slate, well adapted for electrical purposes, at least one inch thick, with braced brackets for properly supporting the switchboard from the wall, so that the rear of the board will be accessible. At the bottom of the switchboard, on the rear side, shall be a line or lines of labelled terminals for attachment of all circuits leading to or from the board.

43. Dynamo potential is not to exceed 250 volts.

44. Motor and generator leads to be connected to the frame of the machine through protective mica condensers fastened to the frame.

45. As nearly as possible, the key should be as small and easy to operate as a Western Union key.

46. No energy to be drawn from the alternator when the key is open.

47. A cord and plug arrangement to be provided, for connecting the antenna directly to the ground at the room end of the roof insulator.

48. It is *not* intended that these specifications shall include only such apparatus as that wherein received sound frequency is controlled by the transmitter. Should the transmitters offered be of such type that waves of constant amplitude are radiated, the transmitter is to be provided with an interrupting device for conductively or inductively varying the energy according to the sound frequencies specified, so the signals may be read on the types of receivers now commonly in use. With bids on constant amplitude transmitters, receivers must be provided that will enable the operator to receive satisfactorily at will, either constant amplitude waves or those of periodically varying amplitude. Also an automatic receiver to be provided, arranged to operate alternately one-half the time in receiving each of the two mentioned types of radio energy.

49. RECEIVERS. All the apparatus used in connection with the antenna to transform electromagnetic wave energy into sound energy, or energy in other forms, that can be used to render the signals intelligible.

50. The tuner to have a sharp tuning arrangement and broader tuning arrangements, with spring motor for continuously varying the wave length between 300 and 600 meters, at any rate from 10 seconds to 1 minute. The automatic device constructed to be quickly disconnected and the tuning done by hand. Motor to require as infrequent winding as practicable, and to be arranged to stop at 600 meters when nearly run down (by increasing friction at 600 meter point, or equally inexpensive means).

51. Receiver to have at least one adjustment by which any wave length from 300 to 600 meters is indicated in wave lengths in a scale.

52. Receivers to be capable of receiving from 200 to *3,000* meters on an antenna having a natural period of 380 meters.

53. Two detectors to be supplied, one as sensitive as the best "Perikon," and the other as stable and sensitive as the best carborundum.

54. Receiver to be fitted with binding-posts for a separate additional detector.

55. Receiver circuits to have a minimum effective radio frequency resistance.

56. Variable condensers in the receiver circuits to be of the air dielectric type, balanced.

57. The headgear to consist of two sensitive watch-case telephone receivers, mounted by universal joints on adjustable

insulated metal straps, and arranged so as to be adjustable and conveniently held on the head of the operator.

58. ANTENNA. Includes hoisting rope, spreaders, insulators, guys, wires, fittings, ground connector, and antenna switch for connecting to either the transmitter or receiver, and controlling circuits in each.

58A. The antenna should be counter-weighted, if possible, at the free end to prevent breakage. A great deal of breakage occurs in time of heavy wind and sleet.

59. Two 16 foot steel spreaders, protected against oxidation, and of minimum practicable weight, 2,000 feet of 13 strand, Number 18, phosphor or silicon bronze antenna wire, 200 feet of one-half inch phosphor bronze running rope, and adequate fittings, deck and strain insulators to be supplied with each set, on the basis of a six wire antenna.

59A. A single one-half inch diameter phosphor bronze cable arranged like a jumper stay between the masts, with proper porcelain, egg insulators at the mast ends, might be more desirable than the present form of antenna; that is, the reliability of such an arrangement might more than counterbalance its possible inferior sending and receiving qualities. Furthermore, on large vessels, where the present multiple wire antenna cannot be used in the L form for the full length between the masts on account of the necessity of using wave lengths as short as 300 meters, this single one-half inch cable in the L form extending full length between the masts might be even as good for sending and receiving as the multiple wire antenna, and have the added advantage of being more reliable in times of wind or sleet.

60. Antenna lead terminals to make good contact at the roof insulators connection, and to be easily removable from that connection, as may be required in handling cargo.

61. Antenna insulation, preferably of porcelain, so constructed that the antenna shall not fall due to breaking of the insulation; and that no piece of dangerous weight will fall in any case.

62. Insulation to be capable of insulating with a large factor of safety, *when subjected to salt water spray.*

63. Antenna switch to be arranged for ease and rapidity of operation, and to withstand hard usage.

64. Bids including prices and delivery time on 125 equipments are desired in any or all of the following ways. Prices to be F. O. B. (i. e. delivered at) docks. Also bids for 100 equipments, instead of 125, are desired.

A. Sale price 100 and 125 sets complete.

B. Sale price 100 and 125 sets complete, except storage battery. In this case, the steamship company will purchase its own batteries.

C. Sale price 100 and 125 sets complete, with maintenance, with and without storage battery.

D. Sale price 100 and 125 sets complete, without auxiliary, and with and without maintenance. In this case, the operation and maintenance will be entirely in the hands of the steamship company.

E. Sale price 100 and 125 quenched gap sets complete, except without auxiliary, motor generator and switchboard. Bidder to state the characteristics of the generator required. The steamship company will furnish its own generator; that is, it will supply alternating current and proper means for its control.

F. Rental prices per year per set for 100 and 125 sets, as in A, B, C and D. All the arrangements outlined above but on a rental basis.

G. Same as F, and including two first grade operators per set.

H. Same as G, except the contractor to take all tolls, and steamship business to be handled free of charge.

Bids according to A, B, and E to include at separate price, sufficient additional parts or units for port stock, to keep the 125 equipments offered in proper repair for one year, and an itemized price list of units and parts. Same for F and D, where maintenance is not included.

These different classifications of bids are suggested so that bids may be sent from all the various manufacturers of apparatus, regardless of whether or not they only manufacture and sell, or manufacture and rent, or manufacture, rent and operate.

Separate prices are desired on the following additional equipment:

125 automatic tape recorders, to be operated by the primary circuit of the transmitter, each in a case, with lock, for the purpose of providing a printed record of messages transmitted.

125 break key arrangements, with receiver protection, for use with transmitters offered.

3 Decremeters, arranged for wave length and decrement measurement, with range approximately 150 to 2,400 meters.

3 portable watt-meters, range 0 to 5 kilowatts for use on potentials from 80 to 300 volts.

3 portable radio frequency ammeters, correct on frequencies from 120,000 to 1,200,000 cycles, range 0 to 20 amperes per second.

3 portable frequency meters, range 450 to 650 cycles per second.

3 portable low-reading D. C. voltmeters, range 0 to 3 volts.

Artificial antenna and complete testing instruments to be provided by the contractor. Laboratory tests to be made by a representative of the purchaser using instruments of the contractor, or such instruments and apparatus as the purchaser may desire to use.

Each equipment to be subject to at least thirty days' operating trial before acceptance.

In the event of purchase, the contractor shall protect, defend and save harmless the purchaser against any demand for patent fees, or other claims of any description for any patented invention, article or arrangement that may be used in construction, or form any part of the articles delivered under the contract or the methods necessitated by their use.

SUMMARY. **The author calls attention to certain serious defects in most existing radio ship equipment. He considers that the best possible radio equipment would be obtained by the steamship companies thru collective purchasing on a large scale of well-built apparatus constructed to meet standard specifications. He then supplies a complete set of proposed specifications for the construction of transmitter, auxiliary storage battery, receiver, antenna, and auxiliary parts.**

DISCUSSION.

Guy Hill: Mr. Marriott has certainly covered the whole case and considered everything very completely, and there is very little which has not been touched upon. Some of the specifications, I do not think I would personally quite agree with, particularly in regard to insulating materials. For instance, I cannot approve the specification of hard rubber for receivers. I do not think that insulation should be limited to definite materials in this way, as some insulating materials on the market are, I think, far superior to hard rubber. Hard rubber has a tendency to deteriorate, especially near salt water. I believe the Navy has had trouble with hard rubber, as rubber parts of sets have shrunk. Another doubtful matter is the specification of porcelain for antenna insulation. This is unnecessary, as the Navy has used various other materials satisfactorily. The Navy, as a whole, has practically eliminated all porcelain insulation. I know a great deal of trouble has been experienced by the porcelain breaking during handling and shipping, and we are now making insulating materials which are much stronger and harder, and give much greater satisfaction on the whole. I have not seen Mr. Marriott's paper before this evening, when it was read, and he has covered so much ground that it is hard to remember all his statements and discuss them off-hand.

As to spare parts which are to be furnished, their choice should be very carefully covered and mentioned in detail, as otherwise it would be quite hard to compare prices of the different companies. Sometimes the spare parts are one of the large items on a bid, and if the nature of these parts is not quite accurately stated, quite some trouble will be caused. The generator voltage, I might say, should be not more than 250 volts on open circuit and with the transmitter key raised, so that when the load is suddenly removed, the highest voltage with which the operator can come in contact, is not dangerously high. The replacing of fuses thereby becomes safe.

Storage batteries require further consideration. Mr. Marriott seems to be very enthusiastic concerning the Edison battery. A great many of the statements he gives are true. Lately, I have not followed the automobile industry very closely, but I know that in the past the automobile manufacturers, in developing their self-starting and lighting systems to meet the severe conditions met with service, have uniformly preferred the lead cells to the Edison batteries. Practically all of the people that investigated storage batteries for self-starters were opposed to Edison batteries and used the lead battery; and I think it might not be a bad idea to get more data from these companies as to their reasons for being opposed to the Edison battery, and favoring the lead batteries instead. Mr. Marriott should be congratulated on the great amount of work he has evidently done in this direction and the excellent specifications he has brought out.

John Stone Stone: I agree with Mr. Hill that it is very difficult to discuss a paper after having heard it only once, particularly when it has taken a year or more of study and construction to draw up the material contained therein. I am also in complete accord with Mr. Hill as regards hard rubber. The term "hard rubber" has not a very definite meaning, for it depends entirely on what kinds of material are purchased as to the amount of rubber present. There is only one further point I desire to mention and that is the omission of the method of changing the type of transmitter when passing from the main set to the emergency set.

Robert H. Marriott: The same transmitters are to be used in each case.

John Stone Stone: Using the same power?

Robert H. Marriott: Using full power as before.

John Stone Stone: Is it not possible to employ a lower spark frequency for emergency transmission, thereby running the motor generator at lower speed and putting less strain on the storage batteries? A smaller storage battery could be used under such conditions. A slower rate of sending dots and dashes might partly compensate for the decreased power. The energy per spark might also be slightly increased.

Robert H. Marriott: The reason for using a high spark frequency is to be able to read the signals thru static, because the high pitched note "cuts thru" atmospheric noises.

John Stone Stone: It might be possible to overcome the bad effect on the range of a lower pitched note by putting more energy into each spark, and thereby keeping the range nearly constant.

Robert H. Marriott: If the atmospherics are strong enough, they will blot out the low spark signals of almost any intensity.

John Stone Stone: Even with very small sets at low spark frequencies, very great ranges have been obtained.

Robert H. Marriott: This is the case in the winter time but not in the summer; and emergency apparatus should be suitable for all year round work.

A. F. Parkhurst: In your discussions you have just mentioned the problem of furnishing emergency and auxiliary service.

We have met this service by the use of an auxiliary source of power; the storage battery.

No one can appreciate as much as we steamship men the necessity for some recognized specifications for Radio Equipments, such as those just proposed by Mr. Marriott.

All of our installations have been made with the end in view of having the most efficient service possible, especially under emergency conditions. In fact, no expense has been spared in supplying every known emergency equipment on our vessels for promoting their safety and that of the passengers.

These precautions comply in both spirit and letter with all compulsory regulations. Naturally it has taken an enormous amount of time and detail, in addition to the expenditure of considerable sums of money, to perfect our radio service and bring it up to its acknowledged high standard of efficiency.

We, however, feel repaid by this one fact: while not being exempt from accidents, we have yet to suffer the loss of a member of our fleet.

After a number of years of experience we have arrived at what we believe to be the ideal specifications for steamship radio equipment in our very exacting service.

These specifications differ but slightly from those contained in the paper presented by Mr. Marriott this evening. I therefore feel in a position to present conclusive argument which should tend towards the adoption of specifications such as these by all steamship lines.

This would naturally be somewhat lengthy. I will therefore reserve further discussion for a paper which I propose to present to you at an early date.

John L. Hogan, Jr.: I did not have an opportunity to read Mr. Marriott's paper before this evening, but, in talking over the matter with some of the National Electric Signaling Company's engineers after the announcement of the subject of the paper, we reached the conclusion that it might interest the members of the Institute to learn of the views and methods of our Company in attacking the problem of emergency and auxiliary service.

We have made a number of transmission tests, and as the result of our experience are convinced that 100 miles cannot be covered under ordinary conditions (or possibly under conditions slightly worse than ordinary) when using less than 250 watts in the primary of the power transformer of an efficient transmitter. The sets which Mr. Marriott has described and those which the United Fruit Company has used, are, no doubt, nearly ideal. Unfortunately (or, from another viewpoint, fortunately), the present law does not require anything like the technical perfection and expense which the specifications of Mr. Marriott would demand. The steamship companies, in general, practice the strictest economy in the matter of radio equipment. They do not seem willing to consider radio service a profitable form of insurance and to balance its small expense against the value of ships and cargoes, loss of which is frequently prevented by even poorly efficient service, nor to credit the stimulating effect of good radio service upon passenger traffic.

In view of this attitude, a compromise between the ideal and the cheapest is required, and to secure a desirable outfit at reasonable cost we must eliminate all but essentials. It is evident that the parts of the radio transmitter which most frequently break down must be supplied in duplicate, if service is to be maintained. We have reached much the same conclusion as has Mr. Marriott as to which parts least stand the strain of service, and believe that the weakness of the set is concentrated at five points, namely:

1. The power source.
2. The motor-generator.
3. The power transformer.
4. The condenser.
5. The spark gap.

These parts should be supplied in duplicate. We have found that the expense of duplicating the large motor-generator set which is used for ordinary transmission is excessive, and we have therefore adopted a complete and separate, but smaller, auxiliary motor-generator set for emergency use. For a 2 kilowatt main set we provide a motor-generator set of ½ kilowatt at 500 cycles for emergency use. As to the auxiliary power source, there is supplied an Edison or lead storage battery which is able to run either the main or the emergency set. If the storage battery is chosen to run the ½ kilowatt auxiliary set for four hours, it can be relied upon to operate the 2 kilowatt main set for half an hour. In this way, in times of distress, the operator can call for help and establish communication on the emergency set. If then static is too severe to permit easy transmission with ½ kilowatt power, he can send important data relative to his position and condition by using the high power set. Many other conditions under which it would be highly important to run the main set when the ship's power is cut off suggest themselves immediately.

The provision of the storage battery and the additional smaller motor-generator provides spares for the items numbered (1) and (2) above. In our sets a duplicate power transformer is furnished, as are spare condenser and gap units. In this way all parts of the transmitter which are subject to failure are reinforced by spares, and we have available two complete radio frequency spark sets, one of 0.5 kilowatt and one of 2 kilowatts. Either of these may be operated from the ship's power or from the storage battery at will, simply by throwing two switches. The wiring is such that even under conditions of excitement the operator can make no mistake in connections.

I agree with Mr. Hill that the experience of the automobile manufacturers in connection with storage batteries for starting and lighting systems is highly pertinent, and think it is further evidence that lead cells may be used for severe service with satisfactory results. Referring again to Mr. Marriott's specifications, it seems to me that the range of the receiving sets should reach at least 3,000 meters wave length with the average ship's antenna. Time signals are now transmitted by the Navy on the standard wave length of 2,500 meters, and since these signals are of great importance to navigators the range of wave lengths of the receivers should include at least 2,600 meters, tho not necessarily at maximum efficiency.

Alfred N. Goldsmith: We cannot, without further tests, agree that the storage battery which will operate a ½ kilowatt set for two hours, under the usual conditions of radio service, will operate a 2 kilowatt set continually for one-half hour. If the storage battery is kept on a greater load, excessive polarization results, and the output of the battery diminishes rapidly. The battery is quite able to recover from this polarization, if sufficient time elapses. The extent to which this fact would affect Mr. Hogan's conclusions would have to be experimentally determined.

John Stone Stone: Is the time required for recovery of the battery not known?

Alfred N. Goldsmith: It may be at least 10 or 15 minutes, and it must be taken into account.

Emil J. Simon: The set which Mr. Marriott has outlined meets the engineering and operating requirements most fully, but it would hardly appeal to the average steamship company. It would be too expensive. Under ordinary circumstances, such a set with duplicate motor and generator and other spare parts as described, could not be purchased for less than $4,000. A storage battery equipment of sufficient capacity to operate such a set with full power for six hours will cost an additional $2,000. A set of one-half the capacity of that described by Mr. Marriott;

that is to say, a 1 kilowatt set, would be sufficient for maintaining communication up to several hundred miles under nearly all of the conditions met with by ships even in the tropics. I would like to hear from Mr. Parkhurst, as to whether in his opinion the 2 kilowatt sets which his company is using are not larger than necessary except under rare atmospheric conditions. I may say, in this connection, that with a modern quenched spark set supplying 350 watts to the transformer and delivering an antenna current of 6 amperes a daylight range of 300 miles (500 km.) in the tropics was easily attained in the summer time on a vessel of the United Fruit Company. I am certain that this range is not at all exceptional, and could be repeated at any time.

A set of the size specified by Mr. Marriott; namely, one delivering 1.2 kilowatts in the antenna, which corresponds to between 15 and 18 amperes antenna current, might well be considered unnecessarily large in a vessel of the Fruit Company type. I think it would be well for the Institute engineers to determine the proper amount of power which should be used to meet the legal requirements in order that no excessive burden or expense shall be placed on the steamship companies. I should value the opinions of the engineers present.

John L. Hogan, Jr.: Referring to the statements of Dr. Goldsmith, concerning the total time of discharge of the secondary cells under overload conditions, I would say that we have found it possible to choose a storage battery such that the ratios between power delivered and time of discharge which I have already given for our sets will hold good.

I agree with Mr. Simon that efficient 0.5 kilowatt 500 cycle sets are in general quite capable of meeting the legal requirements for auxiliary transmitters, with an ample factor of safety. In our design of ship apparatus, the smaller set meets all the usual requirements of service, yet the large set is always on hand in case exceptional conditions render its use, for a limited period of time, desirable or necessary. It may also be pointed out that on many ships the space economy effected makes this design of transmitter of far more value than one in which the large motor generator is duplicated and a large storage battery furnished.

Alfred N. Goldsmith: It is true that a storage battery can be chosen which will operate a 0.5 kilowatt set two hours continuously, or a 2.0 kilowatt set 0.5 hour continuously, but it must be a considerably larger battery than one meeting only the first of these requirements. How much larger it must be, only experiments under service conditions can show. It will be noticed that no attempt at securing inverse proportionality between power delivered and time of discharge is made for the storage battery equipment Mr. Hogan describes.

Robert H. Marriott: As regards hard rubber, I believe that certain other compounds have recently proven more satisfactory. I cannot subscribe to the doubts concerning the Edison storage battery. If it is investigated, it will be found to speak for itself when compared to other auxiliary sources of power.

The equipment which I have specified is not to be regarded as ideal; it is better to call it "fairly up-to-date." Those steamship companies which desire complete radio service and protection will probably add further equipment, as, for example, a radio telephone outfit which will enable the captain, while standing on his bridge, to talk to the captains of other ships in foggy weather, or to get directions from the pilot boat. Radio equipment and service are entitled to more than they receive generally. The vessels having radio equipment are said to cost from $100,000 to $15,000,000 each, *without cargo*. It costs $300 per day to run a small vessel, and a vessel need not be very large to cost $3,000 per day. A consideration of these specifications and the quantities of apparatus required will indicate that the outfit, including the battery, could be supplied at a good profit for less than $3,000, and this possibly even in lots of 50 or less. Furthermore, it should be remembered that good equipment costs less to maintain and operate.

It is very necessary to have a reserve of plenty of power so as to be able to work thru summer atmospherics and absorption. Fog or fire may require an S. O. S. at noon in July as well as at midnight in February. I cannot overemphasize the importance of large factors of safety in radio equipment. When the radio equipment includes a battery it is a safety and emergency device. In designing it, the benefits of any doubt should be given to the passenger and ship, the existence of which may depend on the radio set.

A motion was regularly made, seconded, and unanimously passed, that the thanks of the Institute be extended to Mr. Marriott for his useful and entertaining paper.

At the suggestion of Mr. Hill, a motion to appoint a committee on Standard Minimum Radio Specifications was placed before the Institute. It was carried, and Chairman Stone announced that he would later (he having been designated as the appointing official by the Institute) appoint the Committee. It was understood that the Committee was to restrict itself to the formulation of minimum requirements so worded as to indicate definitely that further progress and increased rigidity of specifications were completely possible, and even imminent.