PROCEEDINGS

of the

RADIO CLUB OF AMERICA

Cone Loud Speakers

A Paper Delivered Before the Radio Club of America on January 27, 1926

By C. L. Farrand

President, Farrand Mfg. Co., Inc.

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Life Membership

The attention of the membership is called to Art. IV, Sec. 7, of the recently amended constitution. This section was added to the constitution at the time of its amendment and reads as follows:

"Sec. 7—Any Member or Fellow not in arrears, upon payment of One Hundred Dollars shall be exempt for life from the payment of Annual Dues."

The Radio Club of America requires funds with which to carry on its plans for expansion and increased service and usefulness to its membership. If twenty-five Members or Fellows will send in One Hundred Dollars each in final payment of their dues for life, the sum of Two Thousand Five Hundred Dollars so realized will help materially in defraying the cost of maintaining our new office and its incidental expense. Without adequate office facilities it would be well-nigh impossible to build up a larger membership. By making adequate provision, however, for taking care of a largely increased membership for the next year or so—then launching a carefully planned drive for new members, (and the radio field is abundant with good potential members) the increased revenue from the new memberships should make the Club more self-supporting. It should be the aim to eventually possess permanent Club quarters befitting the friends of the radio art who make up our membership. Let's make that our goal, and let's get behind the life membership idea.

The Radio Club of America was founded in 1909 by a group of radio amateurs and experimenters with the object of banding themselves together, first, to afford an interchange of ideas among those interested in radio communication, second, as a fraternal organization—a *club;* third, to protect the interests of all the friends of the radio art—particularly those of the amateurs and experimenters—but more broadly, those interests which concern the general public and which may be jeopardized by unfavorable radio legislation.

Singularly enough, The Radio Club of America, unlike other clubs, and prior to the opening of our headquarters at 55 West 42nd Street, New York, had no home other than Columbia University through the courtesy of which lecture halls are made available to our Club for monthly meetings at which papers on current radio development are read. The Club shall continue to avail itself of that courtesy for the present. It cannot be denied, however, that there is a real need for a genuine "Radio Club," national in scope, which possesses a central headquarters in, say, New York City, with quarters for sections in other large cities.

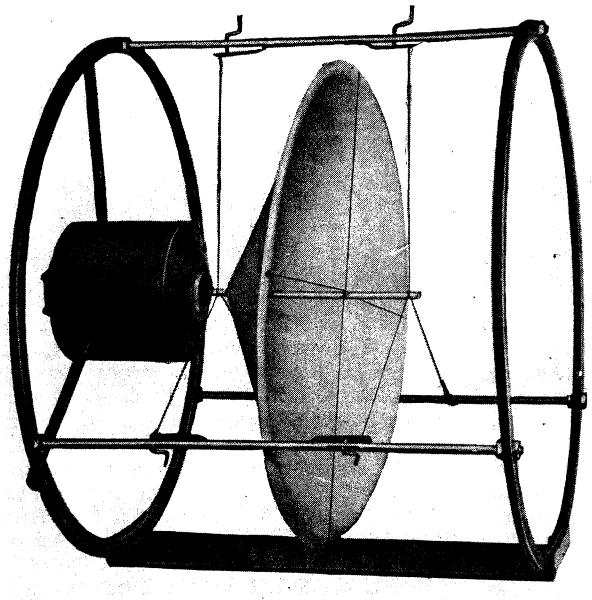
We have "the name and the membership," to quote from an article regarding us in a recent issue of *Radio Broadcast* magazine.

We now possess the executive headquarters, but let us next visualize and look forward to a permanent, commodious home at which members may enjoy real Club facilities.

L. G. Pacent
Chairman Committee on Papers
91 Seventh Ave., New York, N. Y.

Pierre Boucheron
Chairman Committee on Publications
Room 2040, 233 Broadway, New York, N. Y.

(N. B.—See page 6 for other timely notes)



A FREE EDGE CONE DEVICE

In this instance the cone was mounted on a paper straw, and reinforced by silk threads from the straw to its periphery. Bobbin motions as large as one-eighth of an inch were sometimes noticed with this instrument

Cone Loud Speakers

A Radio Club of America Paper Which Tells of the Development of the Cone Type Loud Speaker—The Requirements of a Cone to Reproduce Equally the Whole Audio Frequency Range—Where to Look for Distortion When It Occurs

By C. L. FARRAND

President, Farrand Mfg. Co., Inc.

DEVICES used in the process of converting sound into electrical energy cannot always be used for the reverse process—to convert electrical energy into sound, that is. This is especially true in the case of the common carbon microphone. However, the condenser microphone, to cite one concrete example, is a very satisfactory converter of electrical energy into sound, provided the energy is not considerable. If an attempt be made with this device to obtain the same amplitude of sound as the original input (into the transmitter of a broadcasting station, for example), an electrical rupture will occur. This is due to the low efficiency of the device, and to the low insulation resistance made necessary by the very close spacing of the opposite plates of the condenser microphone. The conversion efficiency of these devices is very low, the electrical output being very small.

Certain types of microphones (better styled "pickups") may be reversed, providing the amplitude is already within the working limits.

For the true conversion of sound into electrical energy, or vice versa, three conditions are necessary. First, we must provide a surface in the wave front of the sound wave which will move in accordance with the sound wave; second, adapt this surface to actuate or control an electric or magnetic field; third, arrange the field so it can be utilized for the production of the necessary voice currents.

The construction of the field and its associated circuit presents but a small problem, while the construction of the moving surface and its supports presents many mechanical difficulties. A disc, secured at its edge, as in the form of the present day telephone, has the disadvantages of stresses in the metal permitting the center portion to deflect a relatively large amount while the edge is stationary. This gives rise to mechanical period in the diaphragm itself, which is ultimately imparted to the associated electrical system. In the development of the telephone it became evident that it would be desirous to have the surface of the diaphragm move integrally from its center to its edge, so a diaphragm of conical shape was resorted to.

The conical shape gives extreme rigidity to axial motion and provides a surface which moves as a plunger, and which is of small weight. Cone diaphragms were used in telephones and were sometimes used in connection with horns as loud speakers. The action of the diaphragm of a plunger was to change the volume of the air in the sound box and force a high amplitude sound wave from the orifice into the horn, while the old style diaphragm changed the volume of air in the sound box by flexing. The usual difficulties of sound box resonance were present, and the addition of the horn added certain resonant periods.

THE REQUIREMENTS OF A GOOD HORN

MUCH time and effort have been applied to the development of horn loud speakers for phonograph and radio purposes. Horns of small size have been made which cover only a small portion of the frequency range. A horn, to reproduce music successfully, should cover a frequency range of 50 cycles to 6000 or 8000 cycles. This can be partially accomplished by a horn of large size, *i. e.*, 6 or 8 feet in diameter and of about the same length. Horns of smaller size generally cover the upper range or the middle range, and depend upon internal resonance to develop the lower notes.

In order to approximate a reasonable range, several horns can sometimes be used in combination. One horn would be designed for the upper range while one or two horns would be designed to cover the middle and lower ranges. The results obtained from devices of this kind have been only partially satisfactory, as a great many resonant periods occur, which tend to accentuate or blur certain tones.

The conical diaphragm, when used in telephone sound boxes, presented different problems than when it was freely exposed to the surrounding air. Hopkins made a large step in this direction by evolving a practical conical diaphragm of sufficient size to produce a sound wave of magnitude comparable to the original sound, without the use of a horn. This was successfully used with a phonograph. Large diaphragms of this character will produce a sound wave of magnitude of a normal speaking voice with a small amplitude of motion. To produce the same magnitude of sound with a small diaphragm and horn, requires a much larger amplitude of motion and higher amplitude sound wave in the sound box. This high amplitude sound wave is passed out through the narrow neck-like opening of the horn and expanded along its walls and, as the area constantly increases, the amplitude of the wave decreases and ultimately passes to free air at approximately the same amplitude as the wave produced by the large diaphragm.

The author, while searching for a suitable loud speaker in connection with talking picture work and wireless telephone systems, and wishing to avoid the distortion of the horn, happened upon the Hopkins conical diaphragm, and combined it with suitable actuating electrical telephone mechanisms. The advantages of a diaphragm of this type for use as a loud speaker were investigated and developed. A conical diaphragm can be constructed so that it moves substantially as a plunger at sound frequencies. By so moving, it acts upon a large area and volume of air, and produces a high power sound wave of large amplitude, with slight motion.

It may be generally stated that the cone moves as a plunger at sound frequency. This, however, is not exactly the case. A cone of a given size will move as a plunger only if the frequency is sufficiently low. As the frequency is increased, the outer portion of the cone will tend to remain stationary, and, at extremely high frequencies, only the inner portion of the cone will move. If a cone is built several feet in diameter, the center portion of the cone will act at the higher frequencies, around 3000 to 5000 cycles, while, as the frequency is lowered, the active area of the cone will progressively increase. That is, at the lower tones, a larger portion of the cone will function. It was noticed in the use of larger cones that there was a greater tendency to reproduce the lower frequencies, or bass notes, and it seemed that there was a relation between the diameter of the cone and the length of the wave. It is not unreasonable to expect that a 10-foot sound wave can be better produced by a plunger which approximates that diameter than by one only a small fraction of that size. Such a diaphragm may be likened to an antenna, and acts as a radiator. With suitable proportion, it may approach an aperiodic radiator. By reducing the mass of the diaphragm and the elasticity of the suspension, and disassociating it from other mechanical portions of the system, it will approach the true conditions of aperiodicity. It is essential that the associated telephone movement does not upset this condition by having undue mass or elasticity. The mass and elasticity should be so proportioned that they do not appreciably reduce the natural damping of the diaphragm. A diaphragm of this character has an extremely large resistance to motion, which is due to the actual production of sound waves, and corresponds to the radiation resistance of an antenna system.

The relation between the size of the cone and the length of the sound wave corresponds somewhat to the relation between the size of the antenna and the length of the wave to be produced, that is, for efficient radiation, it is desirable to have an antenna length which is an appreciable fraction of the maximum wavelength to be radiated from the antenna system.

THE MOVING COIL SYSTEM

THE moving coil telephone is ideal for the purpose of producing a highly damped radiator, as the mass of the coil can be made very low, and the elasticity is only that of the diaphragm, which is extremely small.

The next in choice is the balanced armature telephone. The latter generally requires a reduction lever to reduce the amplitude motion of the armature to a lower motion for application to the apex of the conical diaphragm. A reduction ratio between 0.8 and 0.4 to 1.0 is generally satisfactory.

The moving coil system, with a large conical diaphragm, was developed commercially by the author in the form of the Phonetron of 1921, and used for both loud speaker and pickup purposes.

Fig. 3 is a photograph of one of the original Phonetrons, while Fig. 1 shows its constructional details. The conical diaphragm was supported at its edge by two clamping rings. To these two clamping rings, and located on the axis of the cone, was secured an electro-magnet, by means of a spider-like support. The electro-magnet was pot-like in shape, made of cast iron or steel with a central core of Norway iron, and provided with a field winding of No. 18 B. & S. wire (suitable for 6-volt operation), and thus produced a uni-directional annular field. A cylindrical bobbin of hard rubber was supported from the apex of the cone so as to move freely in the annular field without touching the metal portions of the magnet. This bobbin was wound with 0.002-inch diameter enameled wire, about 4500 turns, for use directly in the plate circuit of a vacuum tube. Fewer turns, together with a transformer, were sometimes used. The apex of the cone was stiffened by means of thin conical metal reinforcements. When used as a pickup, the construction was similar. The Phonetron pickups were installed in the original WJZ station in Newark, New Jersey, and were used there during the spring of 1922 with excellent results. Unfortunately the receiving equipment at that time did not permit the broadcast listener to appreciate the quality of transmission. A receiver utilizing a practically distortionless amplifier and Phonetron loud speaker was installed in the office of John V. L. Hogan in New York City. Tests were made between this receiving station and WJZ of Newark, and various comparisons of pickups and loud speakers were made. The amplifier used in connection with this early work was a resistance-coupled audio-frequency amplifier wherein only the alternating potential of the plate is supplied to the succeeding grid by means of a balancing battery, which balances the d. c. potential of the plate. This circuit is shown in Fig. 2. This amplifier, I believe, is due to Arnold of the Western Electric Company. It is very satisfactory for experimental purposes where it is desired to have distortionless amplification of all sound frequencies. Four resistance-coupled stages will give an amplification equivalent to about two stages of efficient transformer coupling. The new Radio Corporation and Cunningham power tubes, UX and CX 112, are satisfactory for this type amplifier. The purpose of making the resistance of the first stages larger is to decrease the operating voltage on the tube and to permit a smaller balancing battery which balances the operating voltage of the tube to be used. An amplifier of this kind will amplify from zero cycles to 25,000 cycles without distortion, there being no reactance, either capacitative or inductive, to introduce a frequency function. Figs. 4 and 6 are photographs of a battery balanced amplifier of this type built for laboratory purposes.

CHOOSING PAPER FOR A CONE

IN THE development of the cone loud speaker, many different types of construction were tried. Various materials, including hard rubber, celluloid, wood, metals, paper, etc., were tried for the cone. A fibrous paper, not highly calendered, operates satisfactorily, and presents a good commercial solution. The thickness of the paper should be approximately one mil (.001″) for each inch of diameter, providing a soft finish paper is used; the thickness should be less if the paper is hard finish. The harder the finish of the paper, the greater will be found the tendency to depart from the cone shape, and undue stress will be set up in the paper, which will give rise to rattles, due to "tin-can" actions. The proportion of the altitude of the cone to its base can be gauged by the angle of the side of the cone to its axis. This should range between 30 degrees and 60 degrees. These values are approximate, and depend upon the size of the cone, and may be deviated from without affecting operation to any large extent.

The freedom of movement, of course, is hindered somewhat by the flexing of the paper at the edge. This flexing involves a loss of power which can be compared to hysteretic losses. Experiments were conducted to determine the amount of these losses and to lessen them. Sandpapering an annular portion at the edge of the cone, or substituting light flexible paper or other material, and castellating the paper edge, were tried. Where heavy paper was used, the above experiments improved the results, and were manifested by an increased clarity of treble. Complete freedom of the edge was obtained by suspension of the cone on silk thread. The photograph at the top of page 514 is of the free cone device. The cone was mounted on a paper straw, and reinforced by silk threads from the straw to its periphery. On one end of the straw was mounted a bobbin which floated in the annular field produced by the electro-magnet. The complete assembly was supported by threads. There was nothing to retard the axial motion of the bobbin; it floated freely in the sound wave, and motions as large as ⅛th of an inch were sometimes noticed when used.

As this was done, it was found that the edge of the cone, due to the slowness of curvature, was not inclined to move integrally with the rest of the cone. This was overcome by making a circular trough-like portion at the edge, which reinforced it, and retained the circular form of the cone. A method nearly as effective is to reverse a small portion of the cone at the edge, making a V shape trough instead of the circular trough. The advantages of freeing the edge of the cone are so slight that operation can be equaled by suitable proportion, while the mechanical advantage of a supporting ring at the edge of the paper are apparent. The outer portion of the cone can be conveniently turned inward and the mass of the supporting rings and its supports materially reduced without affecting its operation.

Fig. 5 shows a photograph of a large cone speaker built in experimental form. The mechanism is substantially the same as that of the Phonetron, shown in Fig. 1, and consists of a floating coil supported from the apex of the cone and which floats in the annular, uni-directional magnetic field. The cone of this model was about four feet in diameter, and was made of pieces of wood cemented together. The

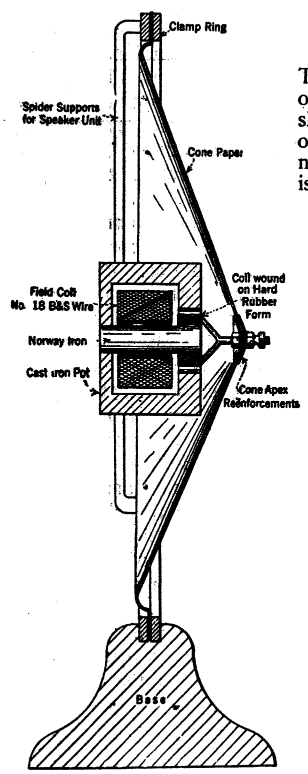


FIG. 1

The construction of the Phonetron, shown at the other lower corner of this page, is made clear by this diagram

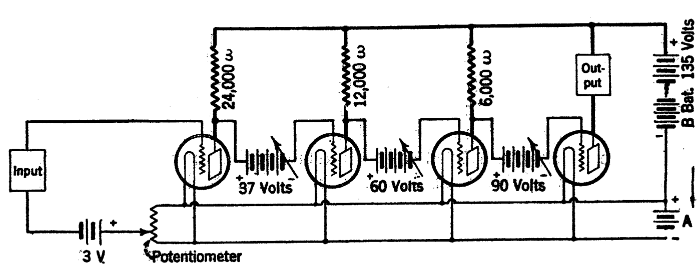


FIG. 2

This is the circuit diagram of the resistance-coupled amplifier used in a New York City location to pick up the signals from the old WJZ at Newark when comparisons of pickups and loud speakers were made in 1922

FIG. 3

In 1921, a moving coil system, with a large conical diaphragm, was developed. It was known as the Phonetron

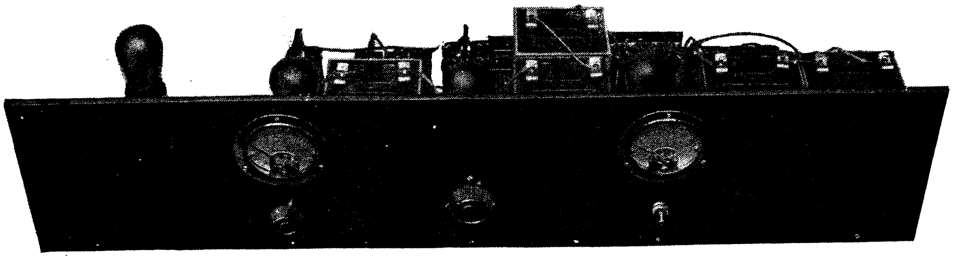


FIG. 4

A battery balanced amplifier as used in the experiments between New York and WJZ of Newark in 1922. It is a resistance-coupled affair wherein only the alternating potential of the plate is supplied to the succeeding grid by means of a balancing battery, which balances the d.c. potential of the plate

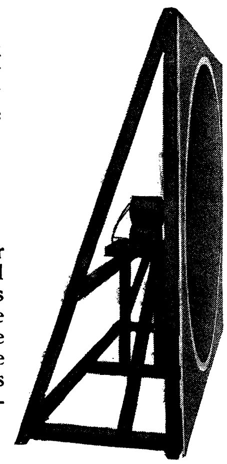
periphery of the cone was cemented to a ring of canvas which in turn was cemented to a square plywood board. The action of this device, as in the case of the Phonetron cone speaker, is as follows: The armature coil is drawn inward toward the field magnet when the voice current is in one direction, and forced outward from the magnet when the voice current reverses to the opposite direction. In this way, the force is applied between the apex of the cone and the heavy magnet pot without a system of mechanical levers.

The loud speaker, being the device which produces the sound, is generally blamed for all the deficiences of the receiving system, including those due to poor receiver, vacuum tubes, batteries, and at times, even the deficiencies of the broadcasting.

The better grade of receiver of to-day contains good audio transformers and is capable of producing good quality music with sufficient bass. It is, however, necessary that the batteries have voltage to supply sufficient power to the vacuum tubes. It is also necessary that the vacuum tubes have sufficient power capacity, *i. e.*, sufficient filament emission and normal filament brilliancy. The type UV-201-A and C-301-A tubes, when new and used with a 90-volt B battery, have sufficient emission and, therefore, power capacity, to permit faithful reproduction at only very moderate intensity. However, when the volume is increased with this combination, an accentuation of harmonics occurs, which are evidenced in a faithful speaker by nasal or rattling tones. An unfaithful reproducer will, however,

FIG. 5

A large cone speaker built in experimental form. Its mechanism is not unlike that of the Phonetron shown on the previous page. The cone of this model was about four feet in diameter

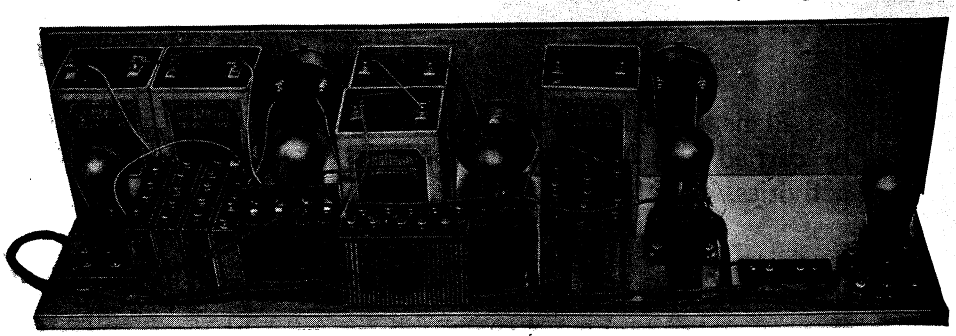


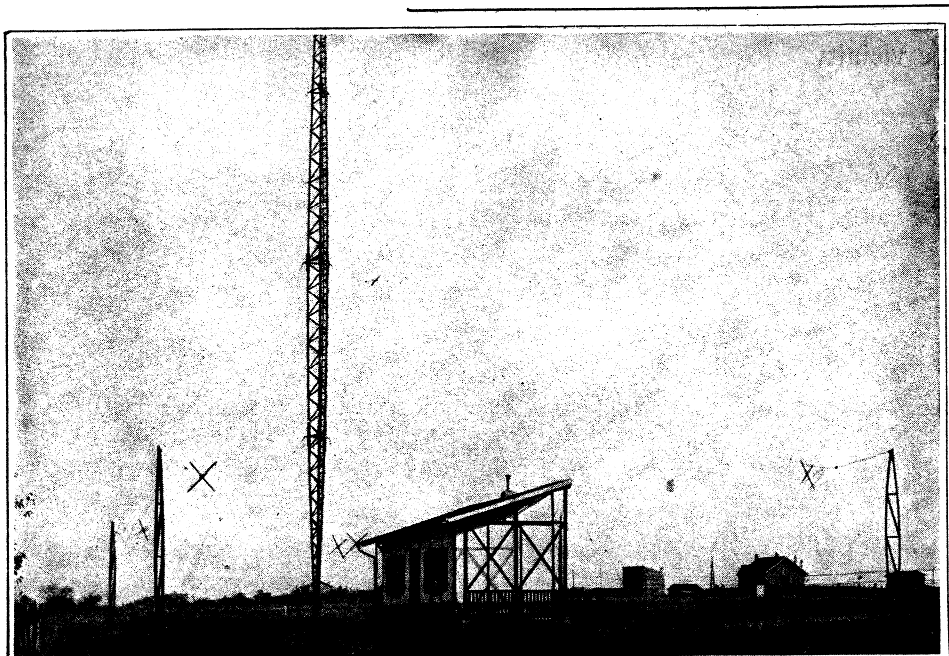
smooth these "rough edges" of the sound and give a more pleasing tone; this deceives the listener into believing that the more faithful speaker is faulty, whereas the facts are that the speaker is faithfully reproducing the voice which has been distorted by the vacuum tubes. This condition can be improved by an increase of plate voltage, which will lower the impedance of the tube and affect a greater transfer of the lower frequencies (when used with a transformer of given inductance), and will also permit the increased amplitude of the lower tones to be passed without distortion.

Super-heterodynes and sets of tuned radio frequency type utilizing regeneration have a tendency to change the tonal characteristics of the music or speech, when tuned. As the receiver is tuned to the maximum volume, an accentuation of the bass will be observed. This may cause all tones to become somewhat drumlike in nature with, at times, a complete loss of the treble. The tuning of a receiver should not change the tonal characteristics of the reception excepting that there is, however, a tendency of the human ear to respond more readily to louder sounds. In practically all radio reception of today, the magnitude of the treble is greater than the bass. This must not, however, be confused with the accentuation of bass due to regeneration as referred to above, when a partial or complete loss of treble occurs at the tuning point of maximum volume. A good receiver and speaker will reproduce throughout its tuning range the true relative value of bass and treble, the reduced bass on either side of the peak tuning point being due to the failure of the ear to notice the bass until it is sufficiently loud. The intensity of treble will not lessen at the tuning point of maximum volume, but the bass will sound louder.

FIG. 6

Below is shown another view of the balanced amplifier shown at the top of this page, and schematically in Fig. 2





A FRENCH AMATEUR SHORT WAVE STATION

Owned by *La T. S. F. Moderne*, a Parisian radio magazine. Its call is 8AÉ and when this station was erected, was using 1764-1499 kc. (180-200 meters). This view shows the antenna and counterpoise

Timely Notes

Proposed Chicago Section

Mr. Sylvan Harris of Chicago has suggested the creation of a section of the Club in that city. The Directors are now taking up this matter officially.

Membership Drive

In the mail which encloses this issue every member will receive a blank form of application for membership. You are requested to use it in procuring at least one applicant for membership. Additional blanks will be mailed by the Corresponding Secretary if they are desired.

Club "Short Wave" Station

Plans for maintaining a short wave station are being considered. It is hoped that, if this idea be carried out, the amateur operators may be brought in direct contact with the Club and its activities.

Change in Our Room Number

About the middle of October, our office will be in Room 819, same building (55 West 42nd Street, New York City). This office overlooks Bryant Park. Members are invited to make it their headquarters when in the vicinity.

The Radio Club of America

Bryant Park Building, Room 469

55 West 42nd Street, New York, N. Y.

Telephone—Longacre 8579

Organized in 1909 by pioneer amateur radio experimenters of America for the purpose of exchanging views and scientific data on the most fascinating subject of modern times—radio telegraphy and telephony.

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