THE HISTORY AND DEVELOPMENT OF RADIO STATION W.R.C. IN WASHINGTON D.C.

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SUMMARY.

THE HISTORY AND DEVELOPMENT OF RADIO STATION W.R.C. IN WASHINGTON, D.C.

1. Introduction
2. General History.
3. Studios.
4. Advertising.
5. Electrical Transcriptions.
6. Microphones.
7. Control Room and Control Operation.
8. Remote Control.
9. Transmission Links.
10. Transmitter.
11. Antenna.
12. Conclusion.
13. Bibliography.
14. Appendix.

Composite of Radio City

INTRODUCTION.

In this paper, practically all the readily obtainable facts concerning the history and development of Radio Station W.R.C. are presented briefly in most part. It is unfortunate that the facts concerning the history of the station could be obtained only from a few individuals, who have been employed by the station since its beginning; the author has thoroughly discussed the subject with them and the results are given in the following pages. No records of the station's activities have ever been kept, except those purely business ones, which are confidential to the station and would prove uninteresting.

Therefore, the majority of the material presented deals with the station in its present status. Much emphasis has been placed on the transmitter and control room, including much technical data. There are two reasons for this: first the author is extremely interested in that phase of broadcasting, and second, much material was available along these lines.

No figures on operating costs, original costs, or any other business or commercial data could be obtained, the reason being obvious.

No actual photographs of the station are presented because none were available and it was not permitted to take any. A few pictures have been added in an endeavor to give a more concise idea of the material, even though most of them are not of W.R.C. A schematic diagram of the transmitter is shown; it is an exact replica of the blue-print furnished with the installation.

GENERAL HISTORY.

Radio Station W.R.C. of Washington, D.C. was planned in the Spring of 1923 and financed by the Radio Corporation of America. It was officially inaugurated to the "air-lanes" in August, 1923. There were two underlying factors which created the necessity of a broadcasting outlet in Washington: first, an inducement to the public to buy radios, the sustaining product of R.C.A. at that time; secondly, to furnish programs directly from the nation's capital, since it was the chief seat of government in the United States.

In 1926, the National Broadcasting Company assumed the management of W.R.C. and in 1932, they bought it outright; however, during that time, N.B.C. and R.C.A. had incorporated into one organization and virtually, the station has never changed hands since its beginning.

Station W.R.C.,including transmitter and studios, was constructed in the Riggs-Thompkins Building at 14th Street N.W. and Park Road. The call-letters at that time were significant: "W", as the initial letter for all eastern stations on the regular broadcast band; "R.C." for Radio Corporation. The call-letters do not stand for Washington Radio Corporation, as commonly believed by some.

W.R.C. began operation on the assigned broadcasting frequency of 630 kilocycles with a power output of 500 watts. With the inauguration of Station W.M.A.L., W.R.C. relinquished that frequency to that station and continued operation on 950 kilocycles, by permission of the Federal Radio Commission. It has maintained operation on that channel up to the present time.

The initial program included an address by Major-General J. G. Harboard, who was at that time president of the National Broadcasting Co.

This program was announced by Milton J. Cross, who is now a well-known announcer on the N.B.C. net-works.

W.R.C. has always been the point of originatión of all broadcasted addresses by the President of the United States.

During the first year, the station operated only 3 or 4 hours per day, including a few remote pick-ups for special occasions. Upon the completion of a year of successful operation, night programs were begun. During the course of the following three years, the broadcasting time was finally increased to 18 hours per day, which quota of time has continued up to the present.

In 1924, the first programs from W.J.Z. in New York were broadcast through the transmitter of W.R.C. via Postal Telegraph cables. A short time later, programs were received from as well as sent to both W.J.Z. in New York and W.B.Z. in Boston.

In February 1928, the studios were transfered to the National Press Building, on F Street, adjacent to the Fox Theatre; the studios are still on this location, but of course many refinements have been made.

The original staff of W.R.C. consisted of only eight members; the present staff, not including those employed directly by N.B.C., consists of 45 members. W.R.C. boasts of having on its staff at one time such noted announcers as: Norman Brokenshire, John B. Daniel (deceased), and Ted Husing.

STUDIOS.

The original studios of W.R.C. were located, with the transmitter, in the Riggs-Thompkins Building at 14th Street N.W. and Park Road. At that time, little was known of proper studio design; however, the walls were soundproof and the floors were covered with thick carpet to silence footsteps.

In 1928 the studios were located in the National Press Building with the business offices. By this time, some progress had been made by radio engineers in the field of studio design and the new studios were built with all these latest refinements and are still in use at present. There are one large studio and two small ones, each of which was designed to have a maximum reverberation time of 1 second and a minimum of .4 second. It is a desirable feature of a studio to have a variable reverberation time, so that the studio can be suited to the particular type of program being broadcast. Since this refinement was not perfected until quite recently, the studios at W.R.C. are not equipped for it. However, at Radio City, the reverberation time is varied by means of electrically controlled panels, which at the same time may present surfaces with variable sound reflection coefficients at will of the operator. The desirability of this quality can be proven in the large studio by a clap of the hands at certain places, resulting in reverberations having a reverberation time well over one second; this is not a good test but it does show that there is the possibility of producing sounds having a reverberation time beyond the limits for which the studio was designed.

It has been proven by the Experimental Research Department of N.B.C. that the ideal studio dimensional proportions are 2, 3, and 5 - height, width, and length, respectively; the studios of W.R.C. have been designed to meet these specifications. They were also designed to have an attenuation of at least 60 decibels, bi-directionally; this feature is of utmost importance and is accomplished by the use of sound absorbing materials on the walls and ceiling and of floating load bearing walls, floor, and ceiling. This latter refinement gives the studio the effect of being semi-detached from the building. It is also important that the window between the studio and the control room present an attenuation equal to that of the walls; this is accomplished by using three separate panes of glass of thicknesses 3/16", 1/4", and 3/8"; this combination with a thin vacuum between the panes gives the desired results.

The studios are sound-proofed against external noises by means of a special wall and ceiling construction, for which purpose a special acoustic celotex, having small air pocket holes in its surface, is used. The floors are covered with thick carpet to deaden foot-steps as well as to reduce the reverberation time.

Actual control of a broadcast begins in the studio; a small control unit having key switches, signal lights, and an intercommunicating telephone to the control room, enables the announcer to switch the microphones at different positions on or off, and to keep the operator in the control room advised on the progress of the program. All microphone and control circuits are carried in lead covered cables behind the wall sound-proofing. Connection boxes are set along the baseboard for microphone outlets, Each studio is equipped with its own amplifier, since with the types of microphones now in use the signal produced is so weak that it requires immediate amplification before it can be sent to the control room.

ADVERTISING

Advertising in radio broadcasting did not start on a large scale at W.R.C. until 1928 or 1929. Before that time, the station itself operated at a loss; but since R.C.A. built W.R.C. for the purpose of furnishing an incentive to the public to buy R.C.A. radios.

During the first few years of operation, the artists were paid directly by the station, but later they performed free of charge in that the publicity they would obtain from the service of the station was sufficient recompense. It was not long until radio artists were sponsored for the purpose of advertising.

With the initiation of network programs, sponsors had to buy time on the air to advertise a product. From that time on, the development of advertising in radio broadcasting, especially in the network programs, has advanced by leaps and bounds.

Just prior to the beginning of the regular network hook-ups, W.R.C. had a fair portion of its daily program sold for advertising purposes. Later on as the demand for better talent increased, the present economic crisis began in 1929, and it was at this time that W.R.C. began to employ electrical transcriptions on a big scale for local programs in conjunction with short advertisements, which method is used instead of a regular sponsored program.

It must be remembered that advertising is practically the only sustainence that W.R.C. has. It follows that the greater volume of advertising, the greater the service that is rendered to the public by the station through the broadcasting medium and consequently, a benefit to both: the station can afford better programs with the capital furnished and the public can therefore derive more enjoyment from them.

ELECTRICAL TRANSCRIPTIONS.

In 1930 it was found necessary to add equipment to the station for the broadcasting of electrical transcriptions; since that time their use has become an integral part of the daily program of W.R.C., in fact the program from 7 A.M. to 9:15 A.M. every morning consists of nothing but electrical transcriptions and advertisements. It was at this time that the present economic depression was at its peak. Since the beginning of their widespread use, they have caused much undue criticism against their being broadcast; from an engineering standpoint, they are fairly comparable to network broadcasts since both have their own peculiar fallacies, both in volume range and frequency range. The electrical transcription method of broadcasting enables a smaller station, which can not conveniently obtain the services of high-grade performers, to broadcast from records made by these highly-paid artists. Thus the cost of a performance by such artists is spead out over a large number of duplicate records made and distributed to the smaller stations, thus enabling them to offer programs of a quality and appeal which they would otherwise be unable to afford.

In the past few years, the quality of electrical transcriptions has improved immensely; the frequency range of the present type is from 100 to 4000 cycles per second, with a standard speed of 78 r.p.m.

When broadcasting electrical transcriptions, the method used, is simply to use an electrically driven phonograph turntable with an electrical pickup unit playing from the record and feeding directly to the speech amplifier in the control room, thus modulating the carrier current in the usual way. Magnetic type pickups are still being used, although much more efficient types have been developed. The turntables are driven by synchronous motors, equipped with counter-balance weights to insure correct and constant speed. There are two turntables and two pickups, both of which are located close enough to the control panel that both can be operated by one man.

MICROPHONES.

The microphone is an instrument for changing the energy produced by air-vibrations into electrical energy. As small as it may be, it plays an important role in radio broadcasting. Its developement at W.R.C. has been practically the same as any other station. Of course some stations were able to take advantage of microphone refinements as they were developed, while others were not, due to financial difficulties; it was the good fortune of W.R.C. to be one of the former, since its owner and operator was the creator of the majority of the refinements.

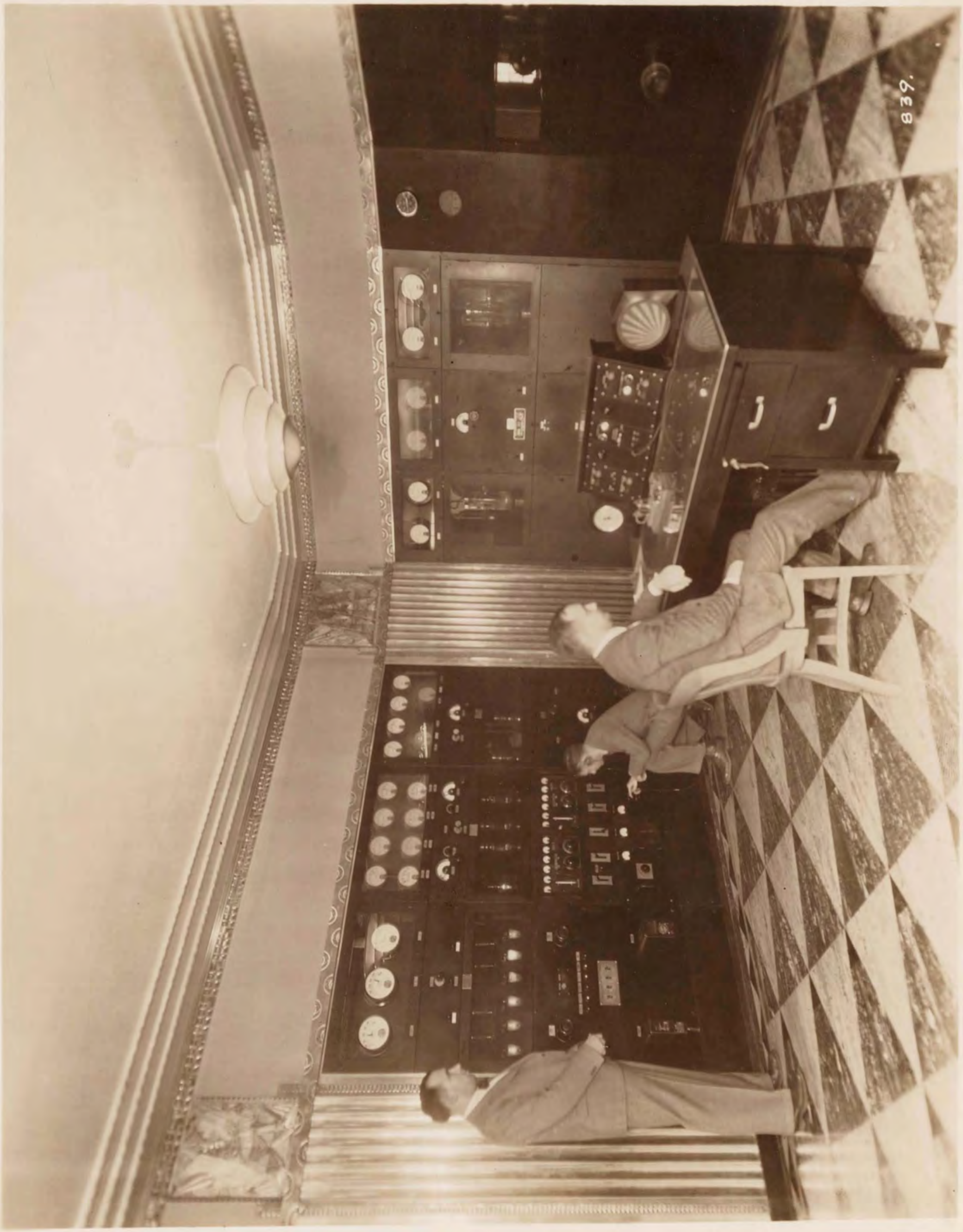
The first microphone to be used by W.R.C was the single-button carbon type; it had high gain, high noise level, and a very limited frequency response and was very inferior to the type which soon followed it. This was the double-button carbon microphone; it was vastly superior to the former type and is still used today, with certain refinements of course, for certain types of broadcasting. The carbon microphone is characterized by an inherent noise called "carbon hiss" which makes it undesirable for good broadcasting.

It was not long after the opening of W.R.C., that the R.C.A. engineers began to concentrate particularly on the developement of a new type of microphone free from this objection. Their first product was the condenser microphone. The principle involved in it is comparatively simple: it consists of a sensitive condenser plate, acted upon by the varying pressure of sound waves, thus varying its capacity.

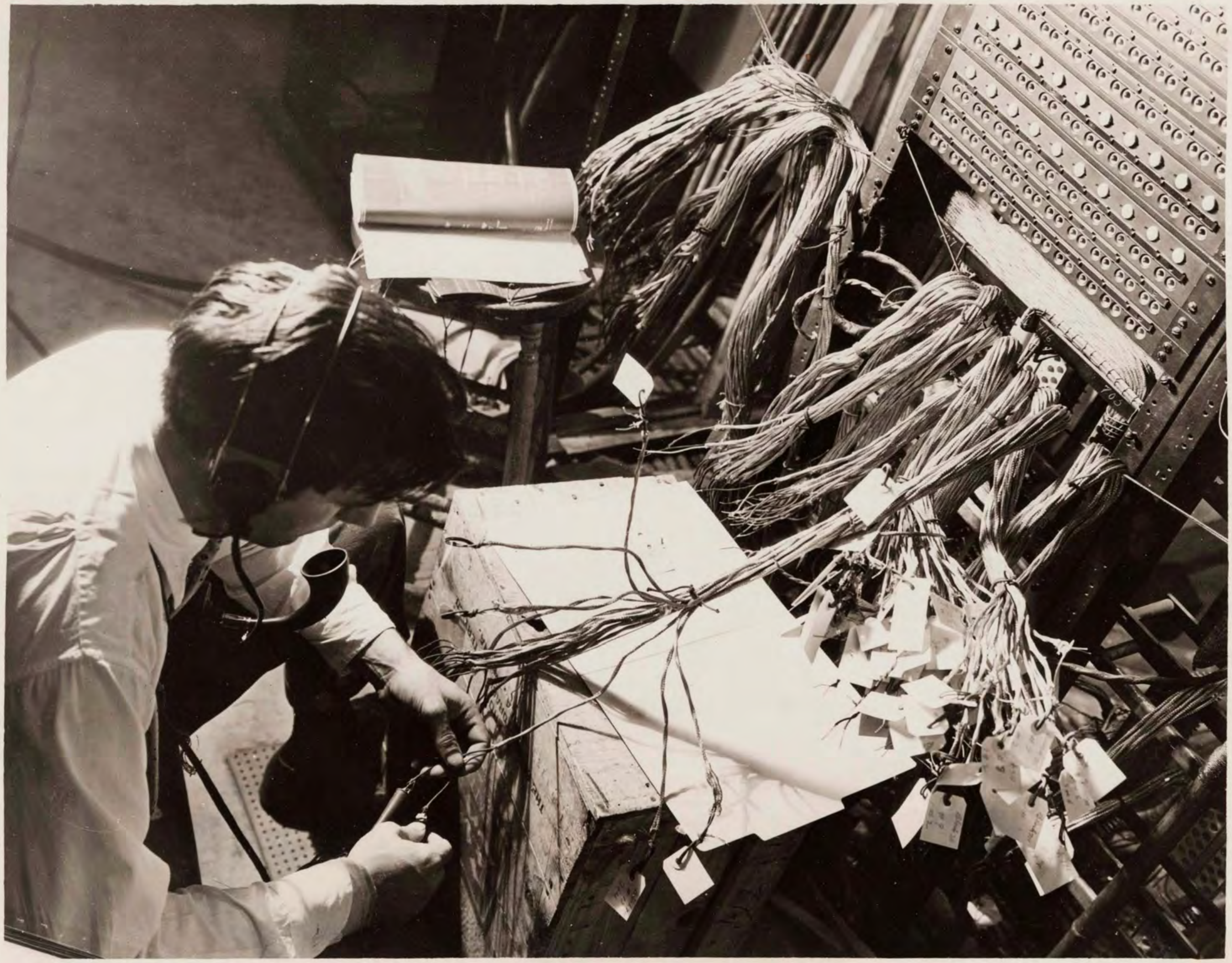
The next developement of the R.C.A. engineers was the dynamic microphone, operating on the principle of a moving coil in a magnetic field. The velocity or ribbon microphone soon followed; it utilizes the principle of a thin ribbon, which presents an edgligible impedance to sound waves, placed between two permanent magnets. This latter type is by far the best produced to date. Recently, the R.C.A. engineers produced a new type, operating on the inductor principle; it has been adopted by N.B.C. as the standard model for field work and is rapidly replacing the double button carbon microphone for portable work. In general, concerning the developement of the microphone, the increased efficiency, both in tone quality and frequency range, is followed by decreased electrical output; thus, higher gain amplification is demanded to bring the energy levels up to the ordinary transmitting levels of the wire links. To rectify this condition, preamplifiers must be added to the microphone itself.

THE CONTROL ROOM AND CONTROL OPERATION.

The control room is probably the most vital part of the broadcast station; all programs must be routed through it before they can be broadcast, whether they originate in the studios, from the network, from the field, or from the electrical transcriptions. It is the duty of the operator to see that the program regardless of its source is sent to the transmitter at the proper energy level and at the correct time. All this seems quite complicated, but the accompanying diagram of the control room shows simply the functions of each part; it must be remembered that this is not a schematic diagram. Following the circuit from left to right, the input of the first amplifier may be connected either to an outside(field) pick-up point, or to the studio microphones of which two are shown combined in a mixer, (more or less may be used). The actual switching would not be accomplished with a knife switch, as shown in the diagram for the sake of simplicity, but by means of a telephone key or plug-in jack arrangement in which the transition from one circuit to another is made without a long break. The output of the amplifier is connected to an artificial line which drops the transmission level. This line presents an impedance of 500 ohms in both directions. The amplifier has the same output impedance, while the input impedance is matched for the type microphones being used; however, the matching requirements are not highly critical. A level indicating device is bridged across the input of the artificial line; this indicator is designed to give correct readings when connected across a 500 ohm circuit of the type shown. The output of the artificial line feeds a monitoring amplifier, but the main circuit passes through a switching system to the input of two or more(8 are used in this case, but not shown) line amplifiers containing two stages of amplification each. One of these amplifiers



N.B.C. Control Room at Bellmore, L.I.



CHECKING THE MAZE OF WIRES

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The operator is identifying and testing the wiring for the termination of trunk lines to the studios and operating rack of the new NBC studios in Radio City.

NBC Photo

feeds the local transmitter at 14th Street and Park Road; another feeds the network whenever the occasion warrants it; another feeds W.M.A.L.; each is installed in duplicate. The purpose of splitting the circuit by means of one-way repeaters at this point is to permit local announcements to be made by short-circuiting the network amplifier, thus confining whatever is said in the studio only, to the transmitter of W.R.C. The operation is practically the same when programs are being received from the network. The function of the artificial line, which may seem an unnecessary loss device between the preliminary and line amplifiers, is to provide an intermediate low-impedance circuit with constant level, suitable for measurement purposes, and unaffected by the addition of ordinary bridging impedances.

The electrical operation of the interlocked studios may be understood from an inspection of the relay circuits. The details are shown for only one studio, the circuits for the other two studios being precisely similar. The output of the artificial line goes to two fixed contact points of a telephone relay. The winding of this relay is supplied with 12 volts when the announcer's switch in the studio is closed. If the "B" main relay is open, the other terminal of the "A" relay winding is connected to the positive side of the 12-volt battery, which is grounded. The same action supplies current to a red light in the "A" studio or the control room, visible to both operator and announcer, warning both of them that their studio is connected through to the line amplifiers. If "B" studio is in use, then it is impossible to connect the "A" studio to the audio-frequency bus which leads to the line amplifiers, since the "B" relay keeps the "A" relay coil from being energized. Thus there is no possibility of putting two studios on the air simultaneously. The studio which is not in use receives a green light from the studio which is in operation. If neither studio is in use both lights are dark. In this condition, also, the audio-frequency bus supplying the line amplifiers is short-circuited by an auxiliary relay. Were this not done the input of the line amplifiers would be open when neither studio was "on the air", with the result that if these amplifiers had their filaments lit, cross-talk pick-up would be likely to go out on the lines.

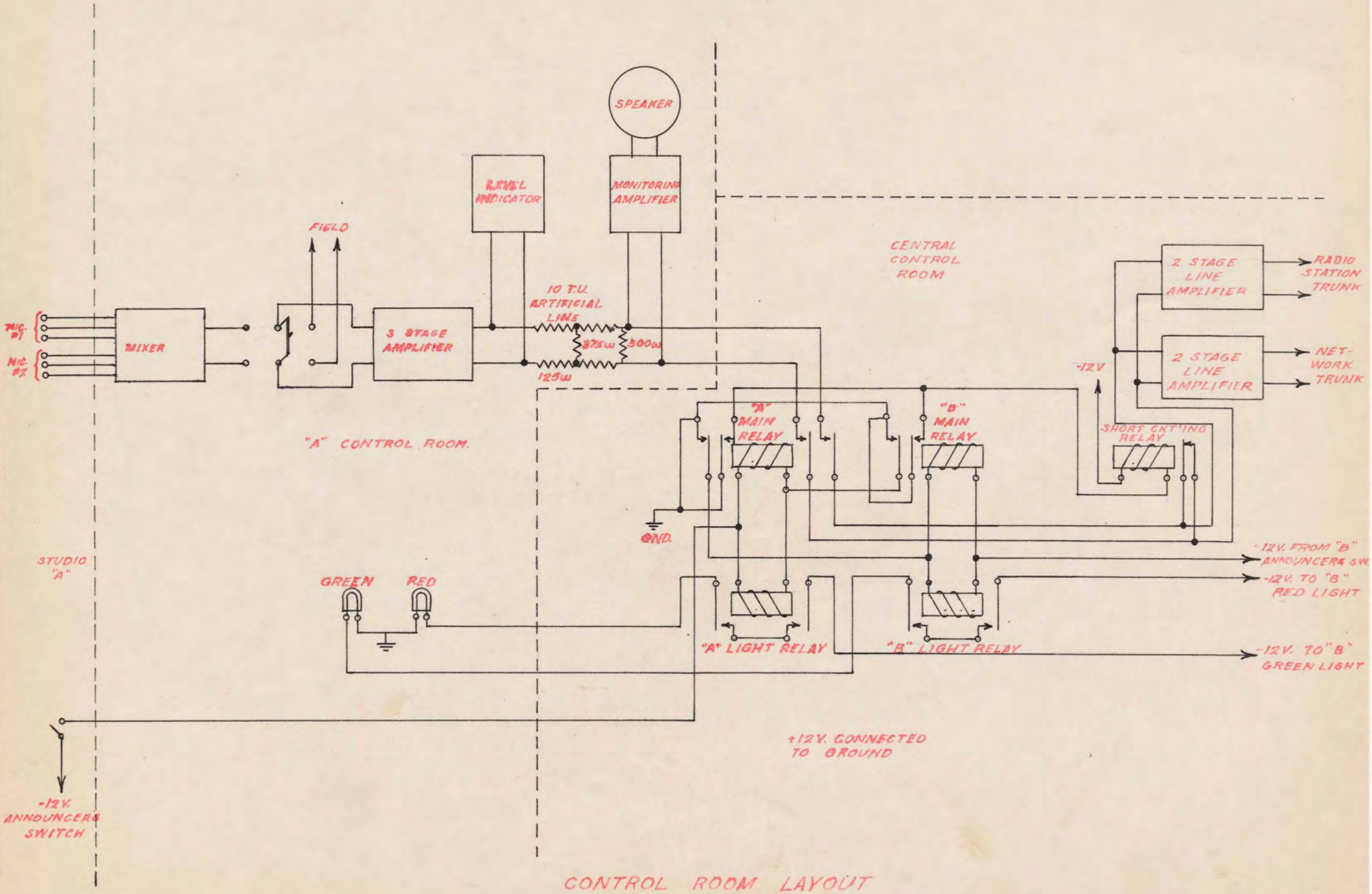
In the diagram only two studios are shown for the sake of sim- p licity; as mentioned before, there are three studios, one large and two small.

The control room at W.R.C. is more than a control room for a single station; it is one of the control points of the National Broadcasting Co. for both the "Blue" and "Red" networks. There are eight stations including W.M.A.L. which receive network programs all of which are routed through W.R.C.'s control room. Essentially, it is a booster station for these other broadcast stations in that the amplifiers raise the transmission level of the network programs to a point where they can be satisfactorily sent on. Of course at the same time, the control room is performing its primary functions in the operation of W.R.C.

Telephone links from any point in Washington where a broadcast is likely to originate (such as night-clubs, centers of political activities, the White House, etc.) are connected to the control panel.

Local programs of W.R.C. proper are boosted to the transmission link level by two amplifiers; the first is the impedance coupled type using the following tubes: 2-841, and 1-210; the second amplifier is transformer coupled and uses the following tubes: 1-841 and 1-210. The latter one is the type used for the network service.

Batteries are used entirely for the power supply of the amplifiers in the control room. The plate voltage is obtained from "B" batteries having a voltage rating of 440 volts; the filament supply is obtained from



CONTROL ROOM LAYOUT

WM. A. MCCOOL
DEC. 1938

"A" batteries having a rating of 350-400 ampere-hours, at 12 volts; the bias voltage supply is obtained from "C" batteries (the "C" batteries are the dry type while the others are wet), having a voltage rating of 22½ volts with various taps for securing lower bias voltages. The "A" and "B" batteries are charged by generators; in the first case, the generator has a rating of 20 volts at 50 amperes, but is used at 14½-15 volts at the rated current; the second, is rated at 600 volts but used at 440 volts. Obviously, the "C" batteries are not charged.

The control room personnel consists of five men; a supervisor, 3 operators, and a maintainence man. Mr. Johnson is the chief engineer of the entire engineering staff of W.R.C. and Mr. Merryman is the field engineer.

REMOTE CONTROL.

If the broadcast originates at some point away from the station as in the case of a football game or other event, the microphones and usually a speech amplifier are installed at the field and special wire telephone lines are run to the control room. Generally, the existing telephone lines are rented from the telephone company. For broadcasts, where telephone lines are not accessible, a portable short-wave radio-phone rtansmitter of low power, operating on a frequency of 34.6 megacycles per second is used, only for short distances, however. When the portable transmitter is used the program is picked up by a short-wave receiver in the control room and then amplified to the level of the transmitter link.

TRANSMISSION LINKS.

The first transmission link to be used by W.R.C. was furnished by Postal Telegraph Co., extending from New York to Washington; later on the link extended to Boston. The resulting programs of this network were very unsatisfactory in that the audio frequency transmission characteristics of the link were poor; but it did afford an outlet in Washington for more programs and at the same time give W.J.Z. and W.B.Z. a linkage with the nation's capital. With the formation of the National Broadcasting Company, in November 1926 W.R.C. became a part of the regular "red" network with W.E.A.F. as the key station. The program service was now transmitted from New York by special broadcasting circuits supplied by the American Telephone Company. These cables which are still in use were entirely underground and gave considerable improvement to the service both from a standpoint of noise level and frequency range, yet far from ideal conditions; the noise level measures approximately 35 decibels, with a usable volume range of 37 decibels, 60 decibels being attained with a symphony orchestra broadcast. The frequency range extended from 80 to 5000 cycles per second and the curve obtained within these limits is flat within 1 decibel; this frequency range is better than the average broadcast receiver on the market today.

The transmitter is approximately two miles from the control room in the National Press Building. Programs for both W.R.C. and W.M.A.L. are routed through this control room. The wire link between the above mentioned points is far superior to that from New York. This two mile link has a usable volume of 50 decibels and a frequency range from 50 to 8000 cycles per second. As a result, the superior quality of local programs can easily be detected by even the layman, when monitoring on a laboratory model receiver. As far as present research has been able to determine, the frequency range between 5000 and 8000 cycles per second has great importance in producing naturalness and good tone quality; however, beyond 8000 cycles per second, little effect can be detected by the human ear. Below 50 cycles per second few tones are produced and therefore are of little importance relatively. As a comparison, the pipe-organ has the greatest frequency range of any musical instrument, 16 to 16,000 cycles per second; these limits are beyond those to which the human ear is sensitive.

THE TRANSMITTER.

The first transmitter used by W.R.C. was originally designed for ship-board communication purposes. It was built by R.C.A. and later redesigned especially for broadcasting purposes, with a power output of 500 watts. According to the usual practice, the transmitter was installed in duplicate--that is, two separate machines, one for regular operation and one for emergency.

These transmitters were used continuously until 1932, when an R.C.A. Victor Type 1-C model transmitter was installed; it has been in use ever since. The old transmitters were torn down and the parts were used to construct another with a power output of 500 watts. This reconstructed job is now being used for the emergency transmitter.

At present, the transmitter is operated on an assigned frequency of 950 kilocycles with a carrier power of 1000 watts in daytime and 500 watts in night-time.

RATING.

Full modulation with the nominal output rating of 1000 watts is produced by an input of about zero level (12½ millivolts). The input impedance is 500 ohms. It is well to observe, here, that in accordance with the conventional form, when specifying the output rating, no account is taken with regard to the degree of modulation. This rating is the measure of unmodulated carrier wave only; however, when modulated 100% the instantaneous peak reaches 4 kilowatts. The tubes and circuit are so designed to permit continuous operation at full 100% modulation.

FREQUENCY RANGE.

This type of transmitter and equipment can be adjusted for maximum performance and efficiency on any frequency within the broadcast band, ranging from 1500 to 550 kilocycles. However, the crystal was supplied to operate on the assigned frequency of 950 kilocycles; therefore, with any change of frequency a new crystal must be obtained.

POWER SUPPLY.

The transmitter is designed to operate from a 220 volt, 3 phase, 3 wire, 60 cycle power supply from the line. The power supply unit consists of two 3 unit semi-enclosed motor-generator sets. The first of these is the filament and bias supplies, which consists of a 70 ampere 19 volt generator and a 550 volt .9 kilowatt generator driven by a 5 horsepower motor. The low voltage generator supplies all tube filaments except the UX-866 rectifier tubes and the speech amplifier tubes. The 550 volt generator supplies the bias voltage for all tubes except those contained within the crystal oscillator unit and the speech amplifier; in addition, this latter machine supplies the field excitation for the remainder of the generators including the machines for the filament and plate supplies. With a 220 volt 60 cycle line, this motor-generator set rotates at 1750 revolutions per minute.

Both units have a remarkably low percentage of voltage ripple in their output when nominally loaded; they were especially constructed for radio transmitter power supply purposes and present a very neat and pleasing appearence.

The second unit is a 3 unit high voltage motor-generator set consisting of two identical 3000 volt 4.5 kilowatt generators driven by 14.5 horse-power motor. In operation, these generators are connected in series and rated at 7.5 kilowatts at 6000 volts. The armatures in each are identical and interchangeable, each being insulated for maximum high voltage so that only one armature, which will fit each machine, need be carried for a spare. This unit, with the same power supply from the line, rotates at 1750 revolutions per minute. Different voltages can be obtained; 1500, 3000, and 6000 volts. Each machine is completely enclosed and protected by means of perforated metal screens.

This equipment must be operated from a well regulated power line. A supply in which the line voltage variations exceed plus or minus 5% is considered unsuitable for broadcast transmitter supply service and requires some form of automatic regulating equipment. However, the line supply used does not vary sufficiently to warrant the use of such equipment: it was found in a two week test run that the line voltage varied only plus or minus 4 volts at a maximum.

A pump for the cooling system and the crystal oscillator supply rectifier are operated from the line instead of the generators. A 110 volt single phase lighting circuit supplies the crystal heater power. Batteries are used to supply the filaments of the tubes in the speech amplifier; but the circuit is so arranged that this filament supply can be obtained from the motor-generator if the batteries should fail.

VACUUM TUBES.

The following tubes are employed in the transmitter:

2 - UX-210	1 - UV-203-A
4 - UX-865	1 - UV-849
3 - UX-860	2 - UX-280
2 - UX-866	1 - UV-1652

The positions of each are shown in the schematic diagram.

THE CIRCUIT.

The carrier frequency is generated by a crystal controlled master oscillator, amplified by five successive stages of radio frequency power amplification, and delivered to the antenna through a transmission line. The modulating frequency, or audio frequency, passes through one stage of power amplification to the modulating circuit. Modulation takes place in the fourth radio frequency stage. The succeeding radio frequency power amplifier acts as a linear amplifier. Such a system of modulation is by convention, called "low level" modulation.

The power supply for operating the radio system is primarily a fully automatic and interlocked system, but provision is made for interrupting the sequence of starting for test or adjustment purposes at several points. Some of the features of the control system are: water pressure actuated device, temperature indicators, overload protection with both manual and remote electrical reset, filament and bias undervoltage interlocks, water under-pressure and excessive temperature interlocks together with the proper sequential starting and stopping of cooling water, filament, bias, and plate voltage.

FREQUENCY CONTROL.

The most refined methods of carrier frequency control known at the time of the construction of the transmitter have been utilized, which provides exceptionally accurate carrier frequency stability. Means are provided for maintaining the mean carrier frequency of the transmitter to within plus or minus 50 cycles of the assigned value.

There are two separate duplicate crystal controlled master oscillators, each associated with two screen grid buffer amplifiers. These are built into compact units with essential meters and controls in view and are accessible from the front of the transmitter panel. In order to insure permanent and reliable adjustment, the internal parts of the units are completely enclosed in metal shields. The tubes can be readily removed for replacement purposes by withdrawing the units from the front panel. These two units are capable of instantaneous switching from the front panel of the transmitter so that either can be used at a moment's notice.

PROTECTIVE DEVICES.

The various devices used for safety of the operating personnel and protection of the apparatus include the following:

1- water pressure gauge and interlock, which prevent injury because of water failure.

2- water temperature, or thermostatic cutout, which protects against excessive operating temperatures.

3- filament undervoltage relay.

4- bias undervoltage relay.

5- overload circuit breaker with manual and electrical reset.

6- sequence interlocks which protect each successive operation in either starting or stopping.

7- thermal overload relays in each motor-generator driving motor circuit.

8- fuses in main and all branch circuits.

9- disconnect switches in various plate supply leads.

10- automatic high voltage disconnect and neutralizing change-over switch.

11- switches on all doors which remove bias and plate voltages, thus protecting operating personnel from accidental contact with dangerous voltages.

12- visual indicators as a guide to all important circuit conditions.

13- sequence interrupting switches which provide manual control of successive stages of operation for test and adjustment purposes.

ANTENNA COUPLING.

A two wire transmission line is used for coupling the antenna to the power amplifier. This system provides a very efficient coupling. When properly terminated and adjusted, radiation from a transmission line is negligible and the efficiency of transfer is very high. In addition, through proper design radio frequency harmonic suppression is accomplished.

AUDIO FREQUENCY CHARACTERISTICS.

The audio frequency response curve from audio input terminals to speech amplifier through the transmitter and into the antenna, as measured by rectified antenna current methods, is substantially flat. By substantially flat, is meant that this frequency response curve will not vary more than plus or minus 2 decibels from a straight line between 30 and 10,000 cycles per second, or more than plus or minus $\frac{1}{2}$ decibel between 100 and 5000 cycles per second.

MODULATION.

The transmitter employs what is known as "low level" modulation. In this system, the audio circuits are simple, and with respect to maintainence and tube costs, quite economical compared to high level modulation. In this low level system, the radio system is modulated in one of the low power stages where 100% modulation of the transmitter output can be obtained. A 100% modulated system has a great many advantages over the older types when only 30% to 50% modulation was obtained, by reason of the fact that the peak output for 30% modulation, as in the former case, reaches 400% of normal carrier output, where as, the peak output for 50% modulation, as in the latter case, would be but 225% or less of the carrier output. Thus, the average output from a 100% modulated transmitter is considerably greater than the average output of transmitters operating at lower percentages of modulation. Naturally, this increased output of power into the antenna gives a greater range of usedfulness to the station, greater area of coverage, and a greater ratio of signal to interference level.

COOLING SYSTEM.

The power amplifier tube in the final stage requires water cooling. Approximately 10 gallons per minute are circulated through the system, propelled by a motor driven centrifugal pump. This cooling water is cooled by being circulated through a copper radiator fitted with copper cooling fins through which air is blown by means of a fan attached to the same motor shaft, which drives the pump. When not being circulated, the water partly drains into a 15 gallon expansion tank which reduces the level of the water in the tube jacket, thus allowing the tube to be changed easily. A visual water flow indicator is provided, the return water being forced through a jet visible through the glass windows in the indicator. The top of the tank is vented to relieve trapped air which collects in any circulating hot water system and which is a constant source of danger to a tube jacket if not relieved, since a bubble of trapped air circulating past the jacket may effectively cause localized heating with consequent tube damage. The dissipation rating of this system is 4 kilowatts; it is designed with a large factor of safety and will effectively cool the tube even though the transmitter be operated in the most unfavorable climatic conditions, provided that the cooling unit is installed where it can obtain a good supply of air.

MISCELLANEOUS EQUIPMENT.

Before a program coming from the control room via the telephone link can be put in the input of the transmitter, it must first go through the equalizer and then through an amplifier, identical to the ones used in the control room, in order to boost it up to the level required by the input of the speech amplifier of the transmitter. This equipment is included on the control panel beside the transmitter. This panel also includes sufficient equipment, such as a microphone for station announcements, a turntable and a pick-up for electrical transsciptions, etc.; this is all kept on hand to use in case of emergency.

A small experimental short-wave transmitter is operated intermittently, but at present it is of no commercial value. It operates on an assigned frequency of 34.6 megacycles, the same as the portable transmitter used in the field.

Testing equipment is used to check the frequency of the transmitter daily; this is absolutely necessary so that the frequency can be kept with in the Federal Communications Commission limits of the assigned frequency.

Modulation can be checked by the oscillograph, a small instrument mounted on the control panel; it operates on the principle of vibrating hot wires, the vibrations being produced by the modulations of the carrier and made visible through a system of rotating mirrors.

The emergency transmitter is tested about once a week with a broadcast of electrical transcriptions after midnight. Should the regular transmitter fail at any time, it takes one man only 15 seconds to switch the program over to the emergency transmitter; with two men, only 6 seconds.

A receiver is in operation at all times to pick up any S.O.S. calls from ships at sea.

The personnel required for the operation of the transmitter consists of three operators, working in 6 hour shifts.

THE ANTENNA.

W.R.C. has been using the same antenna since its beginning. It is situated directly above the transmitter on the roof of the Riggs Bank Building. The antenna was designed and built with this building.

The towers are mounted on concrete columns, 8' square and extend 40' underground; they were at the time of their construction standard equipment of the American Bridge Construction Co. They are called the bridge type of design and will stand wind up to 150 miles per hour. The distance from tower to tower is 225'.

The antenna itself has an effective height of 180'. It is of the "T" type construction, consisting of 4 main wires. The transmission line to the antenna has a matched impedance with that of the final stage of the transmitter.

The transmitter can be tested on a pure resistance dummy antenna.

N.B.C.-WEAF transmitter, antenna at Bellmore, L.I.

CONCLUSION.

The objective in writing this paper will certainly have been attained, if it is as interesting to those who read it, as it was to the author in its preparation and writing. The author regrets the discrepancies in the treatment of the different phases of the station, but as already explained, the absence of some material was unavoidable.

Practically all the men contacted in obtaining the material for this paper were engineers. Each one was particularly accomodating and most interesting to converse with; however, there was only one college graduate in the group.

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PERSONNEL.

Mr. Philip Merryman, field engineer and control supervisor.

Mr. Fred Shawn.

Mr. Callahan, commercial supervisor.

Mr. B. E. Stahl, operator at the transmitter.

Mr. S. E. Newman, operator at the transmitter.

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THE R.C.A.VICTOR TYPE 1-D TRANSMITTER.

Even though W.R.C. does not use this type transmitter, it is a later model of the one they now have in use. A review of it shows very plainly the improvements and their advantages. This material is presented to show in a contrasting way how transmitter design has advanced in the past few years. It is interesting to note the elimination of the generator power supply by the incorporation of transformers and rectifying tubes as the source of D.C. voltage.

The R.C.A.Victor 1-D transmitter has a carrier power of 1000 watts and requires a 220 volt 3 phase 60 cycle line supply. Long time regulation of line voltage should not exceed 5% and rapid variation should not exceed 15%. The power consumption is 5700 watts. The transmitter will operate on any specified frequency from 1500 to 550 kilocycles. Full modulation is produced by an input of about zero level (12½ milliwatts); the input impedance is 500 ohms. The carrier has a stability of better than plus or minus 50 cycles per second from the assigned frequency. The audio characteristic curve is flat within plus or minus 2 decibels from 30 to 10,000 cycles per second. The hum level measures 60 decibels below the signal for 100% modulation. The radio harmonics produced meets the requirements of the Federal Communications Commission. It is designed to operate satisfactorily in any ambient temperature in the range of 15° to 45°C., and to operate with a 400-600 ohm line or with an antenna system having a resistance between 10 and 90 ohms, and a reactance of not over 400 ohms.

The following tubes are required for normal operation: 4 R.C.A.843, 1 R.C.A.865, 3 UV-203-A, 2 UV-845, 4 UV-204-A, 2 UV-849, 6 UV0872, and 1 R.C.A. 904.

The schematic diagram needs some explanation. The circuits are simple yet completely effective. The transmitter is constructed in two sections--a 250 watt exciter and a high level amplifier unit. In the exciter unit is the crystal oscillator, two buffer stages, and the intermediate power amplifier. Two audio stages, and all power supply equipment are also contained in this unit. The power amplifier section contains the power amplifier and modulator with its own power supply.

The crystal oscillator uses a newly developed circuit found to provide excellent stability and to permit changing tubes without greatly affecting the frequency. The crystal is operated lightly to preclude the possibility of fracture and to insure stability well within the Communications Commission's limit of 50 cycle deviation. The crystal oscillator tube is the R.C.A.-843, with a heater type cathode, minimizing the possibility of hum or frequency modulation.

From the oscillator stage, the radio frequency is amplified by a screen grid buffer tube, the UX-865, followed by a UV-203-A, which in turn drives the intermediate power amplifier. This intermediate stage employs a pair of UV-203-A type tubes in push-pull, to supply grid excitation to the power amplifier. This stage, like the preceding ones, operates as a Class "C" amplifier, and uses 4 UV-204-A type tubes in parallel push-pull. The power amplifier tank coil may be coupled directly to an antenna system or to a transmission line. In case no line is used, a harmonic suppression network attenuates the radio frequency harmonics which are otherwise reduced effectively by the line. The use of push-pull amplification and electrostatic shielding in addition to the other devices, provides for an absolute minimum of harmonics and thereby reduces interference with other radio services and assures compliance with Federal regulations.

The audio frequency circuits operate in a push-pull arrangement throughout. The first two stages are placed in the low power section, the last in the power amplifier unit. The first audio stage employs a pair of R.C.A.-843 type tubes in push-pull, Class "A". The second audio stage is arranged to use 2 UV-845 type tubes, Class "A". This stage then energizes the final audio amplifier which modulates the last redio frequency stage. The 1000 watt modulator system consists of a pair of UV-849 type tubes in push-pull, Class "B", coupled through a specially designed transformer to the plate circuit of the UV-204-A, Class"C" stage.

All radio frequency amplifier stages are self-biased. This insures proper operation and again provides for simplicity of design. Provision is made for limiting the plate current in the event of loss of excitation. A 250 volt Rectox unit, with suitable filtering, furnishes plate voltage for the crystal oscillator and also bias for the second audio stage. Plate voltage for the following three stages of radio frequency amplification is supplied by a single phase rectifier using two UV-872 type mercury vapor rectifiers. A 30 volt dry rectifier unit biases the first audio stage and also supplies the field of the monitoring loudspeaker. In the power amplifier section, a single UV-872 type rectifier tube, in a heavily loaded circuit supplies bias for the UV-849 type tube modulators. Plate voltage for the modulators and radio frequency power amplifier is derived from a three phase, half-wave rectifier using UV-872 type tubes. The power supply is obtained from an auto-transformer in each section provided with taps to compensate all voltages when the power line voltage changes. There is no necessity for individual adjustment of filament or bias voltages.

In the 250 watt section, a master rheostat controls all filament voltages, and this is set initially to the correct value. The input power to this section is fed through an auto-transformer with variable taps for shifting from 110 volts to 220 volts or to compensate for voltage changes. The 1000 watt section contains a three phase auto-transformer with a tapped primary controlled by a panel switch. Two starting switches are provided on each section, one for filament and bias and oscillator plate on the 250 watt unit, the other for all plate voltages. Time delay relays prevent application of plate voltage before the filaments have been properly heated. For normal operation, the switches on the right hand unit are closed and all control is automatically shifted to the two switches on the left hand unit.

Protection is afforded by a quick acting over-load relay in the low power rectifier output circuit. Instantaneous overload relays are located in the primary circuit of the high power rectifier, fuses being used in other circuits. Relays are mounted on vibration-proof panels. The meters are furnished to indicate filament voltage, rectifier voltages, D.C. grid currents of the intermediate amplifier and power amplifier, tank currents of the intermediate power amplifier and power amplifier, antenna current, dummy antenna current, and the plate voltage. Sixteen meters are used, with change switches for obtaining all plate current readings. Pyranol filter condensers, the newest and smallest type with the highest safety factor, are used throughout.

The dummy antenna is switched into the circuit or out by a panel control. The monitoring loudspeaker obtains its audio input from the secondary of the modulation transformer through a potentiometer. The speaker then indicates correctly any distortion taking place in the power amplifier, modulator, or audio amplifiers. In the same part of the circuit a small Rectox unit and microammeter are connected to indicate percentage of modulation. The cathode ray modulation meter operates from a coil coupled to the power amplifier tank circuit. No rectifier is required. D.C. potential is obtained from the transmitter rectifier. The tube is placed in a shielded compartment and the electron "gun" is double shielded. Timing deflection is furnished by coils energized from a 60 cycle cource.

The transmitter has complete individual shielding of radio frequency circuits. With the exception of the power amplifier tank coil, every radio stage is placed within individual metal boxes. The amplifier tank coil is placed for convenient adjustment and is electrostatically shielded. This results in reduction of harmonic radiation and is an additional protection against static discharges picked up by the antenna.

Controls for tuning and neutralizing are all placed in line, and are normally operated by a plate. After initial adjustment, these are removed from view, so that there is no tendency to change the proper settings. At the same time, the controls are readily accessible. The controls are connected with the actual tuning devices by means of "dental cable" so that the variable condensers can be placed for shortest electrical connections within the individual shields.

As stated before, the transmitter employs Class "B" modulation. This type was first investigated by Loy Barton, an R.C.A.Victor engineer. The arrangement provides for high level modulation but with the modulator tubes operated as Class "B" amplifiers, instead of Class "A". The radio frequency amplifers are all Class "C", the highest efficiency type. The modulator efficiency is also high, approaching that of the radio amplifier. Hence smaller tubes are used with lower operating costs; by proper design of the modulation transformer and the use of tubes with suitable characteristics, the amount of distortion was made equal to, or less than, that of a low level system. It is for that reason that the transmitter used by W.R.C. has low distortion, and yet high efficiency, by using the Class "B" modulation of high level.

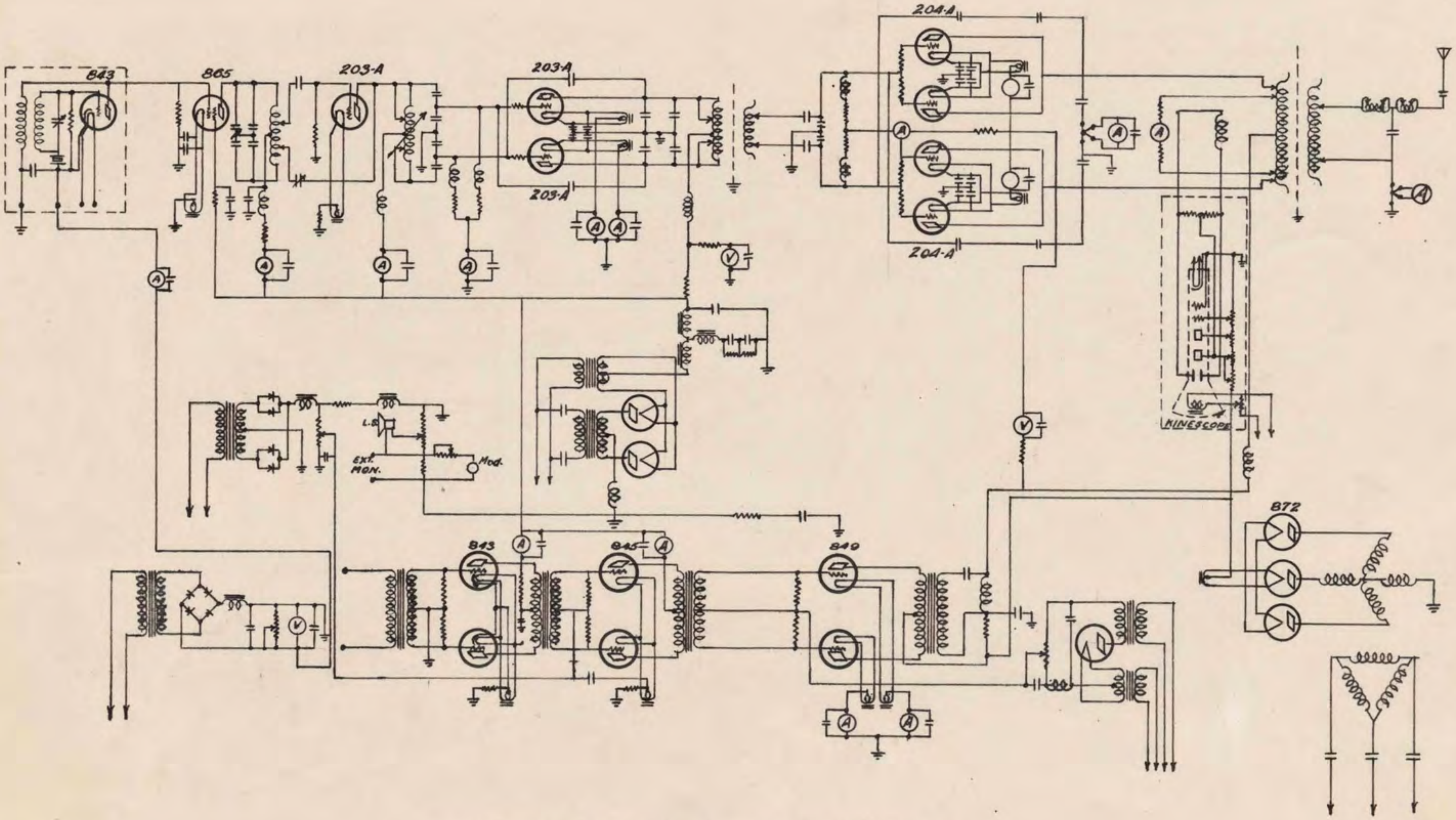
One of the major problems occurring in the operation of a broadcasting station is the difficulty of setting the volume control to produce the correct level of modulation. It is desirable to maintain the average degree of modulation as high as possible in order to produce the best volume of signal at the receiving set and to cover up the static and electrical noise picked up at the recieving location. Nevertheless, if the modulation tends toexceed 100% distortion will be produced which will spoil the fidelity of the transmitted program. The improved fidelity of receivers causes harmonic distortion to become increasingly more noticeable and objectionable.

Operators have been forced to depend upon indicating devices far from satisfactory to determine the modulation percentage. The most primitive method, that of observing the deflection of plate meters, indicates only when distortion has already taken place. There is no way of knowing what the modulation is, if there is no distortion, thus, a transmitter operated this way will tend to have either too high or too low modulation. Some transmitters have been equipped with a modulation meter actuated by a rectifier coupled to the output circuit; such a meter can not follow the rapid variations produced by audio waves, and at best, serve as guides to the operator, experienced in interpreting their readings

To rectify this condition, R.C.A. has produced a cathode ray modulation indicator, which is employed in W.R.C.'s transmitter. Producing a figure bright enough to be seen 20 feet away, in a daylight illuminated room, this instrument makes continuous observation possible and practical. The size of figure, $2\frac{1}{2}$ by4 inches, enables the operator to inspect the indicator accurately from a distance. The cathode ray indicator reproduces high frequency modulation as correctly as that of low frequency, and indicates the amplitude of both positive and negative modulation peaks. In the transmitter, the cathode ray tube is located behind a protective glass in the upper portion of the power amplifier unit. Upon the glass cover are ruled five lines, indicating the zero axis, the positive and negative peak values for 100% modulation and unmodulated carrier amplitude. The oscillogram (illustrated) indicates both parts of the modulated wave, and when the peaks touch the outside lines, and meet the middle, complete modulation is taking place. Lesser degrees of modulation is shown by the peaks extending part way to the outside lines, and not meeting at the middle. Over-modulation is indicated by a break in continuity of the figure at the zero line or by flattening of the peaks.

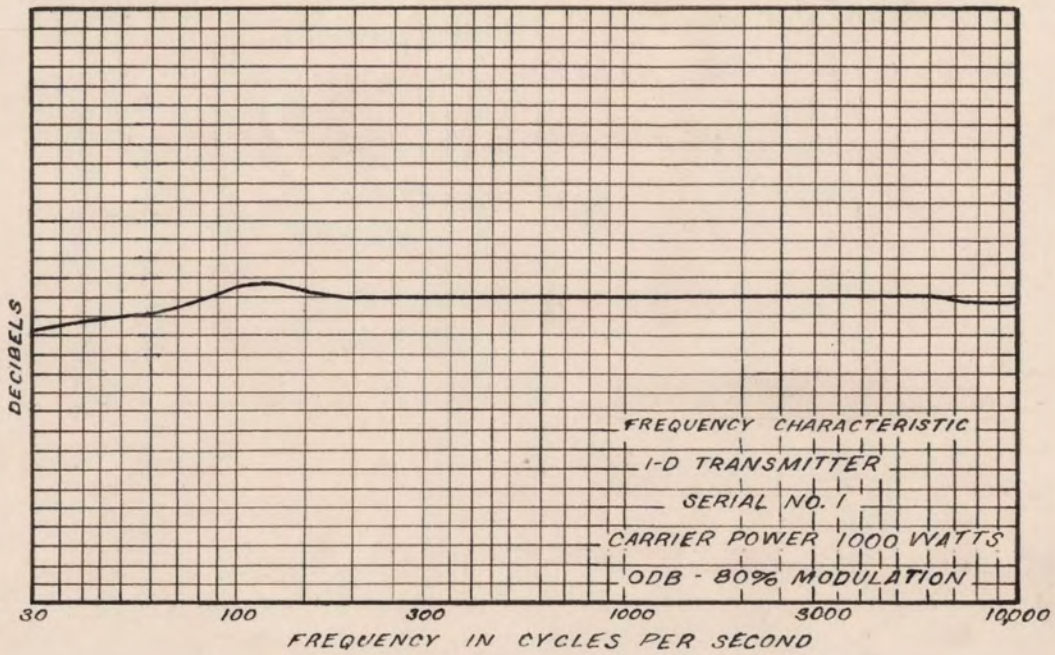
There are four adjustments to the cathode ray indicator for the adjustment of focussing, brilliancy, sensitivity, and for changing the sweeping deflection. Excitation for the instrument is obtained by coupling to the amplifier tank coil. The spot size can be altered, and for precise work,can be reduced to a diameter of 1 millimeter. So sensitive is the tube that it is influenced by terrestial magnetism and a small magnet is used to compensate for the deflection of the beam by the earth's magnetic field. It indicates a symmetrical modulation by unequal amplitudes of positive and negative peaks.

The frequency on which a transmitter operates is governed by a crystal in the oscillator circuit. Quartz plates having a suitable temperature coefficient are used for the crystal. It is mounted in a holder, which in turn is placed in a heat insulated compartment. The latter is heated by a resistance unit and the temperature is controlled by a mercury thermostat in combination with a low current relay. The heater, thermostat and crystal holder form a thermal circuit arranged with suitable thermal filtering so that the temperature variations of a very low order only are permitted. The crystal circuit is designed that the external circuit produces little effect on the frequency. A screen grid buffer stage followed by neutralized buffer amplifiers prevents the possibility of frequency variation caused by the modulated stage. A small vernier condenser permits accurate adjustment of the carrier frequency without changing the setting of the thermostat. The crystal itself is driven lightly. A spare crystal unit, including crystal, holder, oven, thermostat, and indicating thermometer, is located at the bottom, front of the exciter unit and is maintained at operating temperature in case of emergency. Both crystals may be lifted out for inspection without disconnecting wires.

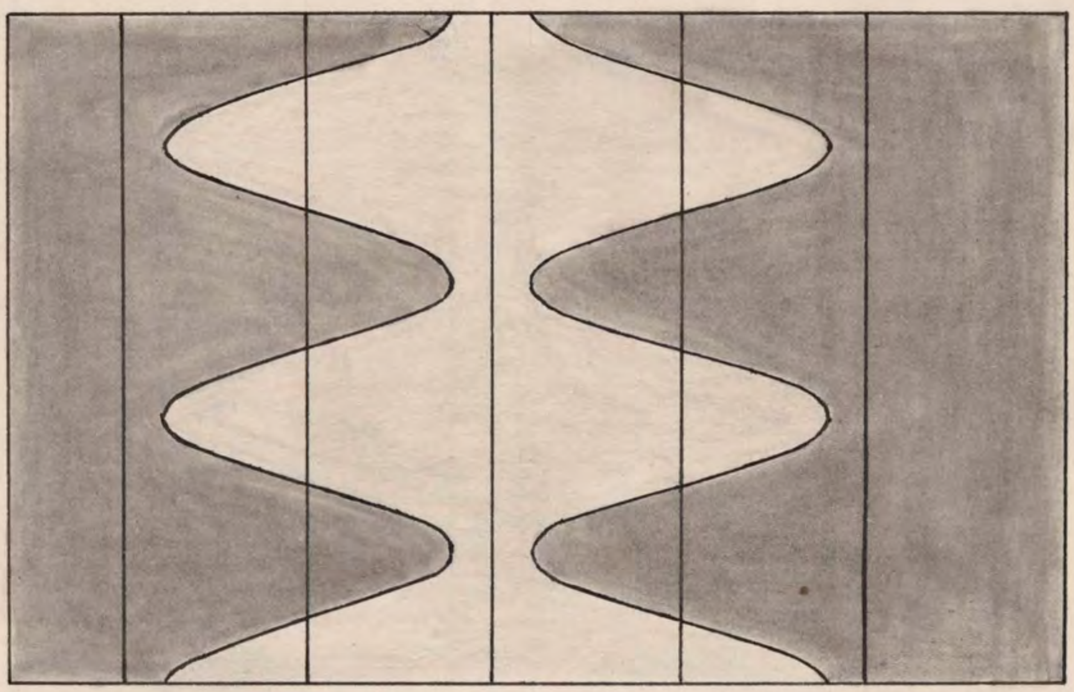


SCHEMATIC DIAGRAM OF THE TRANSMITTER

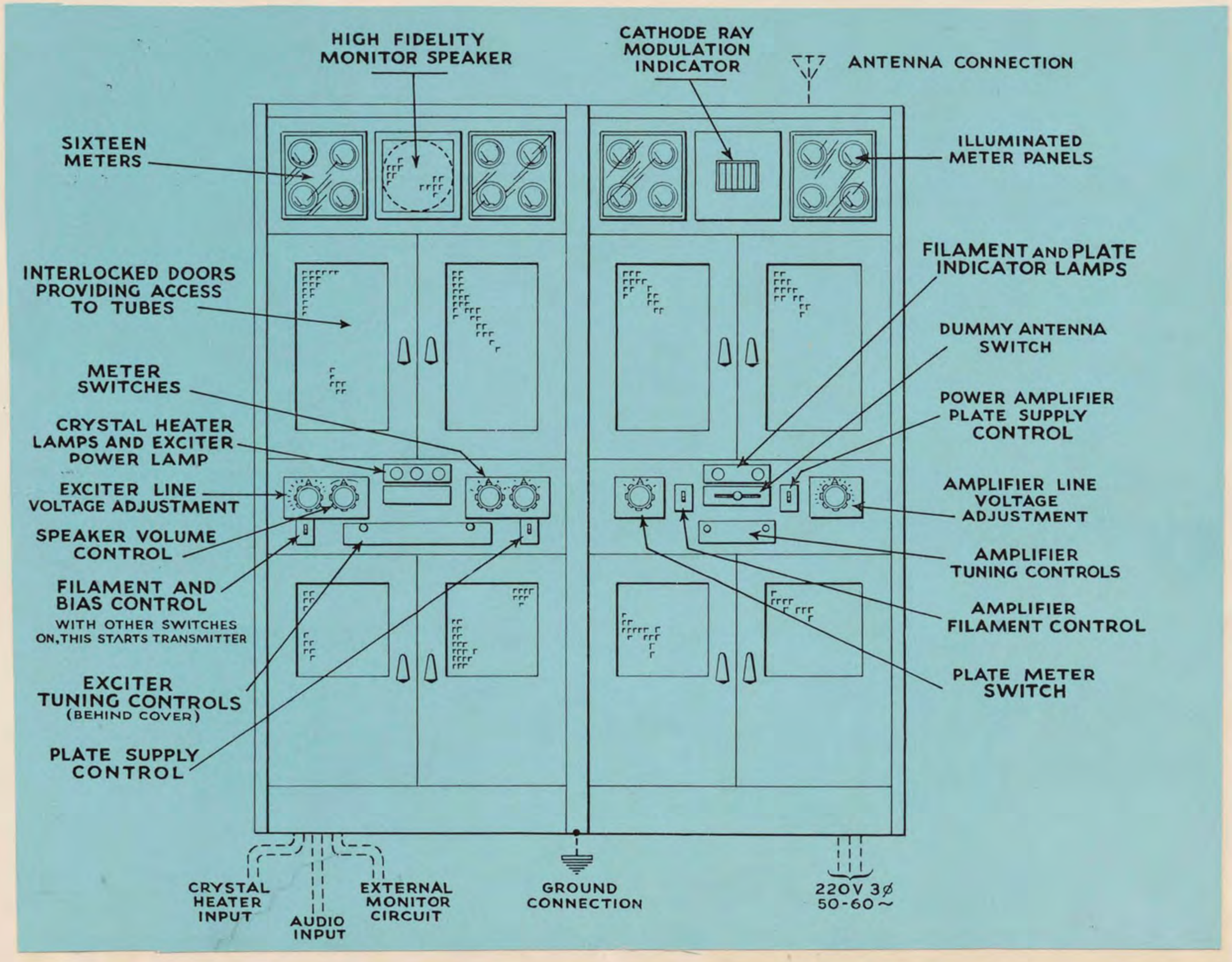
WM. MCCOOL.



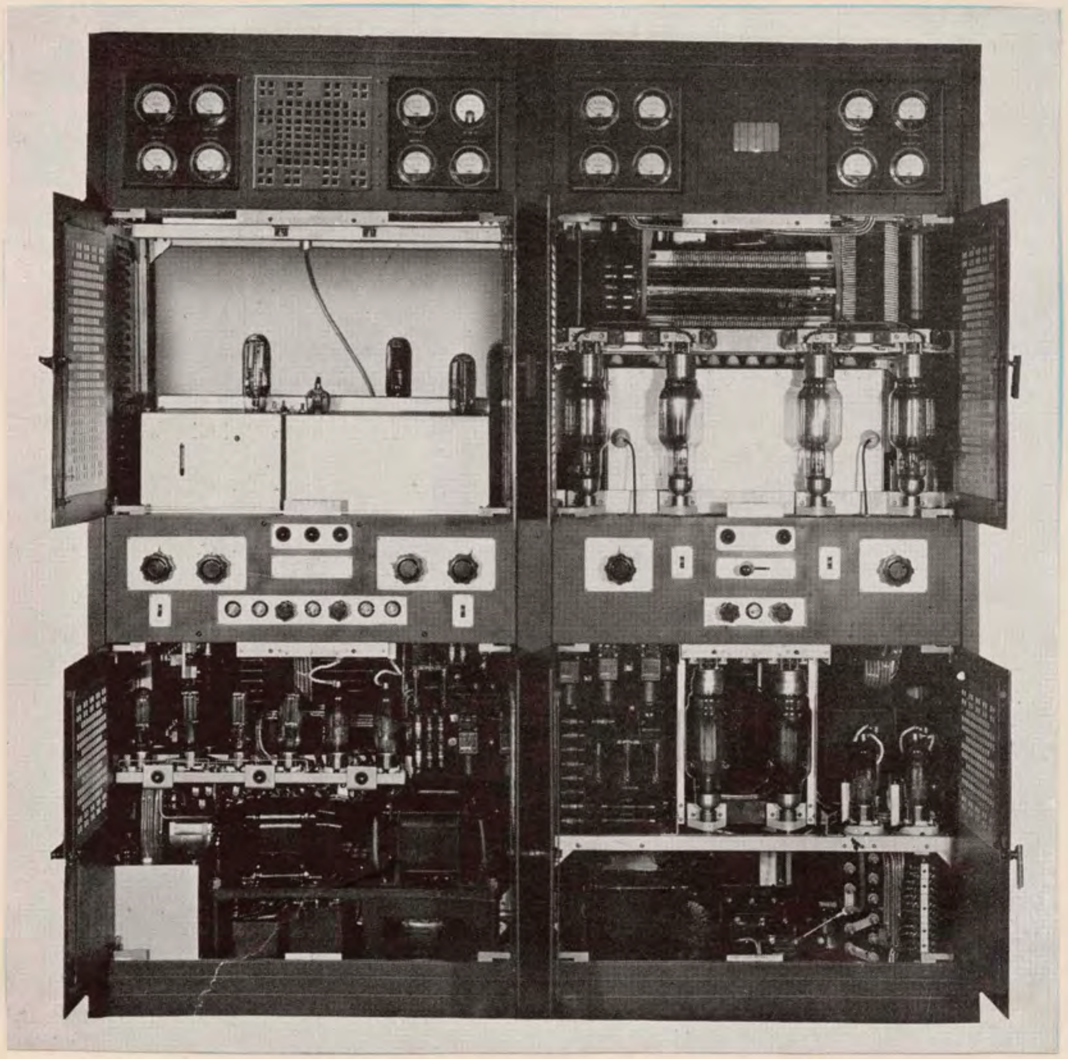
FREQUENCY CHARACTERISTIC CURVE



APPEARANCE OF WAVE ON CATHODE RAY INDICATOR

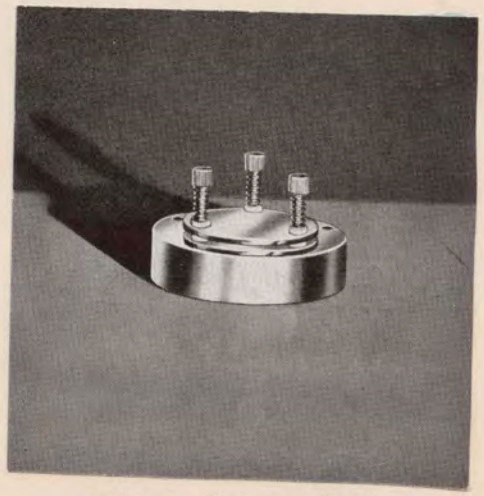


Panel Arrangement of Transmitter 1-D

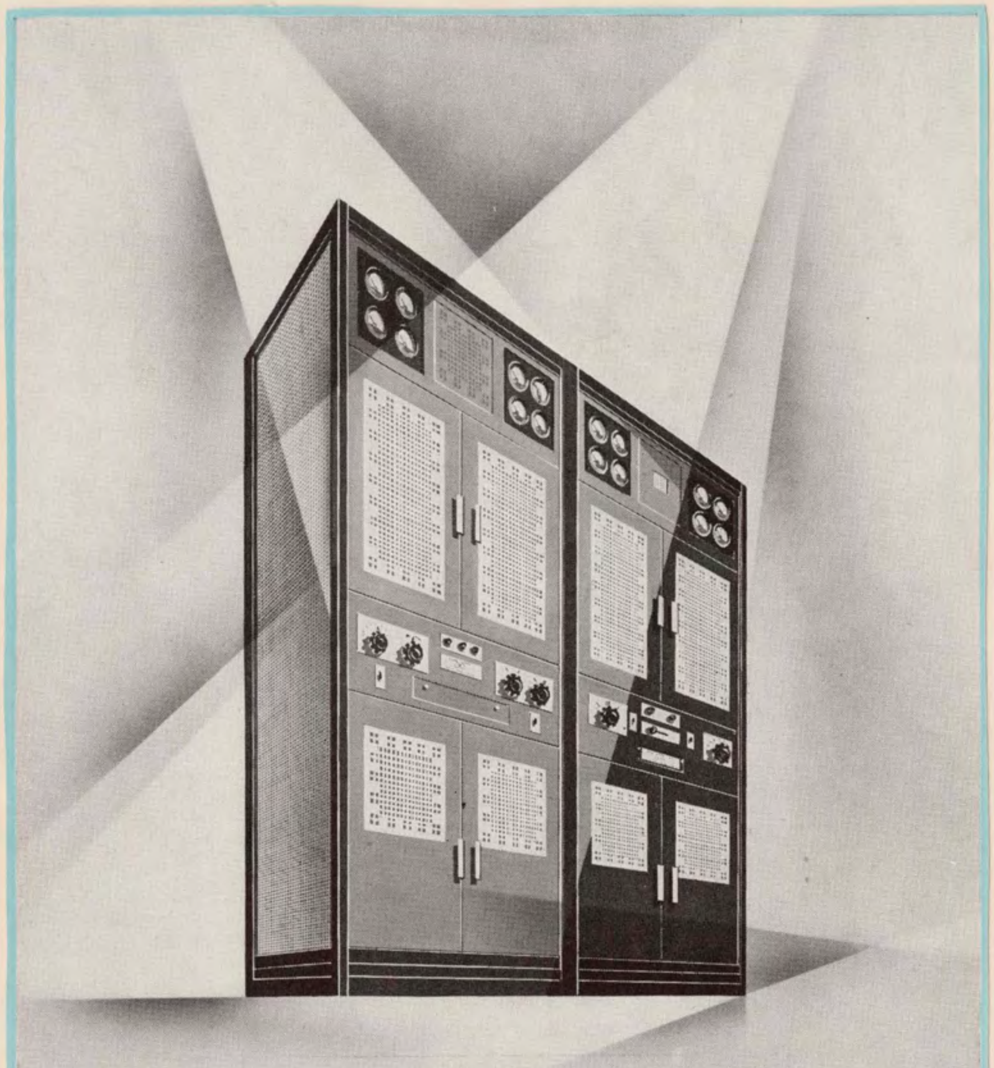


Front View of Transmitter 1-D showing interior arrangement.

Cathode-Ray Tube



The Crystal



THE R.C.A.VICTOR TRANSMITTER
TYPE 1-D.