AM · FM · TELEVISION

BROADCAST NEWS

Large-Screen Television Receiver . . . Feature Story on Pg. 2

Broadcast News

AM • FM • TELEVISION

• • •

Published by the

RADIO CORPORATION OF AMERICA

RCA VICTOR DIVISION..CAMDEN, NEW JERSEY

Subscription Rate $1.50 per year. Single copy 50c.

NUMBER 41 JUNE, 1945

JOHN P. TAYLOR, Editor JUDY J. ALESI, Ass't Editor

Contents

OUR COVER for this issue is an especially attractive kodachrome of the large-screen, projection-type receiver developed by RCA engineers for home use. This picture was made by Frank Ross, RADIO NEWS Staff Photographer, in the home of one of our engineers. Because of the lighting required for color-photographs we had to dubb the scene on the screen. However, we have taken pains to make it look as nearly like the actual reproduction as the limitations of photography and printing will allow. A picture of an actual transmission photographed directly from the screen of this receiver appears on Page 3 of this issue.

THE LARGE-SCREEN RECEIVER itself is described in detail in the article which begins on Page 2. The relatively large amount of space we have given to this story reflects our feeling that the importance of this development can hardly be overstressed. The one important criticism of pre-war television was the oft-repeated, "The picture is too small." The large-screen receiver seems to be the answer. Tests indicate that the picture can be viewed with comfort from any point in a fair-sized living room!

The reflective optical system used in the large-screen receiver receives the major share of the attention. One reason, of course, is its importance, which may be judged by the comparative pictures on Page 11. Another reason is the feeling that the manner in which this optical system works is not generally understood. This we have attempted to remedy by a picture-drawing presentation in which the working of the optical system is explained in easy stages.

This optical system is similar in principle to the Schmitt system used in some recent astronomical telescopes. It was first applied to projection television by Dr. I. G. Maloff of RCA Victor and Dr. D. W. Epstein of RCA Laboratories in 1940 (RCA REVIEW, July, 1941). It was used in the RCA Theatre Television Demonstration at the New York Theatre, New York, on May 9, 1941.

What is really new is the adaptation of such a projection system to home receiver use. This involved the working out of a method of making the lenses at a low cost, the development of a suitable high-voltage projection tube, and other problems incident to building up a complete system into a relatively small cabinet. The answer—developed exclusively by RCA, but likely to be a prototype for the industry—is shown on the following pages.

SHORTWAVE FIFTIES also come in for some attention in this issue. RCA, during the war, has built for OWI, Lend-Lease and the Army, more than twenty-five fifty-kilowatt broadcast transmitters. All of these were Type 50 S-W's (described in the January 1944 issue). This is by far the most transmitters of this power ever built in so short a time. Today these are all in operation—one or more on every continent. CBS operates two on the West Coast in addition to the two at Wayne, N. J. which are described in this issue. NBC has three at Bound Brook, N. J. and two at Dixon, Calif. Associated Broadcasters operate two, as described by Royal Howard's article (Page 39). Installations at Rio de Janiero and Brazzaville, French Equatorial Africa were described in previous issues. The one at Leopoldville, in the Belgian Congo is described in the article starting on Page 51. Locations of the others is still "restricted."

FM PLANNING is the subject matter of two articles in this issue (Pages 26 and 32). This continues the series on this subject which started with the article "Antennas For FM" in the August '44 issue and was continued with "Selecting A Site For FM" in the January '45 issue.

Dick Newman's article (Page 12) continues the series on FM station operation written from the "how-to-do-it" angle. Next issue we'll have an article on how to make a field intensity survey on an FM station.

DESIGN OF VIDEO AMPLIFIERS—by Elliot Henry, which begins on Page 56, departs somewhat from our guiding idea that BROADCAST NEWS should be devoted solely to station installation, engineering, and maintenance (with the advanced design stuff left to others). We feel that as broadcast engineers get into television they will want to understand the fundamentals of television equipment design—even though they will not, in all probability, ever build such equipment themselves. This article of Mr. Henry's—originally written for publication elsewhere—impressed us so with its understandability that we thought it might be a desirable place for you to "start in television." Let us know what you think! Do you want more of this kind of material?

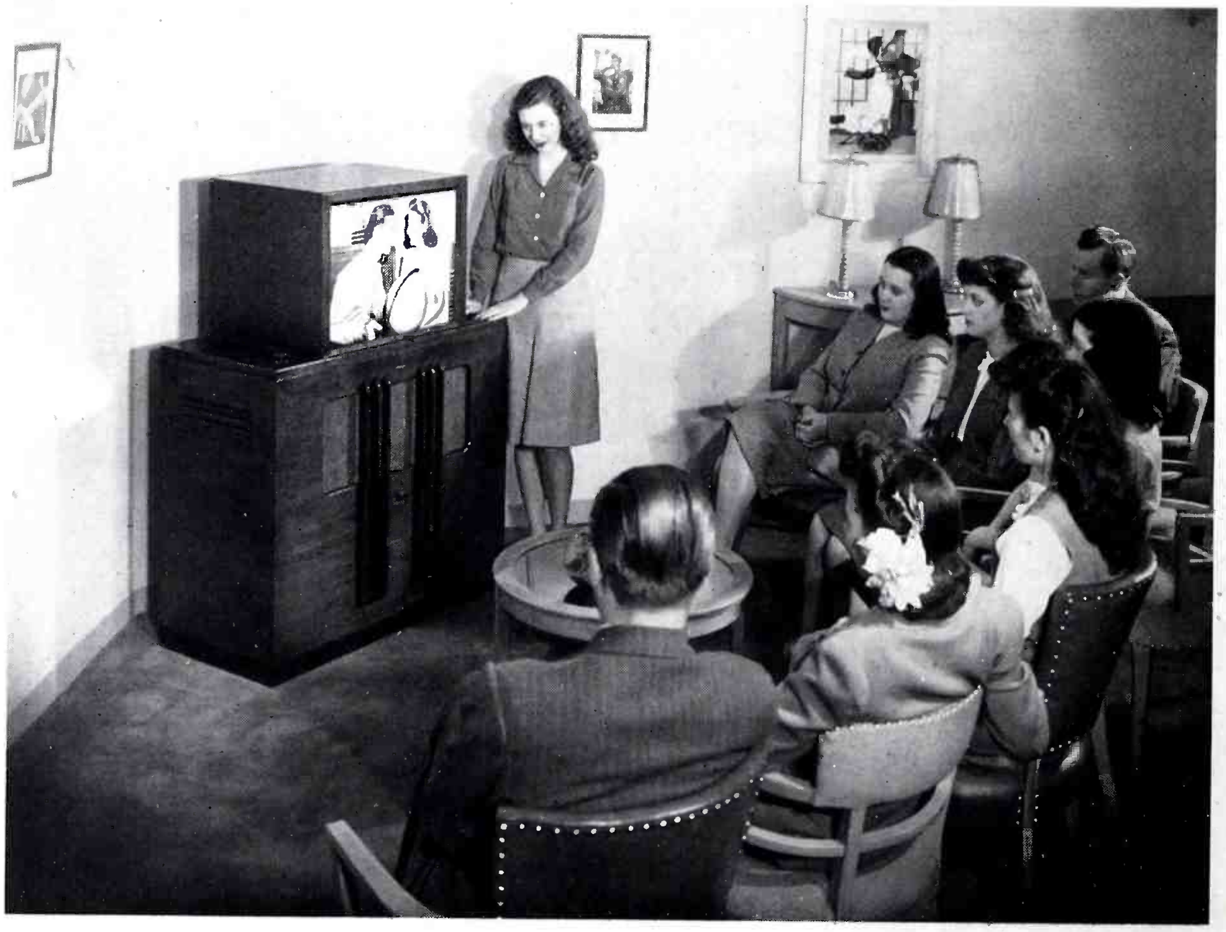
RCA ENGINEERS DEVELOP PROJECTION-TYPE TELEVISION RECEIVER

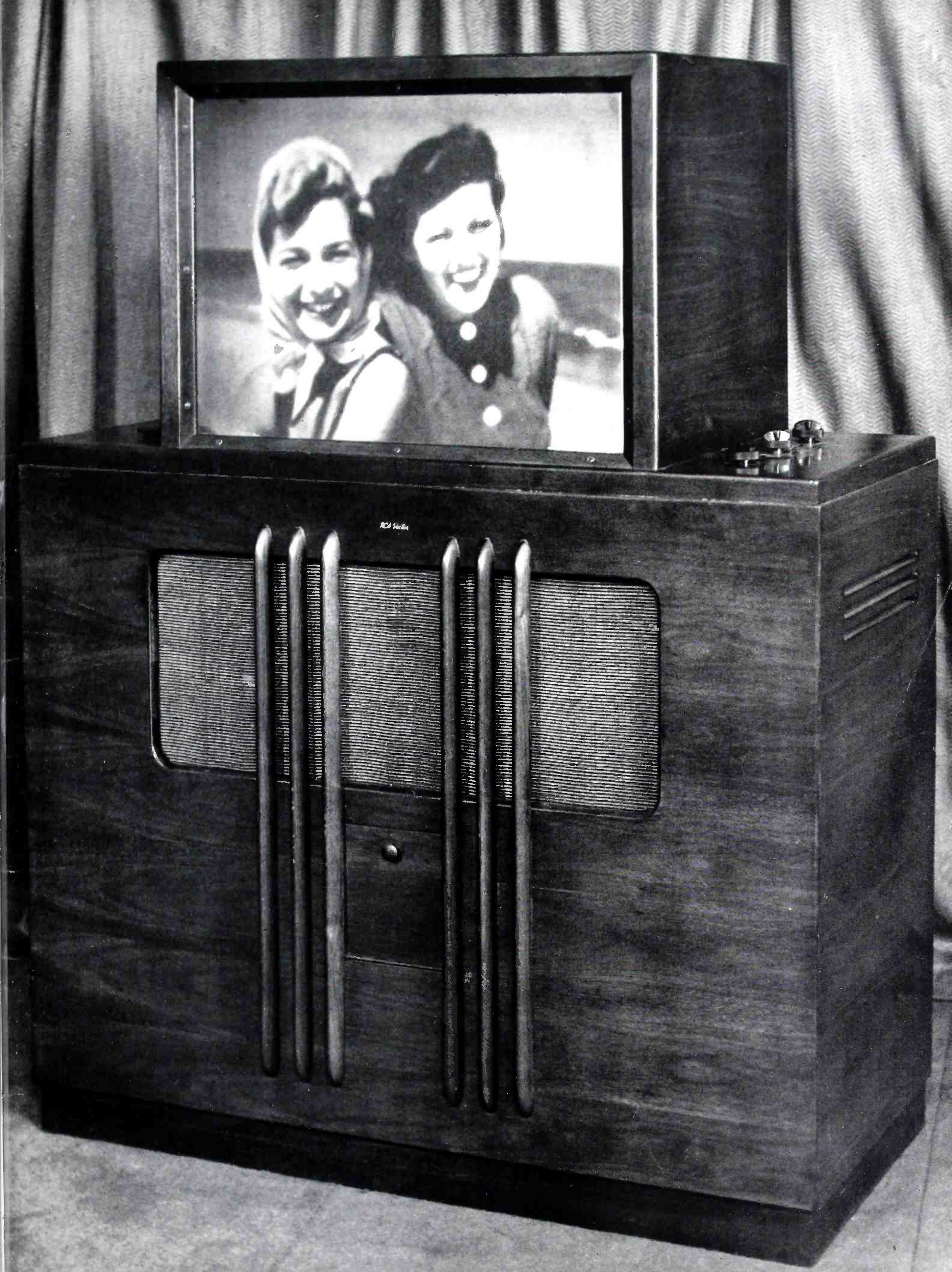
A preview of postwar television—the real thing, not the the "dreamstuff"—is afforded by the RCA projection-type home television receiver shown on the opposite page. This receiver, which has recently been demonstrated for various groups in the industry, is a relatively compact console model in which a picture 16 inches x 21⅓ inches in size is projected on a built-in, translucent screen. Through the use of a new highly-efficient optical system a picture is produced which has about the same brightness and contrast as that of pre-war, direct viewing tubes—while the size is such as to overcome the one important objection to pre-war television receivers; namely, that "the picture is too small." A comparison of this new receiver with the best of pre-war types is provided by the illustrations on this page. A technical description of the new receiver will be found on the following pages.

A developmental model of the RCA Large-Screen Television Receiver for home use. This is an unretouched picture taken during an experimental transmission of slide films. It should be remembered that the 120-line screen used in making half-tone cuts such as this tends to reduce the resolution.

Above: With the 7½" x 10" picture on a pre-war direct-viewing receiver the optimum viewing distance was about 2½ feet. This is satisfactory for small groups, but results in crowding when there are more than three or four lookers-in.

Right: With the 16" x 21⅓" picture on the RCA Large-Screen Receiver the optimum viewing distance is about 8 feet. Much larger groups can look-in without crowding. In fact, tests indicate that a picture of this size may be satisfactorily viewed from any point in a fair-sized living room.





Projection Receiver (con.)

The projection set shown on these pages is an "experimental" model and obviously has not been "styled" or otherwise dressed up. However, the general arrangement of the components in this set approximates that which may be expected in post-war production models and, therefore, will serve as a satisfactory example of the principles involved.

There are four features of this set which represent outstanding engineering accomplishments. These are:

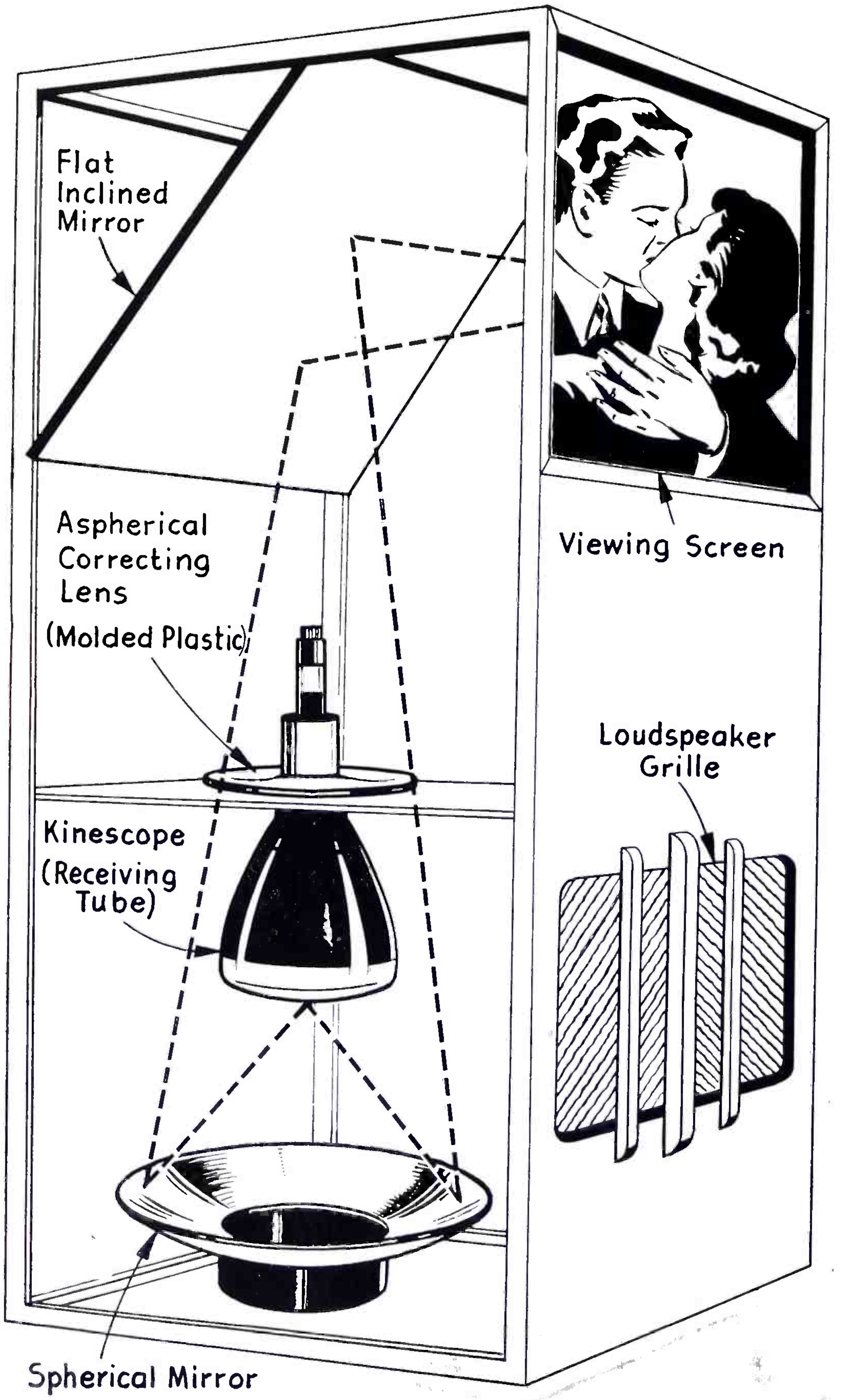
(1) A simple, but ingenious arrangement which allows a projection system having a "throw" of nearly three feet to be mounted, together with high voltage power supply and other components, in a cabinet only a little larger than many pre-war consoles or phonograph combinations.

(2) A new projection-type 5-inch kinescope in which a very bright image is produced by operating with 27,000 volts on the anode and a high beam current.

(3) A new type highly efficient optical system in which an aspherical correcting lens is used in conjunction with a large spherical mirror.

(4) A method of manufacturing (at low cost) the aspherical correcting lens by molding it of clear thermoplastic material.

I. Arrangement of the Projection System



The projection receiver illustrated on the preceding pages is a self-contained unit containing all elements of the system from antenna lead-in to viewing screen. In this respect it differs radically from most of the proposed projection receivers in which the picture is usually intended to be projected onto a wall or screen some distance away.

The built-in system has many advantages. It is a much less awkward addition in the average living room; it is more convenient to use—doesn't need to be re-setup each time the furniture is moved; it can have a fixed focus—eliminating one control and simplifying the optical system; and, for viewing under semi-light conditions, the translucent screen represents a more efficient use of the available image illumination than would a reflective screen.

Getting all the components of this receiver into a single unit, without making that unit unreasonably large, represents more of an achievement than an outward look at the cabinet would indicate. The major problem, of course, was the optical projection system proper. The magnification which can be obtained with a given lens arrangement depends, of course, on the "throw" (i.e., distance from lens to screen). For a picture of the size desired the required distance was about three feet. Obviously, the cabinet couldn't be that deep. The answer was to mount the projection system vertically. To keep this from making the receiver too high, a reflective arrangement was used. This is illustrated in the diagram at the left.

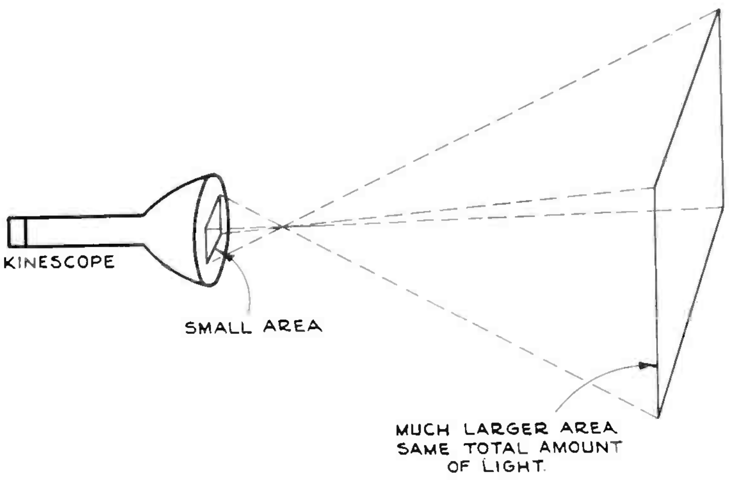
In addition to the optical system it was also necessary to provide space for the receiver chassis, the video diflection circuit chassis, the audio chassis, the high voltage power supply, and the loudspeaker. The first three of these are simply modifications of the standard chassis used in the pre-war TRK-12 Receiver. The development of a stabilized 27,000 volt power supply (in itself something of an engineering achievement) that could be mounted complete on a small chassis made it possible to group the four chassis around the outside cabinet; thus leaving the center free for the projection system. The loudspeaker is mounted in the usual position toward the base of the cabinet.

II. The High-Voltage Projection Kinescope

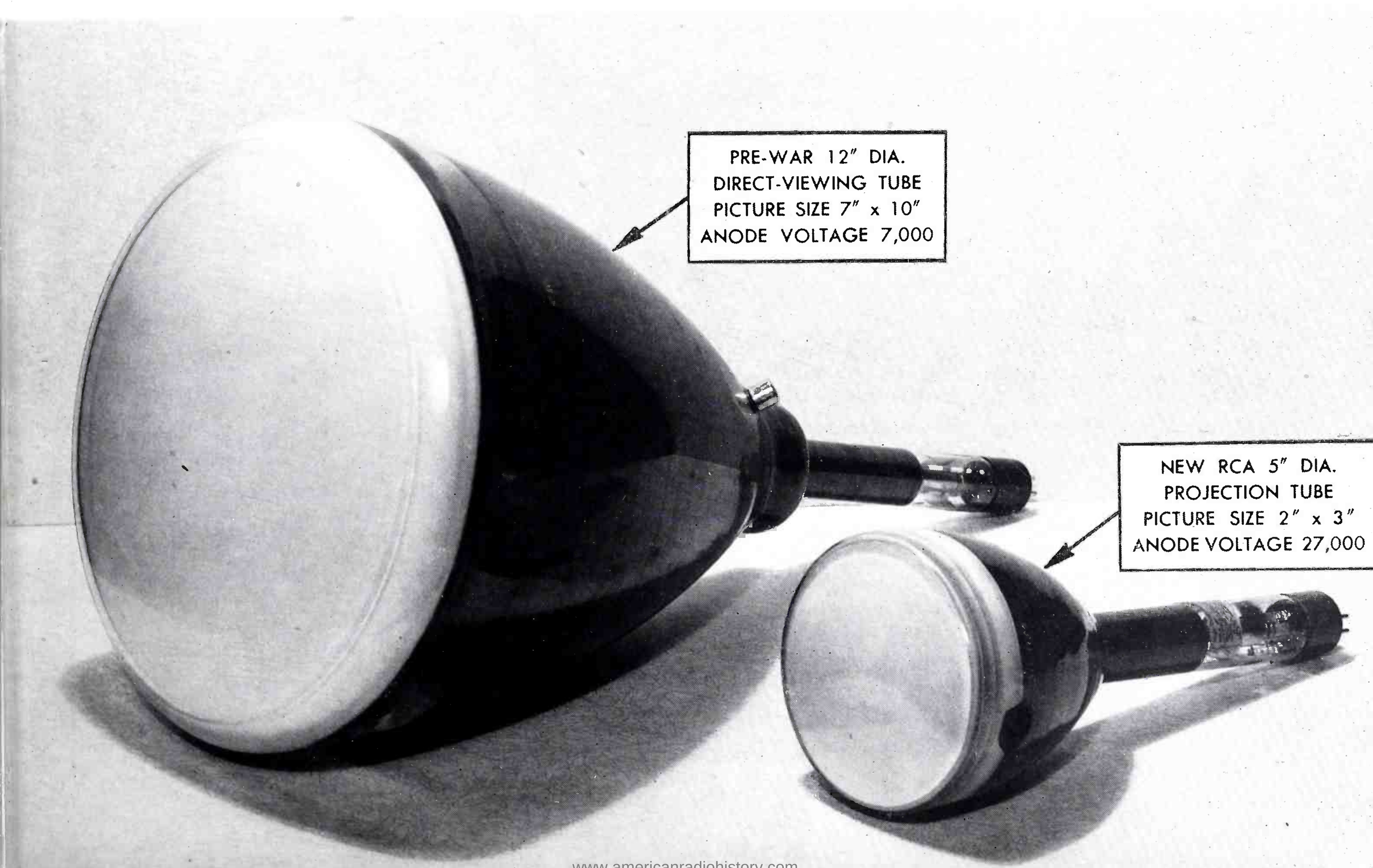
The earliest projection television systems consisted of a standard direct-viewing kinescope plus a lens suitable for projecting an enlarged image on a screen some feet away. The picture projected in this way had very low illumination. There were two reasons: first, the optical systems suitable for use with such a projection system had low "light-gathering" power and hence made available only part of the light in the original image and, second, the light thus made available was spread over a much wider area and hence the average illumination was greatly reduced.

It will be apparent that a successful projection tube must have much higher illumination than a direct-viewing picture tube. For instance, the 16 inch x 21⅓ inch picture on the receiver shown on the preceding pages has an overall area a little more than four times that of the 7½ inch x 10 inch picture on a standard 12-inch viewing tube. If the projection optical system were 100 percent efficient (which, of course, it is not) the total illumination required would be four times as great. Moreover, since the projection tube should preferably be smaller than direct viewing tubes (in order to use small-size lenses) the average illumination or brightness on its face must be even greater. For example, the 5-inch projection tube, shown at the right in the picture below, produces an image about 3 inches x 4 inches in size. Thus, in an area approximately one-sixth that of the picture on the 12-inch viewing tube, there must be produced a total illumination four times as great. This means an average illumination (or brightness) some 24 times that of the image on the direct viewing tube. When the loss in the optical system is taken into consideration these ratios must be even greater.

Increased brightness of the beam spot in a kinescope (and hence of the average illumination) can be obtained by increasing the second anode voltage and thereby causing the electrons in the beam to travel faster, or by increasing the number of electrons in the beam (i.e., the beam current). Both entail difficulties. Increasing the voltage requires greater spacing and better insulation within the tube. Increasing the current requires higher emission cathodes.



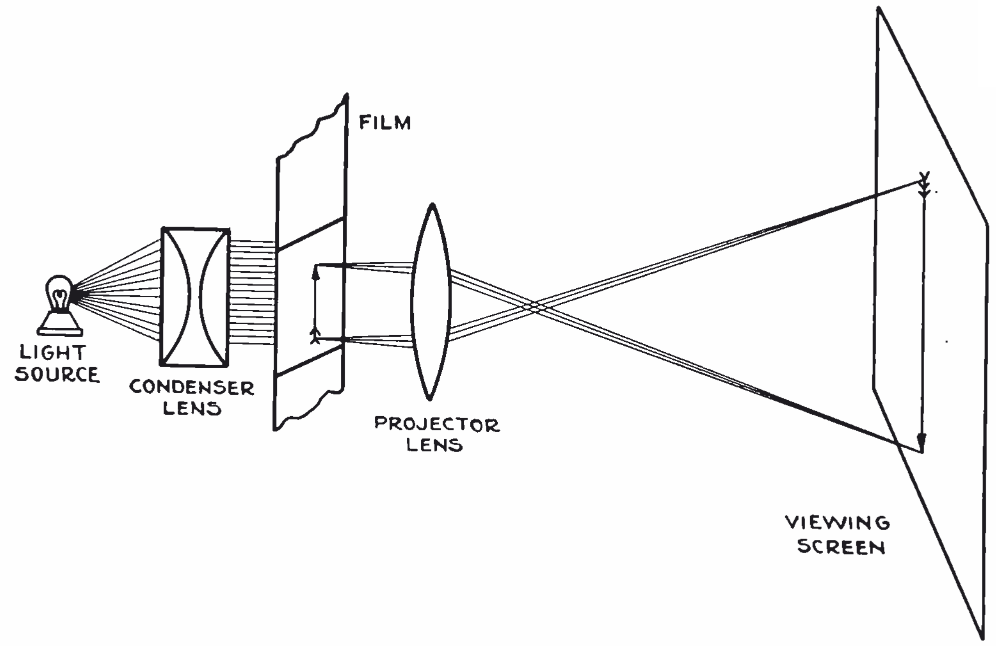
RCA engineers have been working on this problem for more than ten years. The projection tube shown below is the result of this long-extended research. This tube operates satisfactorily with 27,000 volts on the anode (approximately four times that of the standard 12-inch viewing tube). It produces an image having an overall illumination about 12 times that of 12-inch, pre-war, direct-viewing tubes. Used with the improved optical system described in the following pages this tube is capable of producing 16 inch x 21⅓ inch pictures having an average illumination comparable to that of home movies.



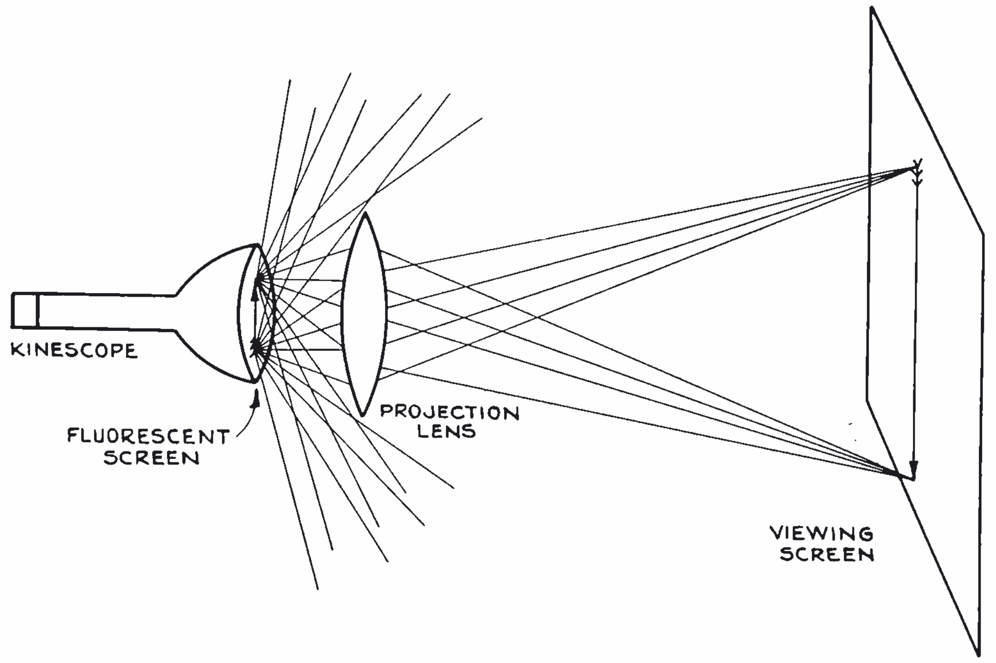
III. How the Optical System Works

It would seem on first thought that the projection of television pictures could easily and satisfactorily be accomplished with a simple projection lens system such as that used in motion picture projectors. The first projection receivers were, in fact, so constructed. However commercially available lenses of the type required have relatively low light-gathering power (which means, in effect, that they gather light in from a relatively small angle). As a result, when these lenses are used for television projection, the overall efficiency of the optical system is very poor. The reason for this can best be understood by comparing the arrangement used for television projection with that used in motion picture work, as shown below.

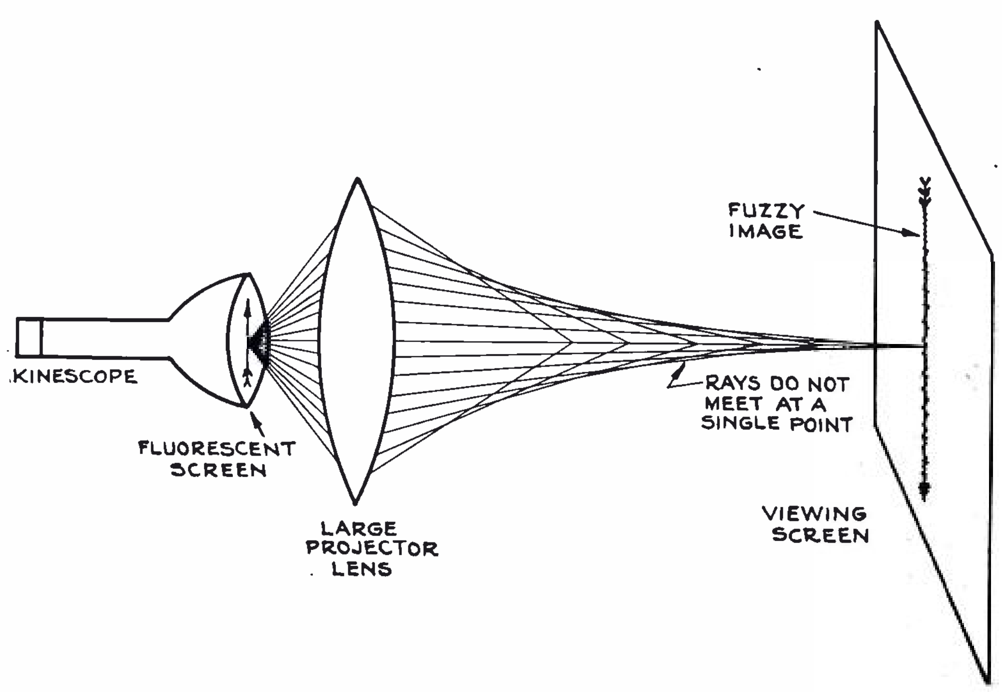
1. In a typical motion picture system, such as shown in the diagram at the right, light from a lamp or arc is converged by a condensing lens so that as it strikes the film it consists of a bundle of nearly parallel rays. Nearly all the light which strikes the film passes through (except, of course, that part which is stopped by the dark part of the film). Moreover, as the light rays emerge from the far side of the film, they diverge only slightly. Thus, all the light originally falling on the film eventually reaches the screen, except that part stopped by the picture on the film. For comparative purposes (and disregarding losses) such an optical system can be said to have a very high efficiency. This fact, together with the relatively intense illumination of the film, makes for a very satisfactory projection system.



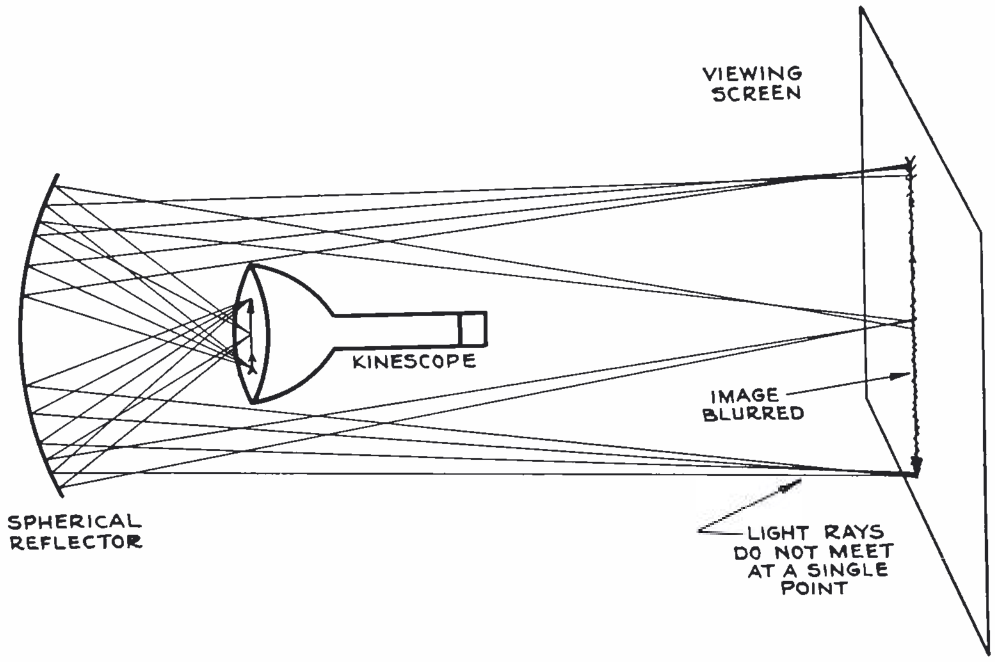
2. Now, what happens when the same optical system is used to project a television picture as shown by this sketch. The only source of light in this case is that in the picture itself. Moreover, this light does not emerge from the fluorescent screen in parallel, or even nearly parallel rays. Rather, since the screen is a perfectly diffusing surface, these rays emerge in all directions and only a small part are gathered in and brought to a focus by the lens system. Thus, the overall efficiency of the optical system is very low. Maloff and Epstein have calculated that good, commercially available (f/2) lenses, when used at the magnification typical of home television receivers, will collect and deliver to the screen less than five percent of the light generated.



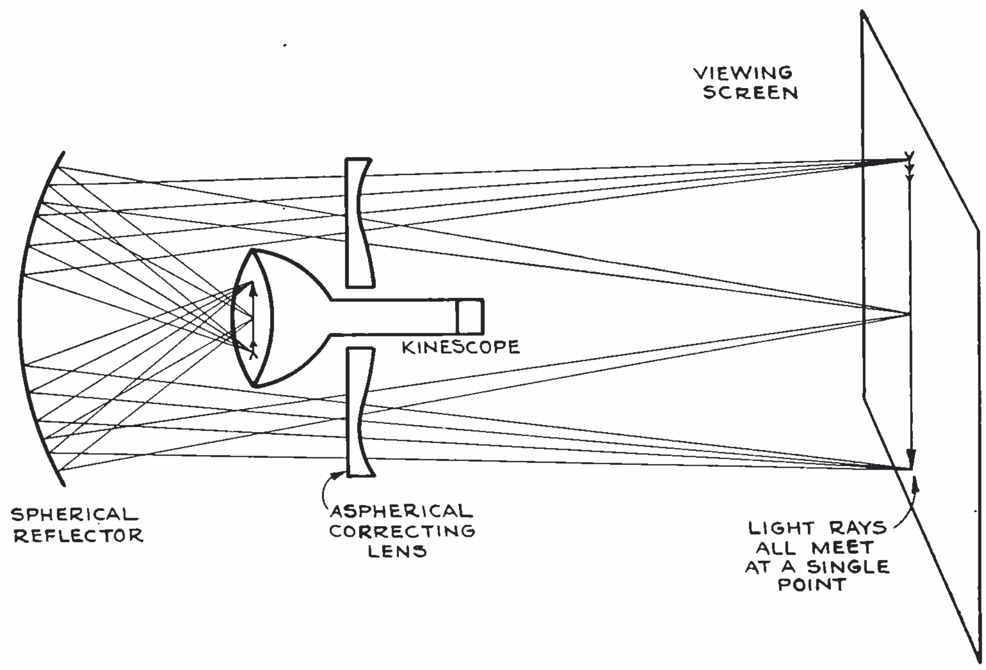
3. From the foregoing, it would seem that the obvious answer would be to increase the size of the lens and thereby increase the amount of light it will collect. This, however, brings up another problem; when the rays from a single point source are refracted on different parts of a large spherical lens, they do not all meet accurately at a single focus. Instead, the rays refracted by the outer portions of the lens come to focus nearer to the lens than those that pass through the central portion. This dissimilarity of focus—known technically as "spherical aberration"—can be avoided by masking all but the central part of the lens ("stopping it down," as the photographers say). Doing this, however, cuts down the "light-gathering" power again so that the net amount gained by going to a larger lens size is relatively small.



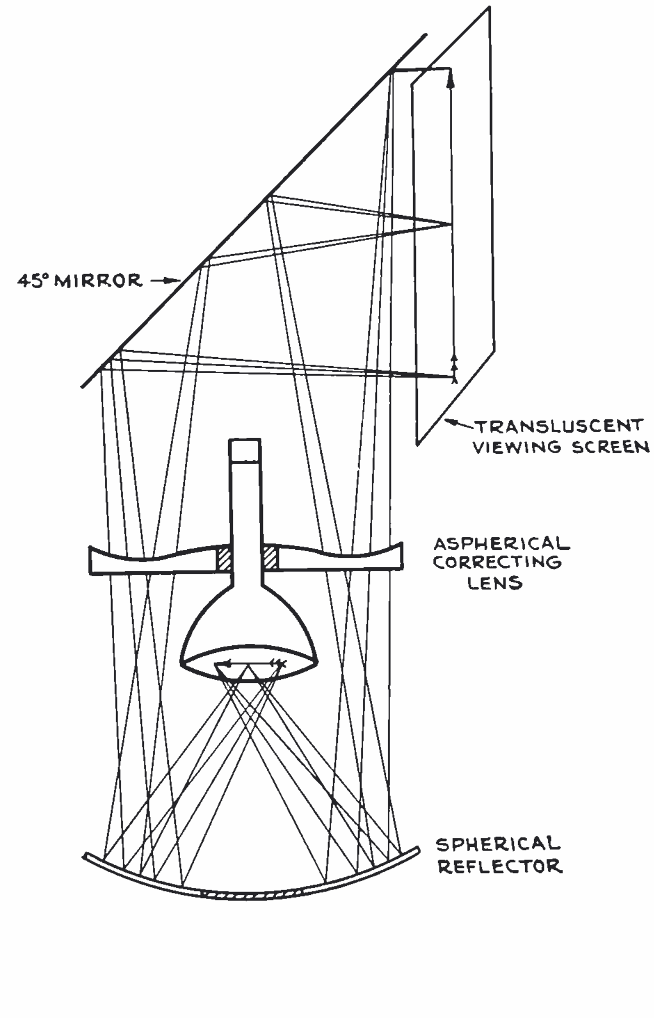
4. In the actual arrangement of the optical system for a home receiver, a reflective system is used as shown in the diagram at the right. The main "lens" in this arrangement consists of a bowl-shaped spherical reflector some 12 inches in diameter. When the fluorescent screen of the projection kinescope is placed at a point between the principal focus and the center of curvature, an enlarged image is projected on the screen. The tube itself blocks off a small part of the reflected rays, but does not affect the image (just as reducing the aperture on a camera reduces the light, but does not affect the size of the picture). Unfortunately, a reflector such as shown here—if of large size, introduces "spherical aberation" with the result that the image is not sharply focused.



5. In order to correct this "spherical aberration," an aspherical correcting lens is arranged as shown in this sketch. A hole is cut out of its center so that it can fit over the neck of the tube. This lens is shaped in such a way that it bends slightly the rays reflected from the outer part of the reflector and thus brings these to a focus at the same point as the rays reflected from the center part. By locating this lens at the center of curvature of the reflector, a minimum of shaping is required. The reflector itself is polished glass with an aluminized surface. The center part of this mirror is masked (actually, it is cut away) since most of the light reflected by this part is blocked by the tube; masking prevents reduction in contrast which would be caused by the light it would otherwise reflect on the face of the tube. So efficient is this arrangement that the overall system has an efficiency of approximately 30 percent (equivalent to an aperture of f/.9). This is six to eight times better than direct projection optical systems.



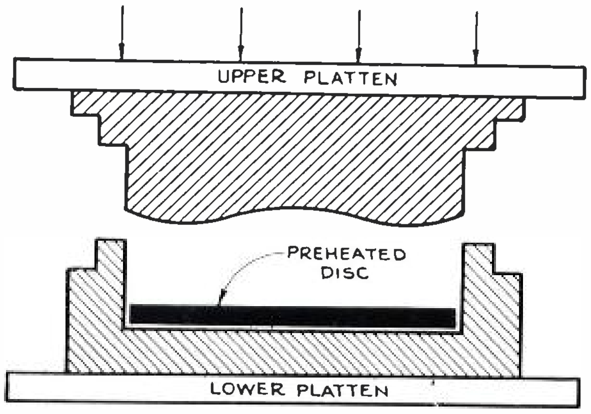
6. The final step in the development of the projection optical system is shown here. In order to get the whole system into a cabinet of relatively shallow depth, the main axis of the system is arranged vertically. The projection kinescope tube points downward. The image, projected downward from the tube, is reflected straight up by the spherical reflector, passes through the correcting lens, strikes a 45° mirror near the top of the cabinet and is projected forward onto the transluscent screen in the front of the receiver. Some added advantage is gained here since a transluscent screen can be made to have a higher efficiency than a diffusive, reflective screen. The picture on this screen actually has a brightness in the highlights of approximately 8 footlamberts, which is about the same as that of home movies.

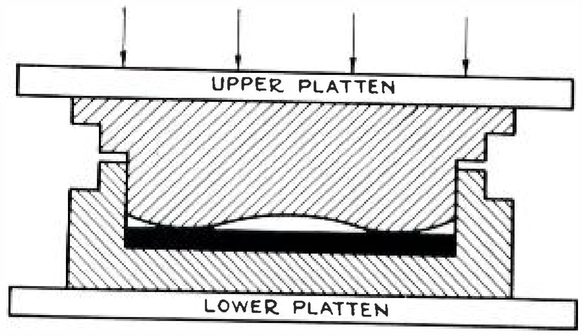


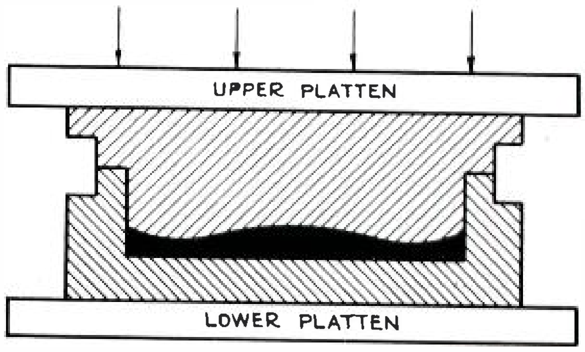
IV. How the Lenses are Made

In order to make the reflective optical system, described in the previous pages, a practical solution for home receiver use it was necessary to find some way of producing the required lenses at a relatively low cost. The spherical mirror, while of larger size, presented no problem because such a surface is naturally generated. Most optical lenses are of spherical shape (largely for this very reason) and equipment suitable for grinding such lenses in quantities is available.

The correcting lens, however, since it is of non-spherical shape, presents a much more difficult problem. No machines are available for mass production of aspherical glass surfaces of the type required. To make them by laboratory methods would make such lenses far too expensive for use in home receivers. The problem, therefore, was one of finding a new method of making the aspherical lens. How RCA engineers did this is shown in the illustrations below.



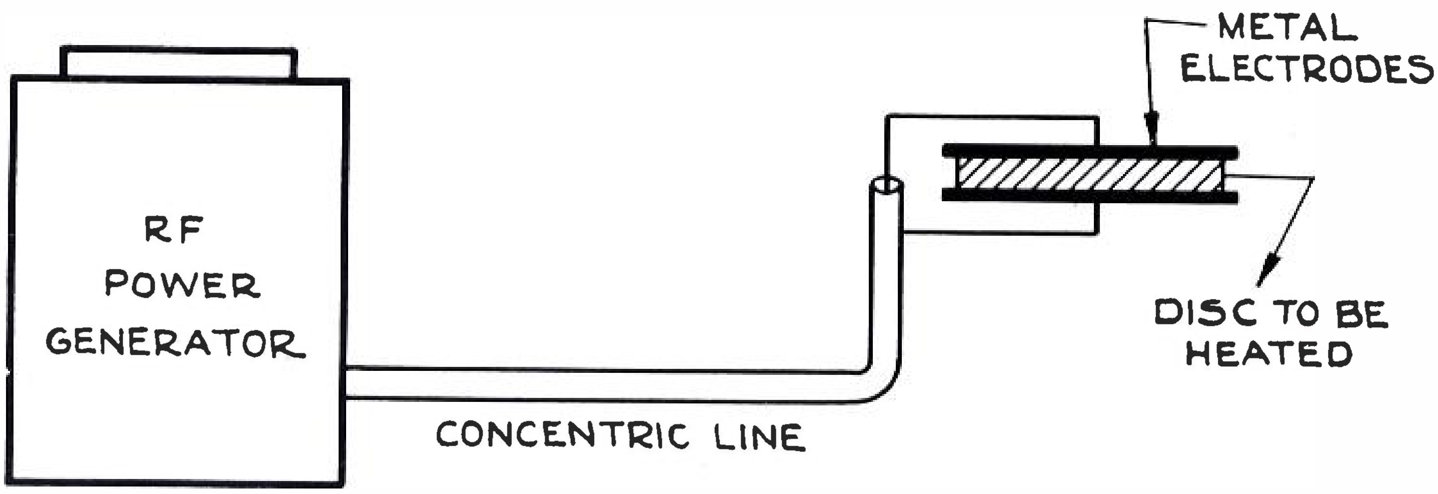




1. RCA engineers solved this problem of making aspherical lenses at low cost by developing a method of molding these lenses from a clear thermoplastic material called methyl methacrylate (sold under the trade names of Lucite and Plexiglass). Essentially, this process consists of placing a flat disk of the thermoplastic material in a molding press (as shown here) and applying high heat and pressure to make this disk assume the shape desired. It is then cooled under pressure so that when removed it retains its shape permanently.

2. This seemingly easy solution was not arrived at without plenty of headaches. In order that the lens will have just the right bending action on the light rays, the contour of dies (shown here partly closed) must be exactly true. Moreover, the faces of these dies must be free from any trace of scratch or blemish. To achieve this, stainless steel plates are carefully ground and polished to exact shape, hardened so that they will resist abrasion, and polished to a mirror finish.

3. In order to speed the molding process, the methyl methacrylate disks are preheated before being placed in the mold. The mold itself is heated by passing steam through pipes inside it. Since the methacrylate is a thermoplastic and does not harden with heat (as thermosetting plastics do) it must also be cooled in the mold. This is done by running cold water into the pipes that previously passed steam. When the shaped lens is down to room temperature it can be removed and it will hold its shape indefinitely.



4. RCA engineers have added a final touch to this molding procedure by using radio frequency power as the means of preheating the thermoplastic disks. R-F current from an 8 Mc oscillator is caused to flow through the disk to be heated as shown in the diagram above. The resistance of the material to the passage of the current causes heat to be generated in the material. It is then placed in the mold and pressure applied as described above. The process is illustrated in the pictures on the following pages.

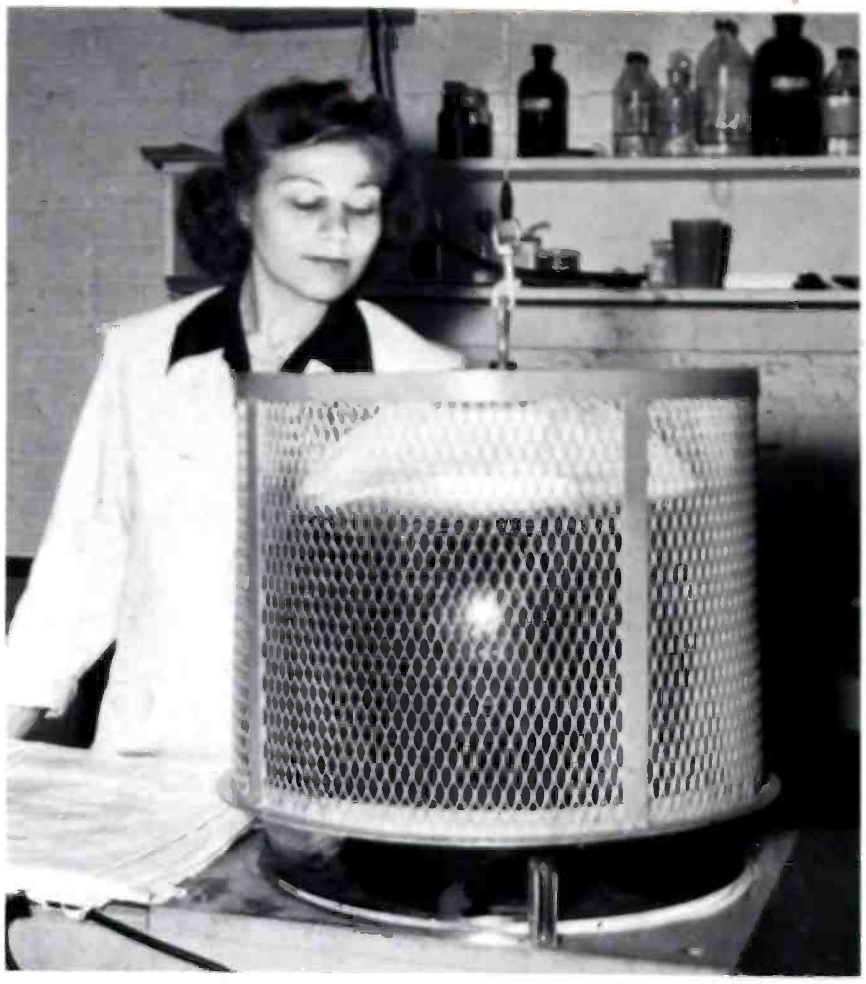
5. A methyl-methacrylate disk, 8 inches in diameter and ¼ inch thick, is placed between metal electrodes connected to a radio-frequency power generator. Application of power (1 KW) for 3½ minutes heats the disk to a temperature of 150° throughout. The electrodes are located in an interlocked, screened enclosure

6. The heated disk (usually referred to as a "preform") is soft and flexible as it comes from the radio-frequency preheating cabinet. The molds, heated by steam pipes, keep it soft during pressing. When the heating cycle is completed, steam is shut off and cold water turned on.

7. When the mold has cooled to near room temperature, the press is opened and the fully shaped lens removed. Except for boring the hole in the center for accommodating the neck of the projection tube, the lens is ready for use as it comes from the mold. No polishing or finishing of any kind is required.

8. Lenses molded in this way have excellent optical properties. They have slightly better light transmission than glass and slightly less light scattering—both of which are, of course, advantageous. They do not have the surface hardness of glass, but in tests have stood up well without any special care.

9. The spherical mirror which forms the main "lens" in the reflective optical system is shown here before aluminizing. It is a salad-bowl shaped piece of glass 14 inches in diameter with a 4-inch hole in the center. The inner surface is ground to a true spherical shape on a standard optical grinding machine.

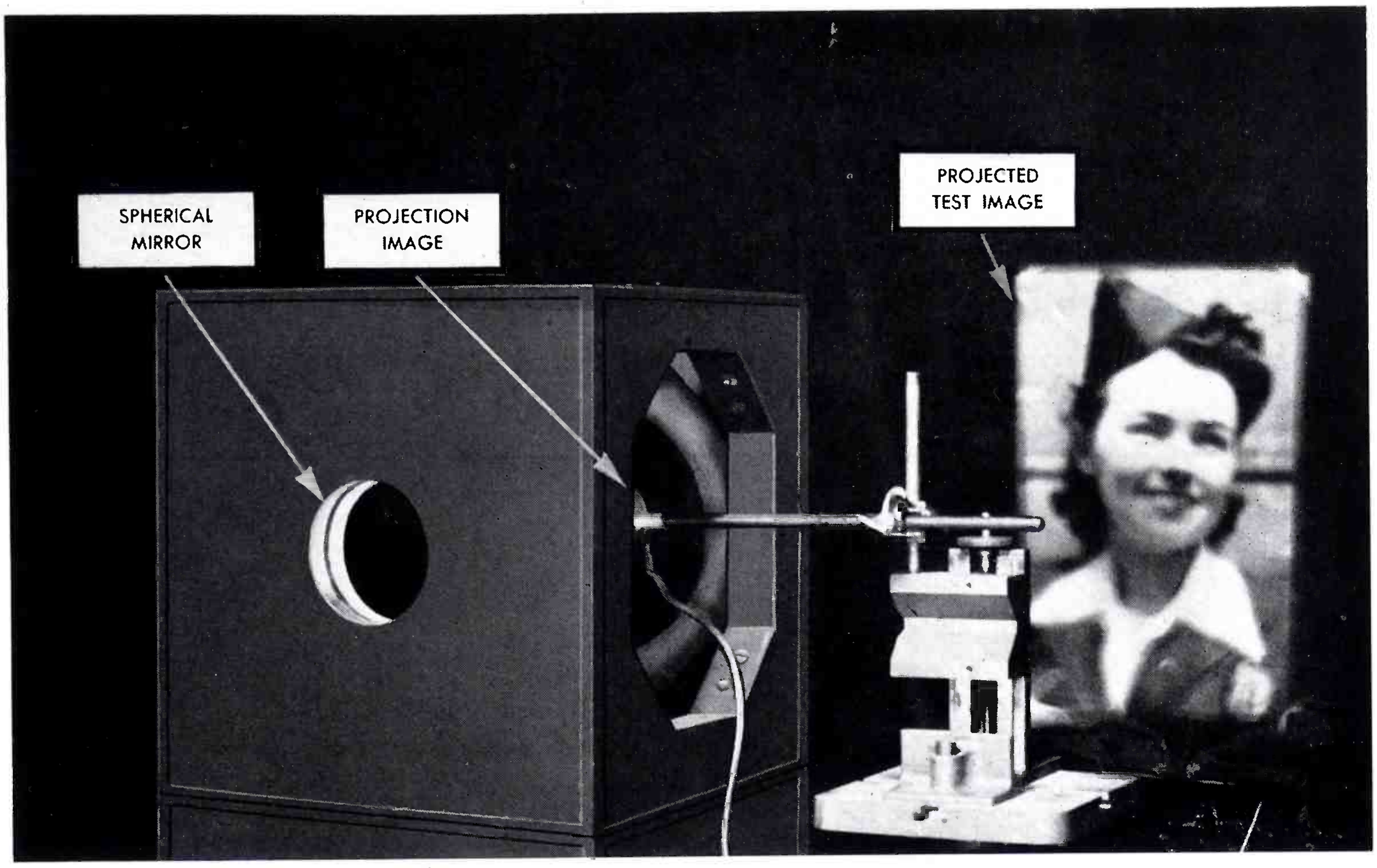


10. The aluminizing procedure consists of placing the glass bowl —inner side down—in a bell jar which is then evacuated. In the jar are two aluminum filaments from which aluminum is evaporated by heating to incandescence. The aluminum vapor which is driven off condenses on the under side of the glass.

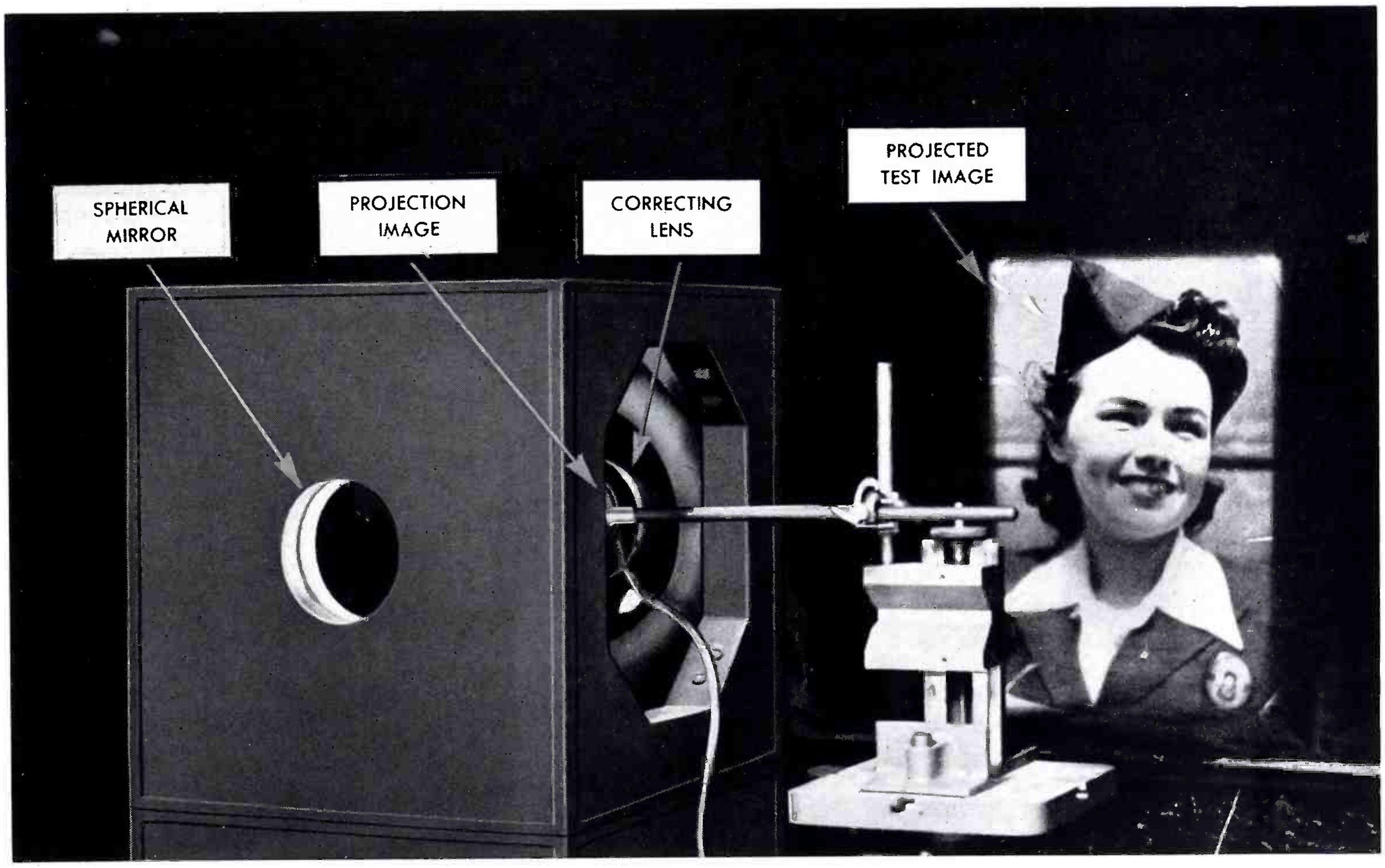
11. The spherical mirror, removed from the bell jar after aluminizing has been completed, is shown in this illustration. The polished, aluminized inner surface has a true "mirror-finish" of high reflective properties. As a "lens" it has very high light gathering power.

12. The two lenses, completed and ready for mounting in the projection-type home receiver. In the background is the standard RCA Type 15-B Radio Frequency Generator used in preheating the plastic disks before molding. At the right rear is the screened enclosure containing the heating electrodes.

V. Testing the Lenses



1. This is a temporary test setup used to check the molded correcting lenses before they are mounted in a receiver. The box in the foreground contains a standard spherical mirror mounted on the inner surface of the near side. At the proper focal point is an illuminated image simulating the face of the projection tube. In this view, no correcting lens is in place, hence the projected picture is very fuzzy.



2. In this view, one of the molded correcting lenses has been placed in the correct relative position on the front of the box (the far side). The picture, as will be seen, is now very much sharper and brighter. (In these two views certain details of the test box have been retouched, but in neither case has the projected picture been retouched at all.)

AUDIO FREQUENCY RESPONSE AND DISTORTION MEASURING TECHNIQUES FOR FM TRANSMITTING SYSTEMS

★

How to make the response and distortion measurements required for "proof of performance" of FM installations

by R. J. NEWMAN
Engineering Department
RCA Victor Division

Section 6 of FCC Form No. 320 (Application for High Frequency Broadcast Station License) is entitled, "Proof of Performance of Audio Frequency Operating Characteristics." In order to comply with the requirements of this section it is necessary to file complete data relative to audio frequency response, both FM and AM noise levels, and audio frequency distortion. All measurements must be made with the equipment adjusted for normal program operation and should include all circuits between the main studio microphone terminals and the antenna output, including telephone lines, pre-emphasis circuits and any equalizers employed, but excluding the compensated microphone amplifier if used. This data is easily obtained, provided standard measuring equipment is available. The best and easiest method for making frequency response measurements is with an RCA 322-A FM Modulation Monitor, a Beat Frequency Oscillator of good stability and low distortion (such as the RCA 68-A or 68-B) and an RCA 89-B Attenuator Panel. The Modulation Monitor is part of the monitoring equipment required by the FCC while the 68-B Beat Frequency Oscillator and 89-B Attenuator Panel are standard test equipment used by both FM and AM Broadcast Stations. Harmonic Distortion measurements can be made with this same equipment plus a Distortion and Noise Meter such as the RCA 69-B or 69-C.

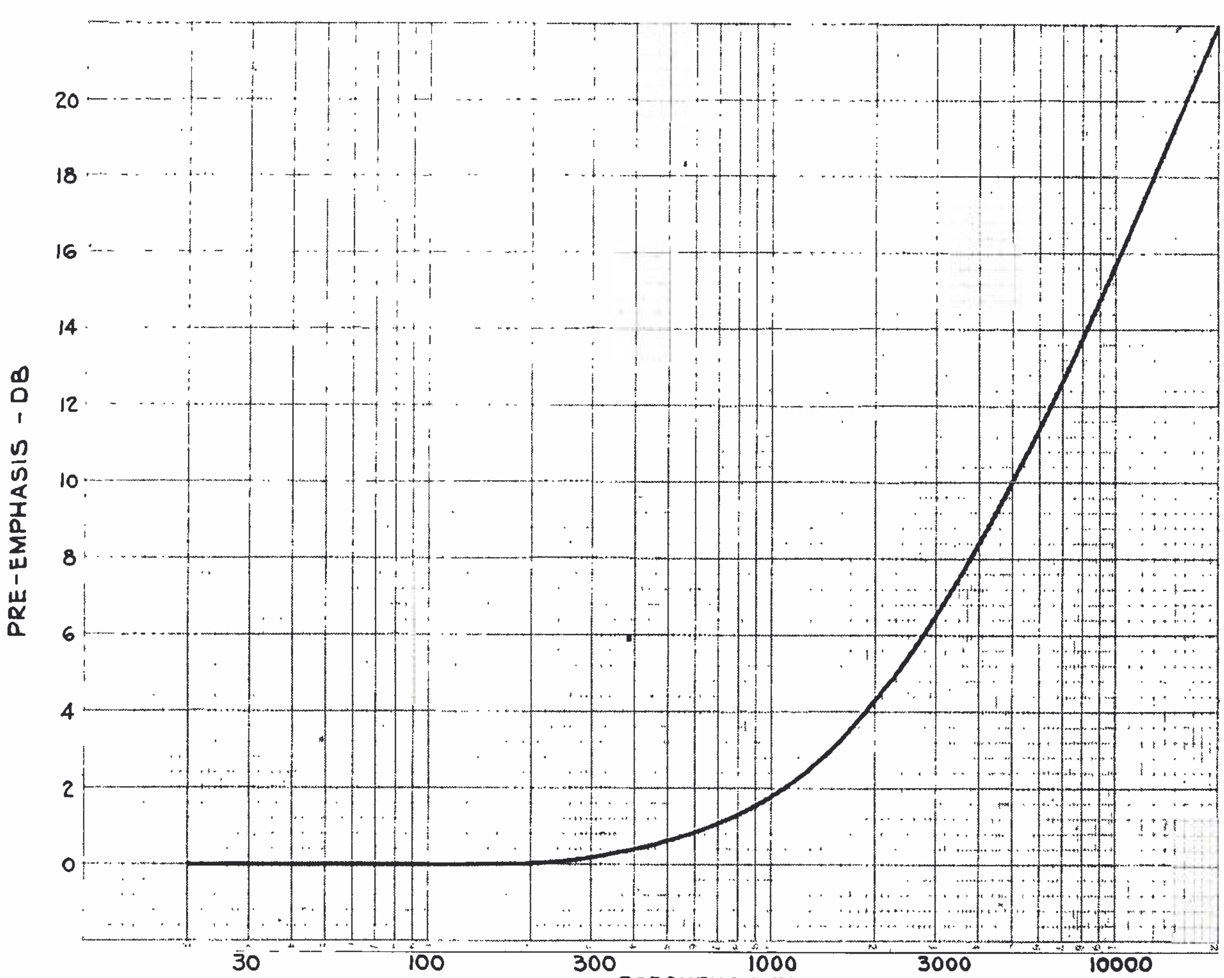


FIG. 1. *RMA Standard Pre-emphasis Curve which is incorporated in FM Transmitting Systems*

PRE-EMPHASIS

Measuring techniques employed in AM broadcast stations are equally applicable in FM stations providing due consideration is given to the pre-emphasized frequency response characteristic which is standard in all FM transmitting systems. Incorporated in the audio frequency circuit of the FM broadcast transmitter is a resistive-reactive circuit, having a time constant of 100 microseconds which boosts the response of the audio signal as much as 19.5 db at 15,000 cps over the level of frequencies below 200 cps. This frequency characteristic, plotted in Figure 1, is the standard RMA Pre-emphasis Response Curve. Pre-emphasis of high audio frequency energy is possible due to the relatively low peak energy existing at these frequencies and it is desirable because it increases the signal-to-noise and signal-to-distortion ratio.

In most installations it is comparatively easy to switch the pre-emphasis network out of the audio circuit and to make the necessary audio measurements with "flat response." However, it is desirable to check the transmitting system under actual operating conditions. Therefore, it becomes necessary to take into consideration the added "gain" of the high audio frequencies.

The standard method for measuring the a-f response of audio and broadcast transmitting equipment consists of determining the audio input level at a reference point of 1000 cps required to produce the desired output (for example, 95% modulation for an AM transmitter) and then, holding this input signal constant, measure the output level obtained (on an AM Modulation Monitor) as the frequency of the input is varied over the audio range.

If this procedure were applied to the FM transmitting system, the pre-emphasis network would cause the transmitter to be overmodulated at frequencies above 1000 cps and undermodulated at frequencies below this reference point. An alternate method which works well consists of setting the system up for 100 per cent modulation at the highest audio frequency to be broadcast, then noting the increase in signal input required to maintain the 100% modulation as the frequency of the signal is lowered.

ARRANGEMENT OF EQUIPMENT

A typical setup for making measurements of this type is shown in Figure 2. To insure that the readings obtained are a true measure of the equipment under test and do not include extraneous fields picked up by the measuring equipment, all of the latter should be securely grounded. This can best be accomplished by "tieing" all of the test apparatus to the system ground with a copper strip two to four inches wide. Ordinary single conductor or stranded wire should not be used. At high radio frequencies such a wire has appreciable inductive reactance and, therefore, instead of furnishing a ground actually raises the equipment above ground.

All interconnecting r-f and audio conductors running between the test and transmitting equipments should be shielded cable with a cotton braid, or equivalent, covering the shield to insulate it from ground. The shields are then grounded at one end only to prevent circulating ground currents. For the r-f circuits, single-conductor shielded cable of the low-capacity type is best. Two-conductor twisted pair encased in a shield braid and cotton outer braid is standard audio cable.

CALIBRATING THE AUDIO OSCILLATOR

Prior to actual response measurements, the 68-B Beat Frequency Oscillator must be calibrated in order to assure a precise source of audio frequencies. While this is a simple operation, its importance should not be overlooked. A correct knowledge

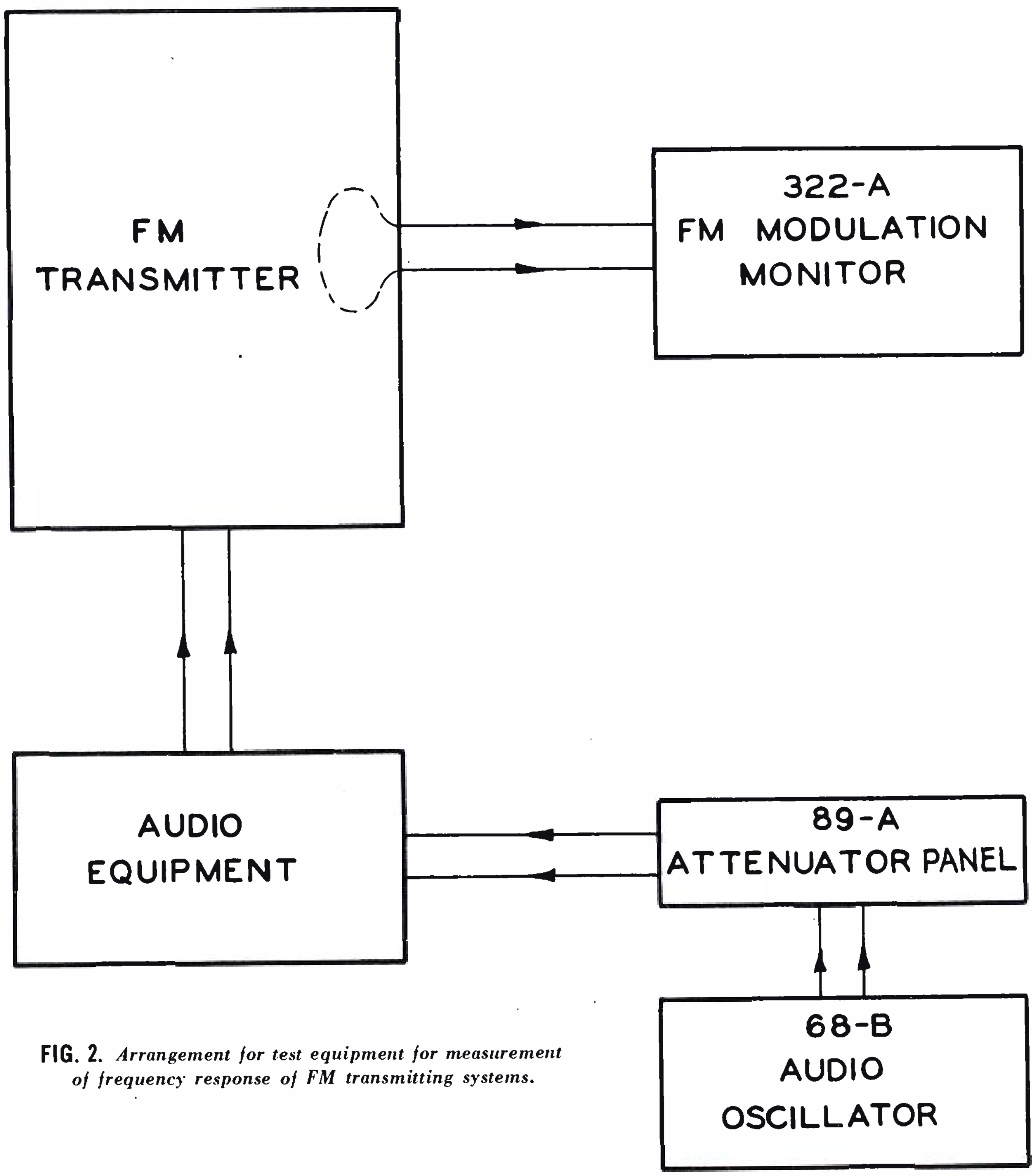


FIG. 2. *Arrangement for test equipment for measurement of frequency response of FM transmitting systems.*

of the signal frequency is vital to the proper adjustment of the transmitting system. This calibration is accomplished as follows:

(1) Throw the "Power" switch to "On" and allow approximately 10 minutes for the circuits to "warm-up" and arrive at a steady-state condition.

(2) Rotate the "Cal. Gain" control fully counterclockwise. The eye of the electron ray tube should appear about half-closed.

(3) Set the main frequency control to a dial reading corresponding to the power-supply frequency. This will probably be 50 or 60 cycles.

(4) Turn the "Volume" control to maximum; that is, fully clockwise.

(5) Advance the "Cal. Gain" control to about one-quarter of the total rotation from the minimum (one-quarter from fully counterclockwise).

(6) Turn the "Cal. Adj." control to the extreme clockwise position and return slowly toward minimum (rotate counterclockwise) until the plate milliammeter needle pulsates, which indicates proximity to zero beat. Now reverse the direction of rotation again, turning the control knob very slowly clockwise until the eye of the electron-ray tube again swings open and then closes as far as possible. At the exact setting, the eye deflection will remain fixed.

(7) Adjust the "Cal. Gain" control until the eye is completely closed, reducing the gain if the images overlap or increasing the gain if the deflection is insufficient. The size of the shadow obtained in the preceding step (6) will depend upon the phase relationship between the power-supply and beat-frequency voltages.

(8) Check the calibration by observing the appearance of the image upon the eye of the electron-ray tube.
   (a) At one-half or twice the reference frequency (power-supply frequency), each half of the deflecting area of the eye will appear to have two images, one superimposed upon the other and moving in opposite directions. That is, the eye will appear to have two pairs of shutters with one pair opening while the other is closing and vice versa.

   (b) Similarly at one-third or three times the reference frequency, there will be three superimposed images on each half of the deflecting area.

It is a good practice to check the calibration by setting the main frequency control to the second and third harmonic of the supply frequency and observe the above images. For example, if the supply frequency were 60 cycles, the second harmonic would be 120 cycles and the third would be 180 cycles.

FREQUENCY RESPONSE MEASUREMENTS

To determine the fidelity of an FM broadcast transmitting system, the output is determined for 100 per cent modulation at 15,000 cycles modulating frequency; this output level is held constant and the input level is varied to maintain it. The procedure is as follows:

(1) A 15,000-cycle signal furnished by the 68-B B.F.O. through the 89-B Attenuator Panel is fed into the RCA 76-B Consolette. From here it goes through the S-T link to the input of the FM transmitter. The RCA 322-A FM Modulation Monitor (which is inductively coupled to the transmitter output) measures the percentage of modulation.

(2) With the various gain controls set for normal operation, adjust the volume level of the 68-B oscillator until 100 per cent modulation is indicated on the 322-A Modulation Monitor. Note and record the audio-input level as metered by the volume indicator on the 89-B Attenuator Panel.

(3) Adjust the 68-B B.F.O. to the next lower audio frequency to be checked, and bring the input signal level up until the 100 per cent modulation mark is again reached. Note and record the input level indicated on the 89-B Attenuator Panel.

(4) Continue this procedure for the entire audio range (30 to 15,000 cps). It will be necessary to increase the audio input level considerably as the 30-cycle point is approached. Since this level will change approximately 20 db, it is desirable to start at the 15,000-cycle measurement with 20, 10, and 5 db attenuator pads cut in on the 89-B Attenuator Panel so that the proper combination of pads may be selected for the desired input level to the speech input equipment. Of course, these attenuator pads must be included in determining the actual volume level being fed into the equipment under test. The true audio level is the algebraic sum of the pads in the circuit plus the signal level indicated by VI on the 89-B Panel.

(5) Record the data as shown in the first two columns of Table I. Correct the readings for reference to 200 cycles as shown in the third column. Subtract the values of standard pre-emphasis curve (shown in the fourth column). The results, shown in the fifth column, represent the values for the curve as referred to 200 cycles. This can now be corrected to refer to 1000 cycles as shown in the sixth column.

(6) Plot the values given in the sixth column of Table I against frequency as shown in Figure 3. Repeat the measurements at 75, 50 and 25 per cent modulation levels and plot the corresponding curves. This series of form curves should be filed as exhibits with Form No. 320.

TABLE I

Audio Mod. Freq.	Audio Input Level for 100% Mod.	Input Level Corrected for 200 Cyc. as Ref. Point	Standard Curve	Deviation from Std.	Audio Freq. Response Corrected for 1000 Cycle Ref. Point
CPS	*DB*	*DB*	*DB*	*DB*	*DB*
30	+6.1	—0.1	0	—0.1	+0.1
50	6.0	0	0	0	+0.2
100	6.1	—0.1	0	—0.1	+0.1
200	6.0	0	0	0	+0.2
300	5.9	+0.1	+0.2	—0.2	0
500	5.7	0.3	0.4	—0.1	+0.1
1000	4.7	1.3	1.5	—0.2	0
2000	1.4	1.6	4.1	+0.5	+0.7
3000	—1.3	7.3	6.7	+0.6	+0.8
5000	—4.7	10.7	10.4	+0.3	+0.5
7500	—8.1	14.1	13.6	+0.5	+0.7
10000	—10.4	16.4	16.1	+0.3	+0.5
12000	—11.8	17.8	17.6	+0.2	+0.4
15000	—14.0	20.0	19.5	+0.5	+0.7

USING THE 69-C DISTORTION AND NOISE METER FOR FREQUENCY RESPONSE MEASUREMENTS

A second and more flexible method for measuring the a-f response is similar to that just described with the exception that the 69-C Distortion and Noise Meter is employed as an output level indicator. The 322-A FM Modulation Monitor now acts solely as a detector or demodulator of the FM signal, delivering the audio component of the detected signal to a pair of terminals for monitoring or measuring purposes. Into this audio circuit is built a de-emphasis network which is the counterpart of the pre-emphasis circuit employed in the transmitter. This de-emphasis network may be switched in or out of the circuit, thereby making it possible to measure either the pre-emphasis or flat response of the studio-transmitter system.

Figure 4 shows the complete equipment "setup" for this type of measurement. The procedure employed here deviates from that discussed above in that once the audio level for 100 per cent modulation has been determined an arbitrary level is set up on the 69-C and this reading maintained constant instead of that on the 322-A Modulation Monitor.

If the output from the 322-A is being metered through the de-emphasis network then the standard method of taking a-f response measurements may be followed and the customary reference point of 1000 cycles used.

A few simple directions are all that is necessary for using this method of measurement. Prior to making measurements, however, the 69-C should be calibrated in the following manner:

(1) Turn the power on by rotating the "Calibrate" control in a clockwise direction and wait at least five minutes to allow voltages to stabilize.

(2) With no input signal to the "Osc." binding posts or jacks and with the "Distortion-Noise Level" switch at the "Calibrate" position adjust the "zero" control for a meter reading of zero per cent (not 0 db).

(3) Set the coarse and medium "Amplitude" controls to "0" positions and the "Fine" control with the pointer approximately vertical. Also, set the "Distortion-Noise Level" switch to the "0" position, and the "Input" switch to the "Check"

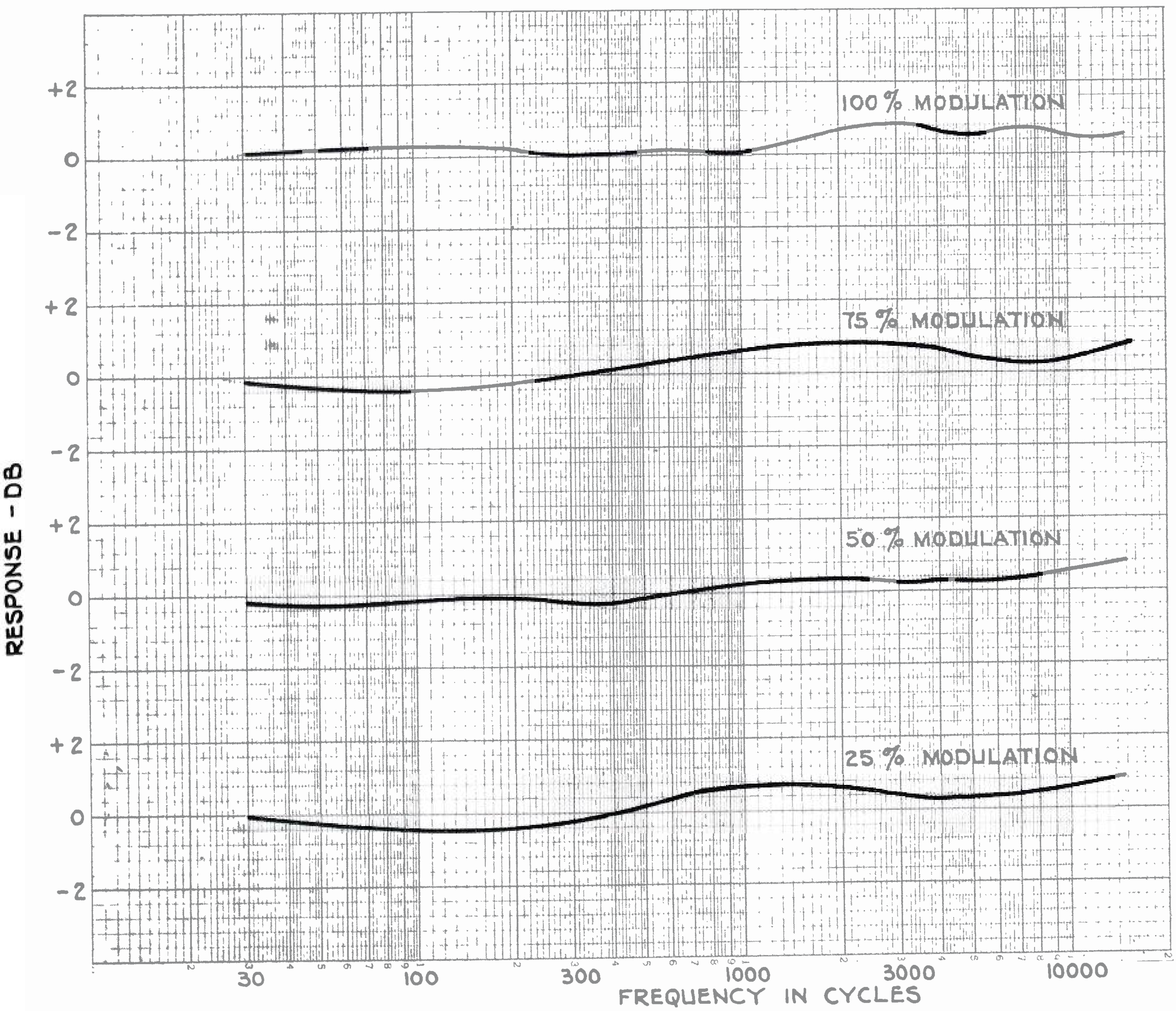


FIG. 3. *Frequency response curves of an FM system for several percentages of modulation. A set of curves similar to these must be filed in answer to Par. 6(a) of Form No. 320.*

position. Adjust the "Gain" control for full-scale meter reading (0 db).

This completes the calibration of the Distortion and Noise Meter; next, set up the 100 per cent level as follows:

(4) Be sure the a-f output of the 322-A is connected to the Hi-Audio terminals of the 69-C. Rotate De-emphasis In-Out switch (located adjacent to a-f Output Terminals) to desired position.

(5) Following the procedure outlined under the first method of a-f response measurement, adjust the audio input level to the transmitting system for 100 per cent.

(6) Place the "Distortion-Noise Level" switch on "0", the Input-Switch should be on "Hi-Audio", and adjust the Amplitude controls for approximately mid-scale deflection of the instrument.

(7) Holding this level constant proceed as outlined earlier for the type of characteristic to be measured (flat or de-emphasized as determined by position of switch—see step 4, above).

HARMONIC DISTORTION MEASUREMENTS

The circuit arrangement shown in Figure 4 may also be used for checking the amount of harmonic distortion present in the transmitted signal. If the speech input equipment and transmitter are installed in the same room, a system check can be made; otherwise, individual measurements will be necessary on the transmitting and speech input units. The reason for this is that it is undesirable to operate the Distortion and Noise Meter remotely from the oscillator (68-B) since they are interconnected and the effects of noise and distortion in long interconnecting lines may be great enough to seriously affect the accuracy of the measurements.

In making distortion measurements the indicating instrument on the 69-C Distortion Measuring Meter denotes the distortion factor; i.e., the ratio of the rms total distortion to the funda-

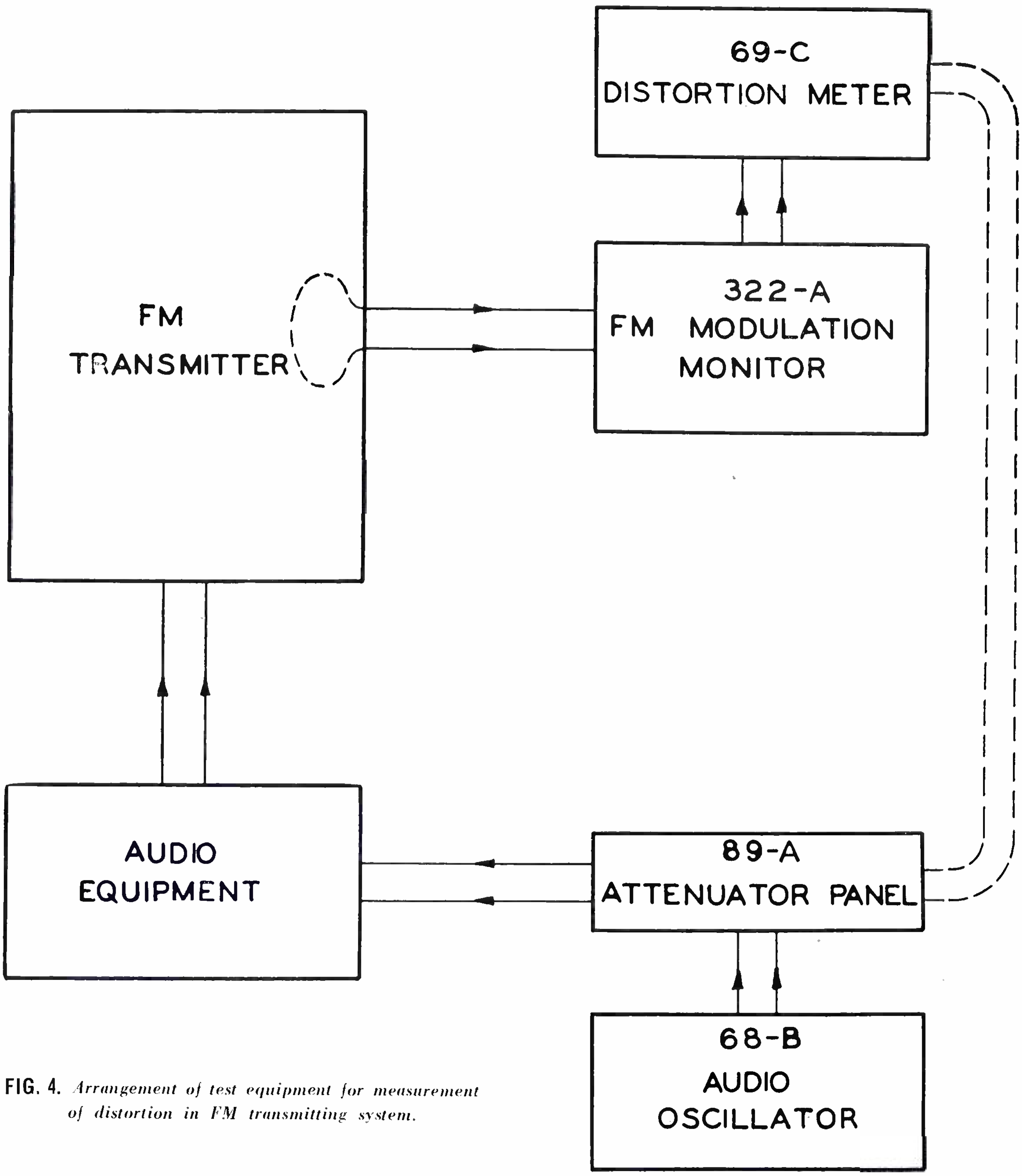


FIG. 4. *Arrangement of test equipment for measurement of distortion in FM transmitting system.*

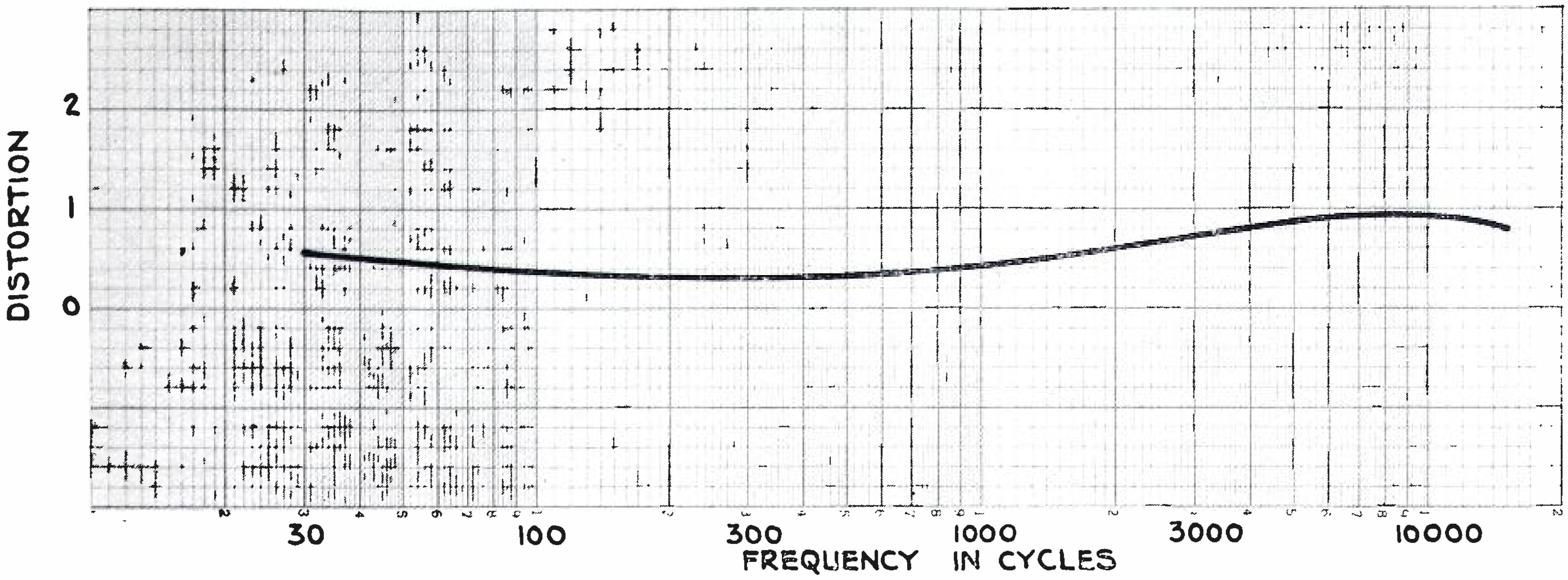


FIG. 5. *Typical distortion versus frequency curve for an FM transmitting system. A curve of this type must be filed in answer to Par. 6(d) of Form No. 320.*

mental amplitude. This is accomplished by suppressing the fundamental frequency component of the wave in question and measuring the rms total of the remaining components. Elimination of the fundamental frequency component is secured by adding to the signal, from the equipment under test, a sine wave of the same frequency, equal in amplitude to the fundamental component, but 180 degrees out of phase with it. This voltage is secured from the same oscillator (68-A or 68-B) which supplies the signal to the equipment under test and is adjusted in amplitude and in phase by use of the controls on the panel of the Distortion and Noise Meter. Distortion readings directly in per cent of the fundamental amplitude are obtained by first adjusting the meter to read full scale (100 per cent) with only the sine wave input connected.

Distortion measurements are accomplished as follows:

(1) Check the calibration of the Distortion and Noise Meter as outlined in the section for frequency response measurements (see steps 1 through 3).

(2) By regulating the volume control knob on the 68-B B.F.O.; adjust the audio input level to the equipment under test to produce 100 per cent modulation (as indicated by the 322-A FM Modulation Monitor). It is desirable to operate the B.F.O. at as high an output as practicable, thus improving the signal to noise ratio; therefore, one or two attenuator pads on the 89-B Attenuator Panel should be "cut in."

(3) Apply a signal from the 89-B Attenuator Panel to the Distortion and Noise Meter by plugging in a "patch cord" between the jack marked "Dist. Meter" on the Attenuator Panel and the jack labeled "Oscillator" on the 69-C. Place the "Distortion-Noise Level" switch on "Cal." and adjust the "Calibrate" control for full-scale reading. This setting should remain unchanged. If a full-scale reading is unattainable by adjustment of the Calibrate Control it will be necessary either to "cut out" or "cut in" some of the pads on the attenuator panel. Should any change in the pads be necessary, a readjustment of the volume control knobs on the B.F.O. will also be required to bring the audio level back to the required for 100 per cent modulation of the transmitter.

(4) Place the "Distortion-Noise Level" switch on "0", the Input Switch should be on "Hi-Audio" (the 322-A Monitor is connected to these terminals) and adjust the Amplitude Controls for full scale deflection of the meter.

(5) Place the "Distortion-Noise Level" switch on "100" and adjust the "Phase" controls until the meter reading is below the calibrated portion of its scale. Turn the "Distortion-Noise Level" switch to "30" and by further adjustment of both the "Phase" and "Amplitude" controls obtain a minimum meter reading, turning the 'Distortion-Noise Level" switch for increased sensitivity as required.

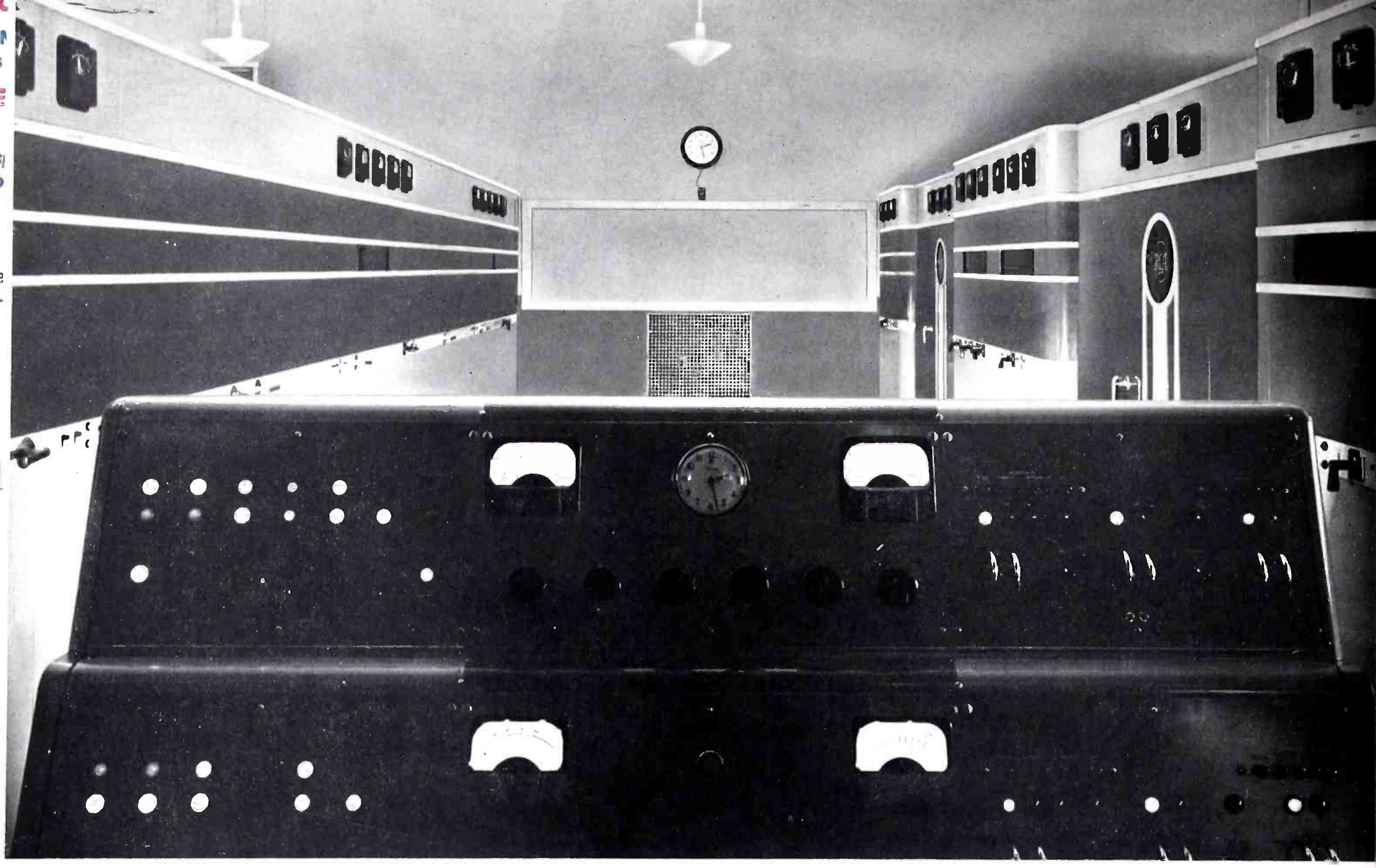
With the selector switch placed on "Cal." during distortion measurements, the meter reading may vary with the position of the "Phase" controls. This is a normal characteristic resulting in an error of not more than 10 per cent on the "% Distortion" scale indication. In order to eliminate this error, place the selector switch on "Cal." (after adjusting the phase controls for a balanced condition) and readjust the "Calibrate" control for a full meter indication. A slight readjustment of the "Fine" amplitude control will then be necessary for the final balance.

After obtaining an exact balance, the amount of total distortion is obtained by reading both the "meter" and "switch" scales. After a reading has been taken the switch should be returned to the "Cal." position before making any adjustments to the equipment, in order to protect the meter. Distortion measurements should be made in this way at frequencies of 50, 100, 400, 1000, 5000, 10,000 and 15,000 cycles for 100 per cent modulation. The readings may be conveniently plotted in the form of a curve of distortion vs. frequency as shown in Figure 5.

FM AND AM NOISE LEVEL MEASUREMENTS

The necessary measurements of FM noise level may also be made with the test equipment shown in Figure 4. The 69-C is adjusted for full-scale deflection at the 100 per cent modulation level. The input signal is removed from the transmitting system and the input terminals shorted. The residual noise and hum is amplified until a reliable meter deflection is obtained. The noise level is then read directly in decibels from the meter and attenuator scales.

For measuring the AM noise component of an FM carrier, a simple, untuned r-f rectifier inductively coupled to the PA plate tank coil is substituted for the 322-A FM Modulation Monitor. The rectified or demodulated output signals from this diode rectifier are fed into the 69-C Distortion and Noise Meter. In order to "calibrate" the 69-C a special procedure must be followed. The article "FM Noise evel and AM Noise Level" printed in the January 1944 issue of BROADCAST NEWS describes this procedure in detail.



WOOC . . . . . . WOOW

INTERNATIONAL BROADCAST STATIONS INSTALLED By CBS AT WAYNE, N. J.

by R. N. DeHART

General Engineering Department

Columbia Broadcasting System, Inc.

Radio programs originating in the United States are being successfully received in both the "European Theater" and the "Pacific Theater" of the present world conflict. Shortwave transmitters located in this country and operating on frequencies within the various international bands from 6 to 21 megacycles are beaming transmissions directed at all the major areas of the world. These transmissions are received direct by listeners employing shortwave receiving sets in the enemy homeland and occupied territories. To augment this service, these same transmissions are picked up and relayed by transmitters located in allied and liberated territory which operate on frequencies in the "broadcast band." Thus, people in enemy territory have the opportunity of hearing the United States' messages of liberation even though the receiving sets in their possession may not be capable of tuning through the international bands. In addition to foreign language programs, entertainment is broadcast by the Armed Forces Radio Service to men of the United States Armed Forces stationed throughout the world and includes the retransmission of popular programs carried by the major networks in this country.

With this country's entry into World War II all of the then existing shortwave broadcast facilities located in the United States "went to war." Transmissions originating at the Columbia Broadcasting System plant located at Brentwood, New York, were heard in Europe and Latin America over stations WCBX, WCRC and WCDA.[1, 2, 3]

Early in 1943 the United States Government, through the Office of War Information (OWI), completed plans to expand greatly the International Broadcast transmitter facilities within this country. The Columbia Broadcasting Systems' part in this expansion included:

1. Placing a fourth transmitter in operation at Brentwood employing a carrier power of 50 kw and identified by the call letters WCBN.
2. The construction of a "super-power" international transmitting plant near Los Angeles, California where two new 50 kw transmitters, KCBA and KCBF, "took to the air" in November, 1944, and where construction is now progressing towards the completion of a third transmitter capable of emitting a carrier power of 200 kw.

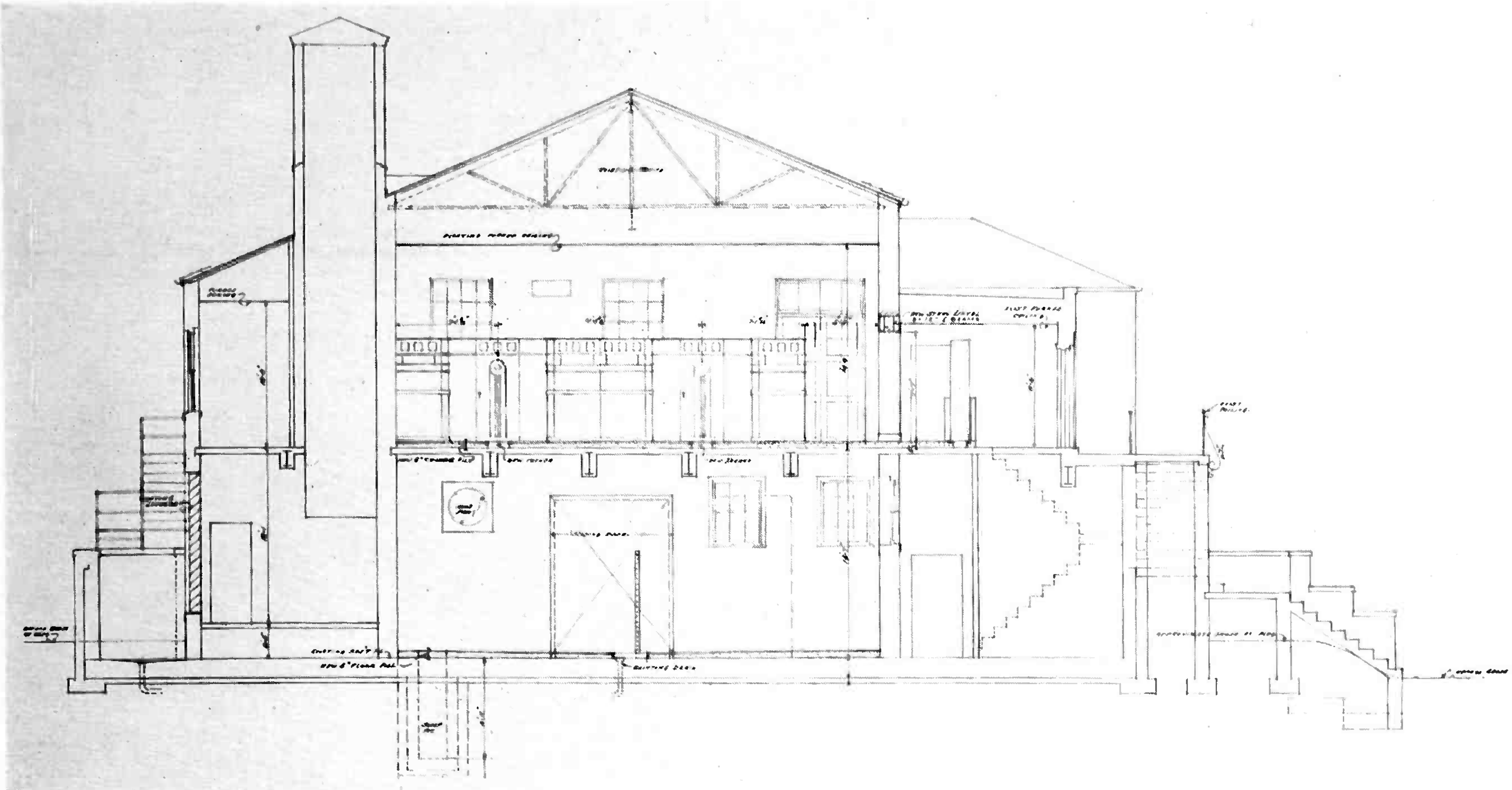


FIG. 1. *Longitudinal section of transmitter building, located at Wayne, N. J., which houses OWI-CBS International shortwave stations WOOC and WOOW.*

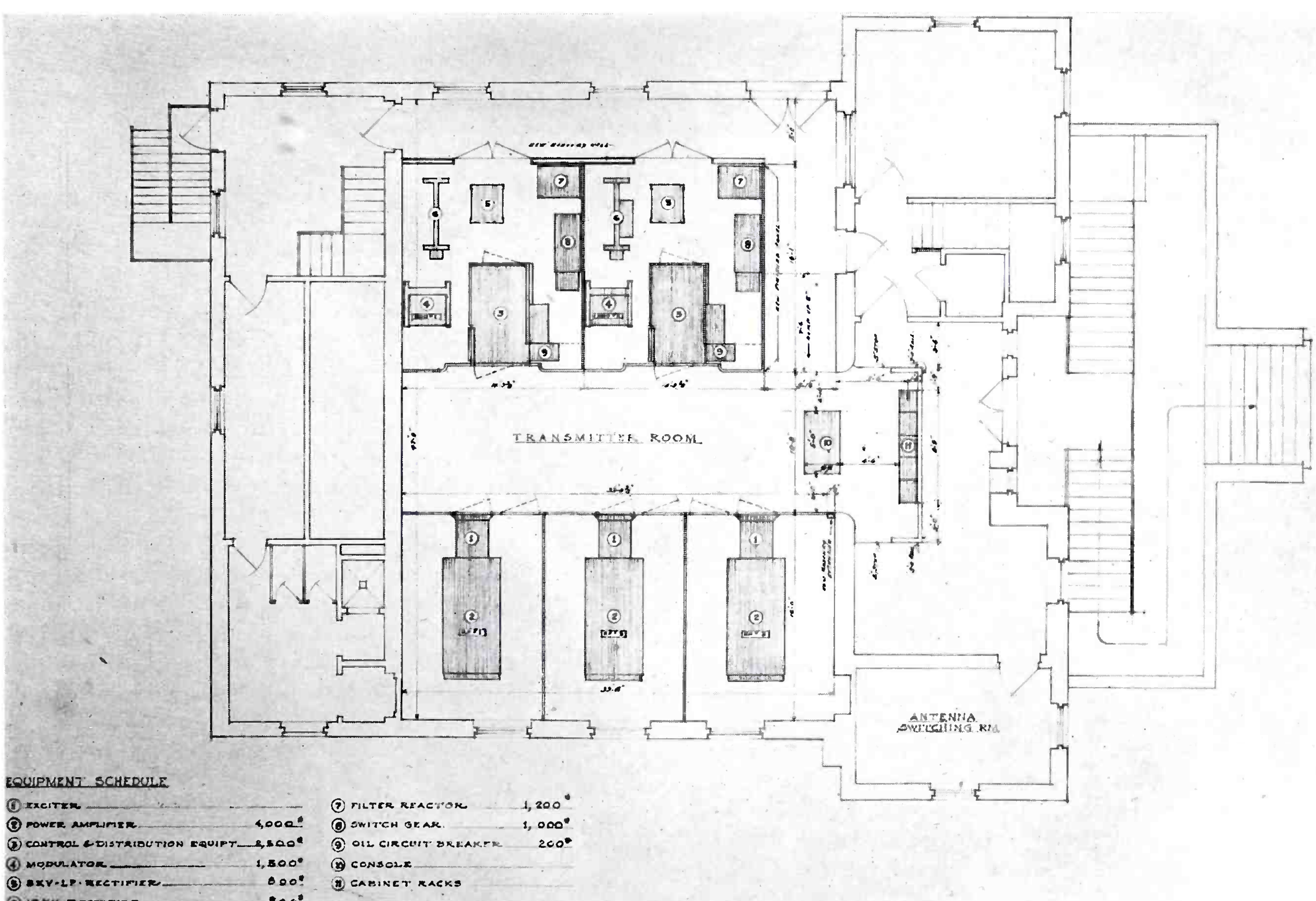


FIG. 2. *Floor plan of OWI-CBS plant showing general placement of the two RCA 50 KW shortwave transmitters. Three complete r-f channels are mounted adjacent to one another on one side of the transmitter room and two complete modulator-power supply units are on the opposite side.*

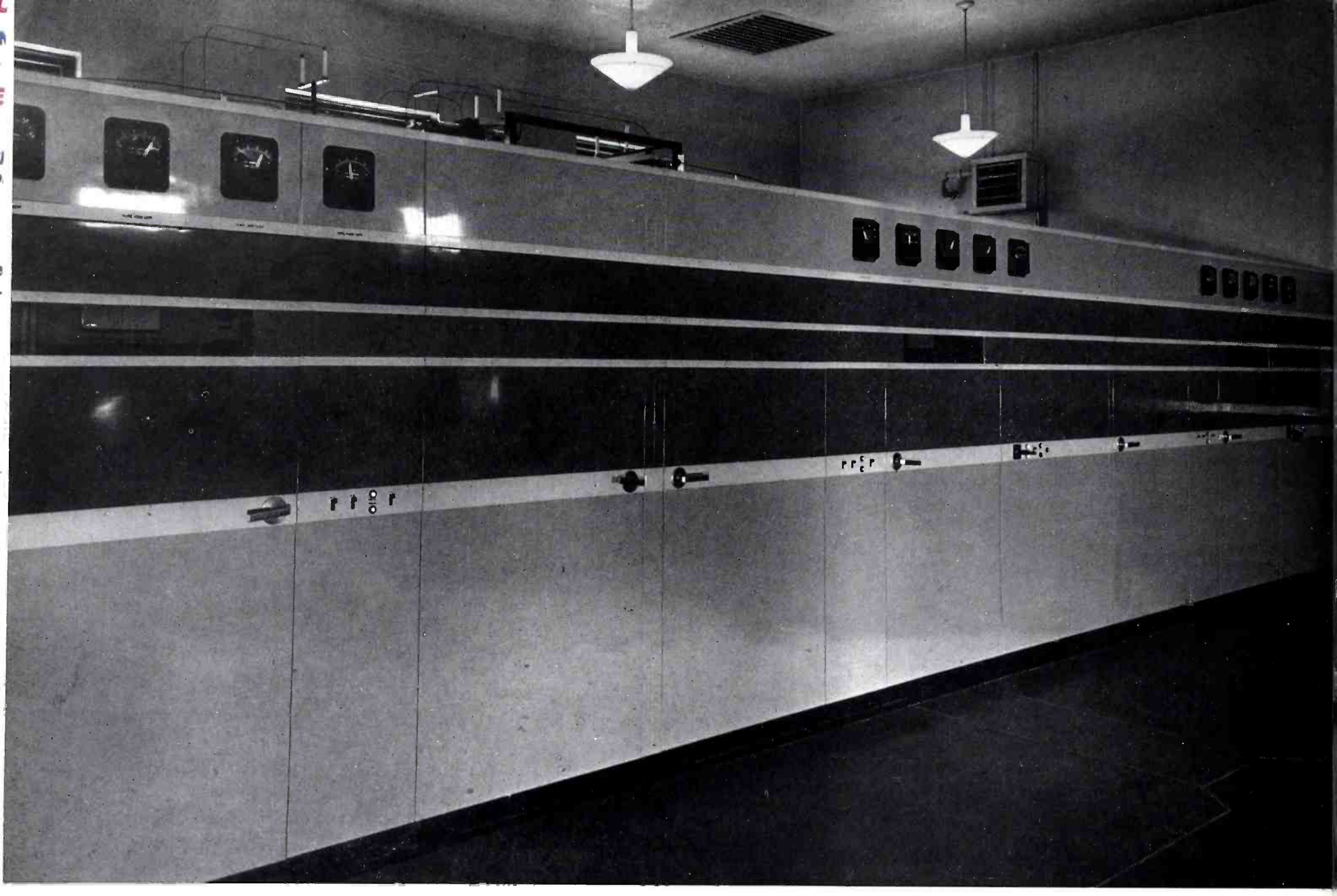


FIG. 3. *View of WOOC and WOOW transmitter panels at Wayne for the three RCA r-f channels; each channel consists of a complete exciter unit, from crystal oscillator to driver stage, including a 50 KW r-f power amplifier.*

3. The installation of two new 50 kw transmitters at the former WABC transmitter site located at Wayne, New Jersey.

In order to place these latter transmitters in operation in a minimum of time, it was decided to utilize the existing building and land at Wayne. By so doing, a building planning and construction period of from four to six months was eliminated.

Two modified RCA Type 50-SW, 50-kw transmitters were installed and three directional antennas of the rhombic type constructed. The engineering and installation plans were fashioned with the main objective of placing this plant in operation in the least possible time. Delivery of transmitter equipment was accepted from RCA as it became available at the factory. Component parts, which usually arrive as part of a completed transmitter, were installed long before fabrication of the transmitter proper was completed at the RCA factory. The major part of all wiring and plumbing was finished prior to the delivery of the transmitters.

Construction work at Wayne was started on July 1, 1943 and the last shipment of transmitter equipment from RCA was received in November 1943. The WOOC and WOOW transmitters were placed in test operation in December 1943 and officially took the air for regular operations on December 31, 1943. The following is a description of some of the more interesting features of this installation.

BUILDING

Although considerable time was saved by utilizing an existing building, it did offer some problems. Usually the area required to house the transmitting equipment is laid out and a building designed accordingly. In this case, however, this practice could not be followed. Instead, the equipment layout was tailored to fit the building in a manner which would require the fewest possible alterations. The major building alteration consisted of the removal of a section of a main bearing wall at the entrance to the transmitter room proper. A horizontal lintel was placed to take the load originally carried by this section. This alteration provided enough additional area in the transmitter room to house the control console and associated audio and test equipment racks. Figure 1 shows a longitudinal section through the building.

The floor trench system required to accommodate the interconnecting wiring of the various transmitter units was constructed in the following manner. A false concrete and cinder fill of approximately six inches was laid over the existing concrete floor. The proper form work provided the required trenches.

The transmitter units on the first floor were so located that advantage could be taken of the existing transformer vaults in the basement. Figure 2 shows the floor plan of the first floor of the building.

TRANSMITTER DETAILS

The standard RCA Type 50-SW, 50 kw shortwave transmitter consists of two complete r-f channels, each capable of being tuned throughout the International bands of 6 to 21 megacycles, and one modulator-power supply unit. Switching facilities are provided enabling the modulator-power supply unit to energize either of these two r-f sections. With this arrangement it is

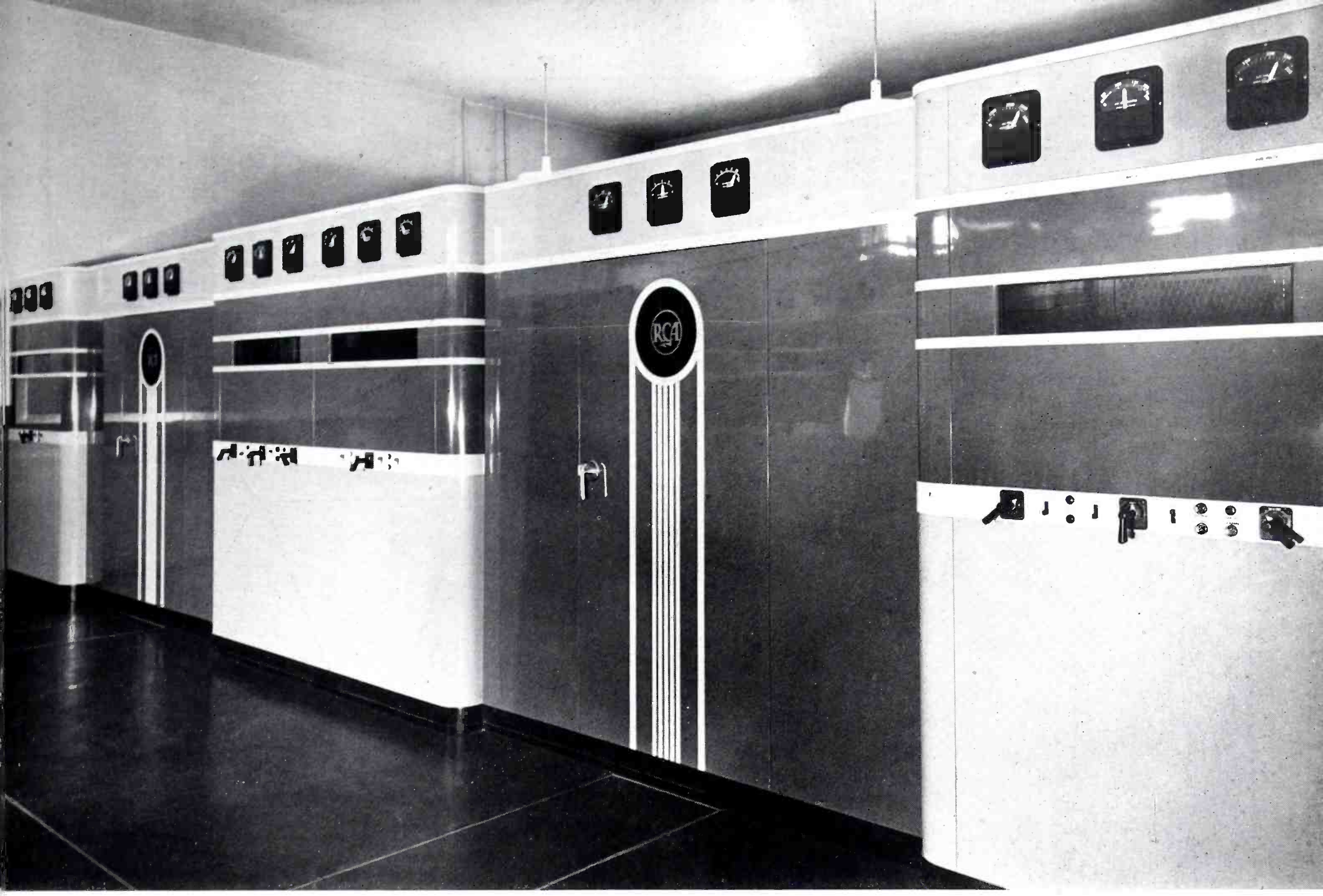


FIG. 4. *General view of modulator-power supply panel arrangement. To place these units, as well as the r-f channels, within existing CBS building area required an alteration in the standard RCA enclosures and panels.*

possible to pre-set an idle r-f channel and then instantly change operating frequency at the desired time. This transmitter has been previously described in detail in BROADCAST NEWS, ("The 50-SW", BROADCAST NEWS, No. 38, Jan. 1944).

The RCA transmitter equipment furnished by OWI for installation at Wayne consisted of two complete modulator-power supply units and three complete r-f sections; these were of standard design and assembled by RCA in accordance with their regular layout. In effect, therefore, we had one complete standard RCA 50 kw transmitter including the two r-f channels and associated switching facilities, and one RCA 50 kw transmitter with one, instead of the usual two, r-f channels.

Building layout requirements, and a desire to provide a flexible switching system whereby each of the two modulator-power supply units could be switched so as to energize two r-f channels, necessitated considerable additions to the standard RCA circuits and layout. The standard RCA panels and transmitter enclosures of the r-f sections and the modulator-power supply unit were designed and constructed to be mounted adjacent to one another. As can be seen from the Wayne floor plan drawing, these units were not placed in this fashion. The three r-f sections were located adjacent to each other on one side of the transmitter room (see Figure 3) and the two modulator-power supply units on the opposite side (see Figure 4). The separation of these sections required some alteration in the transmitter enclosures and panels. This work was done at the RCA factory to CBS specifications.

MODULATOR AND POWER SUPPLY SWITCHING

Figure 5 shows a simplified block diagram of the transmitter switching circuit used at Wayne. It illustrates how r-f channel #2 can be switched to either modulator "A" or modulator "B", whereas r-f channel #1 can be energized only from modulator "A", and r-f channel #3 only from modulator "B." It will be

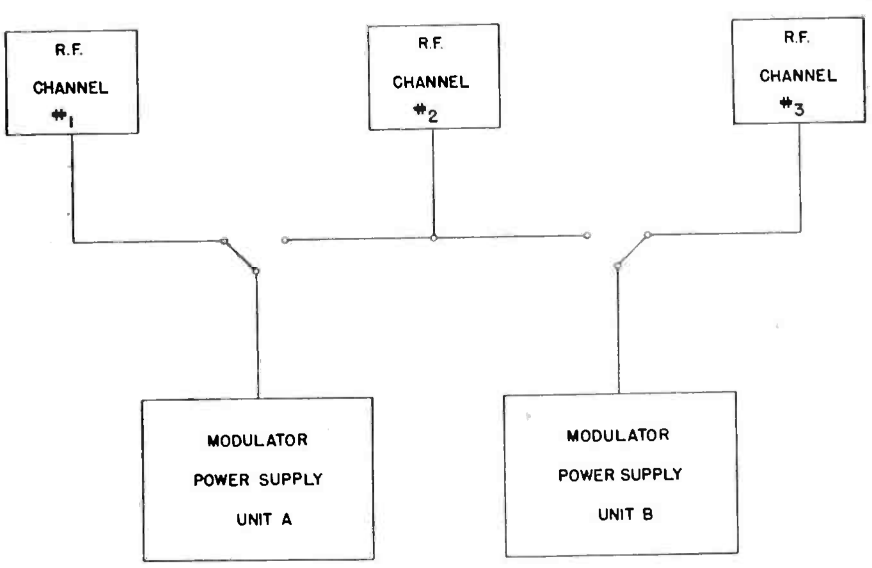
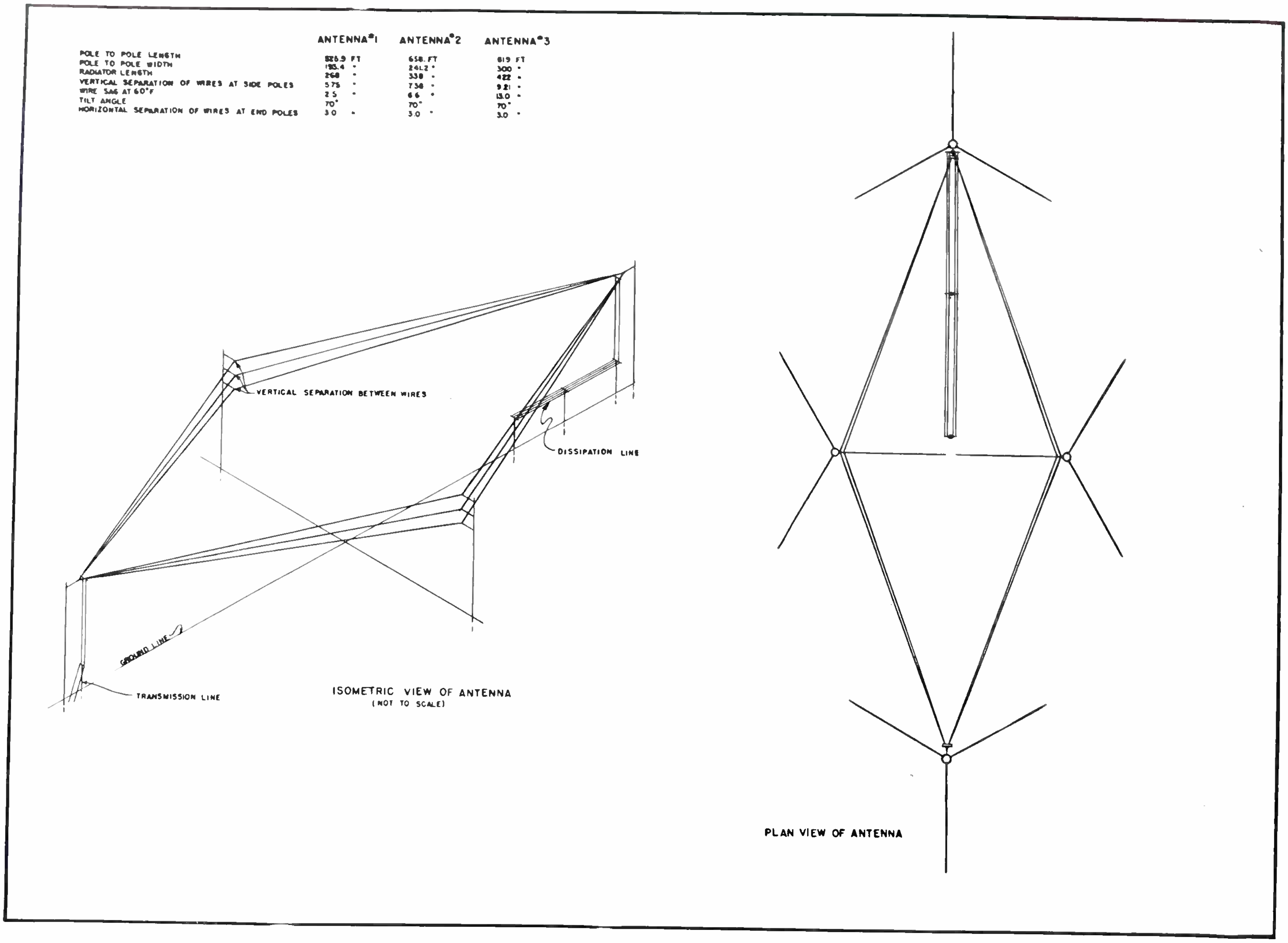


FIG. 5. *Simplified block diagram of transmitter switching circuit in use at OWI-CBS International transmitting plant located at Wayne, N. J. It illustrates how r-f channel #1 can be energized from modulator "A", and r-f channel #3 from modulator "B"; whereas r-f channel #2 can be switched to either modulator "A" or modulator "B".*



	ANTENNA #1	ANTENNA #2	ANTENNA #3
POLE TO POLE LENGTH	526.9 FT	658. FT	819 FT
POLE TO POLE WIDTH	193.4 "	241.2 "	300 "
RADIATOR LENGTH	268 "	338 "	422 "
VERTICAL SEPARATION OF WIRES AT SIDE POLES	5.75 "	7.38 "	9.21 "
WIRE SAG AT 60°F	2.5 "	6.6 "	13.0 "
TILT ANGLE	70°	70°	70°
HORIZONTAL SEPARATION OF WIRES AT END POLES	3.0 "	3.0 "	3.0 "

FIG. 6. *Illustration of multiple-wire rhombic antennas employed at Wayne plant. Three different sizes are in use, their dimensions being determined by design frequencies of 9.6 Mc, 11.8 Mc and 15.3 Mc. These are connected as terminated rhombics and each can be operated over a relatively wide band of frequencies providing antenna facilities for the International frequency range of 6 to 21 megacycles.*

noted that three basic circuits are switched: the 10 kv modulated plate supply for the final r-f stage, the 5 kv plate supply intended for the r-f driver stage, and a 1.5 kv plate supply voltage used for the remaining r-f stages of the transmitter.

From a design and construction requirement, this switching system appears relatively simple. However, the necessary circuit changes from the standard RCA layout were quite complex and required the addition of numerous multiple contact relays and contractors. The complexity of the switching system results from the fact that a large number of auxiliary circuits must be switched as well: i.e., all overload protection, interlock circuits, control circuits, and indicating circuits. From an operations standpoint the system is simple and foolproof. It is possible to pre-set the transmitter combination desired and, by the use of one manually-operated switch, transfer a given modulator unit to a pre-tuned r-f channel. Antenna selection is performed in this same operation as detailed below. The time required to make a switch is approximately five seconds. The switching system is completely interlocked. It is impossible for an operator to switch a "hot" unit or place two r-f channels on one modulator unit.

ANTENNAS

The OWI and the International Broadcast Licensees, with the cooperation of the FCC, standardized on the type of antenna to be installed at the various International transmitter plants during the present war. The rhombic was chosen as standard because it possesses the following advantages:

1. Requires less "critical" material for its construction.
2. Is easily constructed.
3. Can be operated over a wide band of frequencies and thereby reduces the number of antennas required, at a given plant, to cover the International bands of 6 to 21 mc.

These rhombics, Figure 6, are of the "multiple wire" type; each side consisting of three conductors. The purpose of using this type of design is to minimize terminal impedance variations with frequency. The use of multiple wires compensates for the increasing distance between the antenna conductors as the side poles are approached, the maximum separation occurring at this point. The three wires are joined at each end pole and taper to a maximum separation, in the vertical, at the side poles. In effect, this increases the antenna wire diameter as the sides of the rhombus separate.

To obtain the desired characteristics of a rhombic antenna, its open end must be terminated in an impedance equal to the characteristic impedance of the antenna. Provision must be made in this termination to dissipate from one-third to one-half of the power fed to the antenna, the exact amount depending on the operating frequency. A high-attenuation transmission line was constructed at Wayne to serve as a dissipation network. Stainless steel wire possesses both the desired attenuation characteristic and long life. It was therefore selected to be used in the construction of the dissipation lines. The impedance of these lines is approximately 600 ohms, obtained with a wire size #6, spaced 12 inches. A value of 600 ohms approximates the open end terminal impedance of the rhombics at their design frequency.

The antenna switching system employed at Wayne is shown in Figure 7. It is designed around a "trip-lock" type r-f contactor and is operated by applying a momentary pulse to its solenoid coil. This pulse causes the contractor arm to lock in one of its two positions.

Ten contactors are required at Wayne to facilitate selecting any of the three antennas to be connected to any of the three r-f channels. Provisions were made to increase readily the switching capacity of this system so as to accommodate additional antennas. This system of contactors is mounted on a framework located over the r-f channels. The antenna transmission lines are brought into the building at this point.

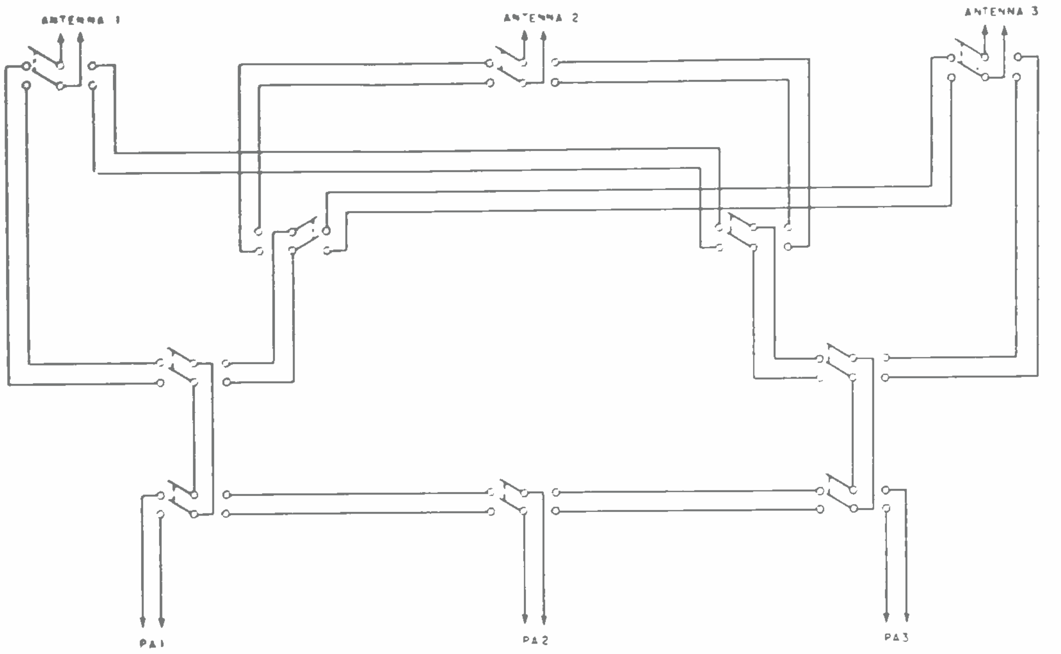


FIG. 7. *Schematic diagram of the antenna switching system. A "trip-lock" type of r-f contactor is operated by applying a momentary pulse to its solenoid coil, which causes the contactor arm to lock in one of its two positions. The antenna selection and modulator r-f channel transfer is performed by the same operation. The entire system can be pre-set and the manual operation of one switch will connect the selected antenna to the correct r-f channel, and at the same time a given modulator will be connected through to the pre-selected r-f channel.*

The selection of a desired antenna to be driven from a given r-f channel is made by operating a small selector switch located on the transmitter control panel. This panel is mounted in the equipment racks that contain the audio measuring equipment and is readily accessible from a position at the control console. As mentioned above under "Transmitter Details," the antenna and modulator r-f channel transfer is performed by the same operation. The entire system can be pre-set and at the desired time the manual operation of one switch will connect the selected antenna to the correct r-f channel. At the same time, a given modulator will be connected through to the pre-selected r-f channel.

As with the modulator r-f channel transfer system, the antenna switching system is completely interlocked. It is impossible to switch a "hot" antenna, nor can plate power be applied to an r-f channel not connected through to an antenna.

AUDIO FACILITIES AND MEASURING EQUIPMENT

The audio facilities at Wayne were designed and assembled by CBS. Two identical audio channels provide an independent feed to either of the two modulators. This layout follows the conventional practice whereby the studio line-circuits normally supply program to to the transmitters. In an emergency, however, a transcription turntable or microphone can be operated direct at the Wayne plant.

Each channel includes an automatic program amplifier capable of being adjusted for a value up to approximately 15 db of limiting. The use of this large amount of limiting is a wartime measure intended to increase the coverage of a given transmitter.

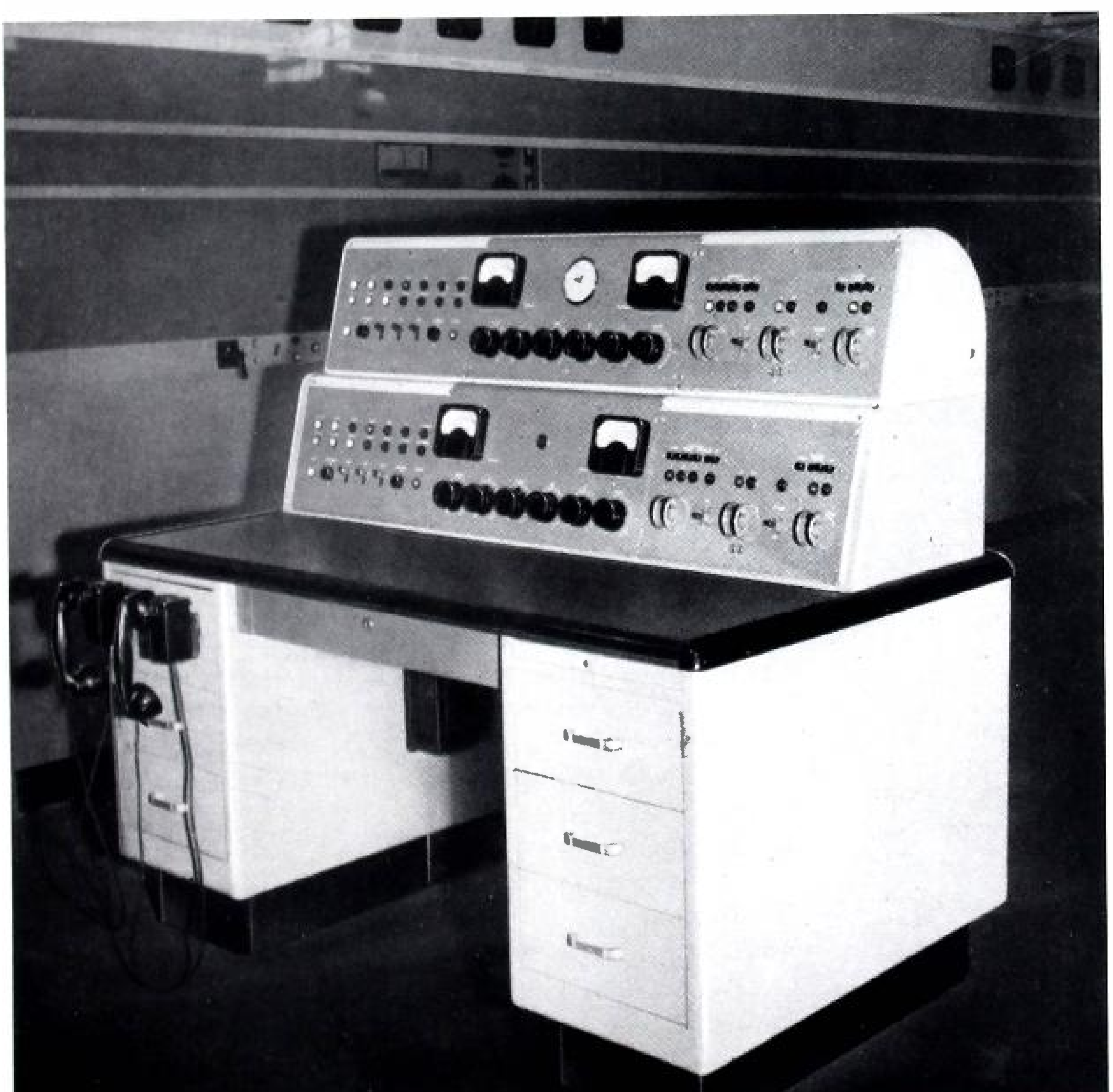


FIG. 8. *The RCA control consoles include both an audio mixer panel and a transmitter supervisory control panel. The control panel contains transmitter-indicating lamps, overload re-sets, and transmitter-plate-voltage controls.*

The RCA r-f transmitter channels received at Wayne did not contain an r-f monitor circuit for driving a monitor-speaker system as an air-check. Therefore, three diode rectifier units were constructed for use with each of the three r-f channels. A system of relays, operated in conjunction with the r-f modulator transfer system, automatically connects the output of a given r-f rectifier to the correct monitor-speaker channel. Two monitor-speaker channels are provided, each being associated with one of the two call letters, WOOC and WOOW. These speakers are mounted in baffles located directly above the audio racks.

Two RCA control-console desk assemblies were furnished as part of the Wayne transmitter equipment. These control consoles consist of both an audio mixer panel and a transmitter control panel. The transmitter control panel contains the usual transmitter indicating lamps, overload re-sets, PA plate supply controls, etc. The CBS audio facilities were designed so as to utilize components of the RCA mixer. The two RCA control turrets were structurally modified and mounted one above the other as shown in Figure 8. The rack equipment layout is illustrated in Figure 9. Five racks were installed; three of these house the audio and the monitoring equipment; the remaining two are used to mount various measuring equipment and control panels. In this way all equipment that requires a source of r-f is segregated into two of the racks, thereby minimizing the possibility of r-f pickup by the audio circuits.

The measuring equipment complement includes: GR 731-A modulation monitors, RCA 303-A and 306-A frequency deviation monitors, HP audio frequency oscillators, and a GR 732-B noise and distortion measuring unit. R-F switch panels were constructed and installed. These enable the connecting of any of the various test equipment to an r-f source from any of the three transmitter channels.

PRIMARY POWER FACILITIES

Power is supplied to the Wayne plant by the Jersey Central Power Company. Two independent circuits terminate at the CBS power mat, which is located a short distance from the main transmitter building. Each of these is 4160 volt, 4 wire, 3 phase. Three transformers, each rated at 200 kva, are Y-delta connected to obtain the 2400 volts fed to the transmitter building. This provides a 2400 volt, 3 phase source capable of handling a maximum load of 600 kva.

At the transmitter building the 2400 volt, 3 phase circuit is fed to each of the two RCA modulator-power units. In addition, a bank of general distribution transformers are energized. These furnish both a 120-volt, single phase, and a 208 volt, 3 phase source, used for building lighting and general utility.

Of the two 4160 volt circuits supplied by Jersey Central Power, one is intended as a regular line, the second as an emergency service. Automatic switching gear has been installed at the power mat. In the event of a failure of the regular circuit, the switch gear instantly selects the emergency line. When the regular line has been restored to normal, the switch-back to this circuit is effected by the push of a button located in the transmitter room proper. Indicating lamps are provided at the transmitter building, showing which of the two circuits is in service at a given time.

CONCLUSION

The OWI-CBS international transmitting plant located at Wayne has now been successfully operated for over a year. Stations WOOC and WOOW have regularly transmitted on a schedule averaging twenty hours daily. The "hour-meters" of the two RCA transmitters now read 8,600 each, or a total 50 kw carrier time of approximately 17,200 hours.

The overall performance of the Wayne plant has been in agreement with the original design requirements and little scheduled transmission time has been lost as a result of equipment failure.

[1] A. B. Chamberlain, "CBS International Broadcast Facilities," Proceedings of the IRE, Vol. 30, No. 3, p. 118 (March, 1942).

[2] H. Romander, "New 50 KW CBS International Broadcasters," Electrical Communication, Vol. 21, No. 2, p. 112 (1943).

[3] H. A. Chinn, "Audio and Measuring Facilities for the CBS International Broadcast Station," Electrical Communication, Vol. 21, No. 3, p. 174 (1943).

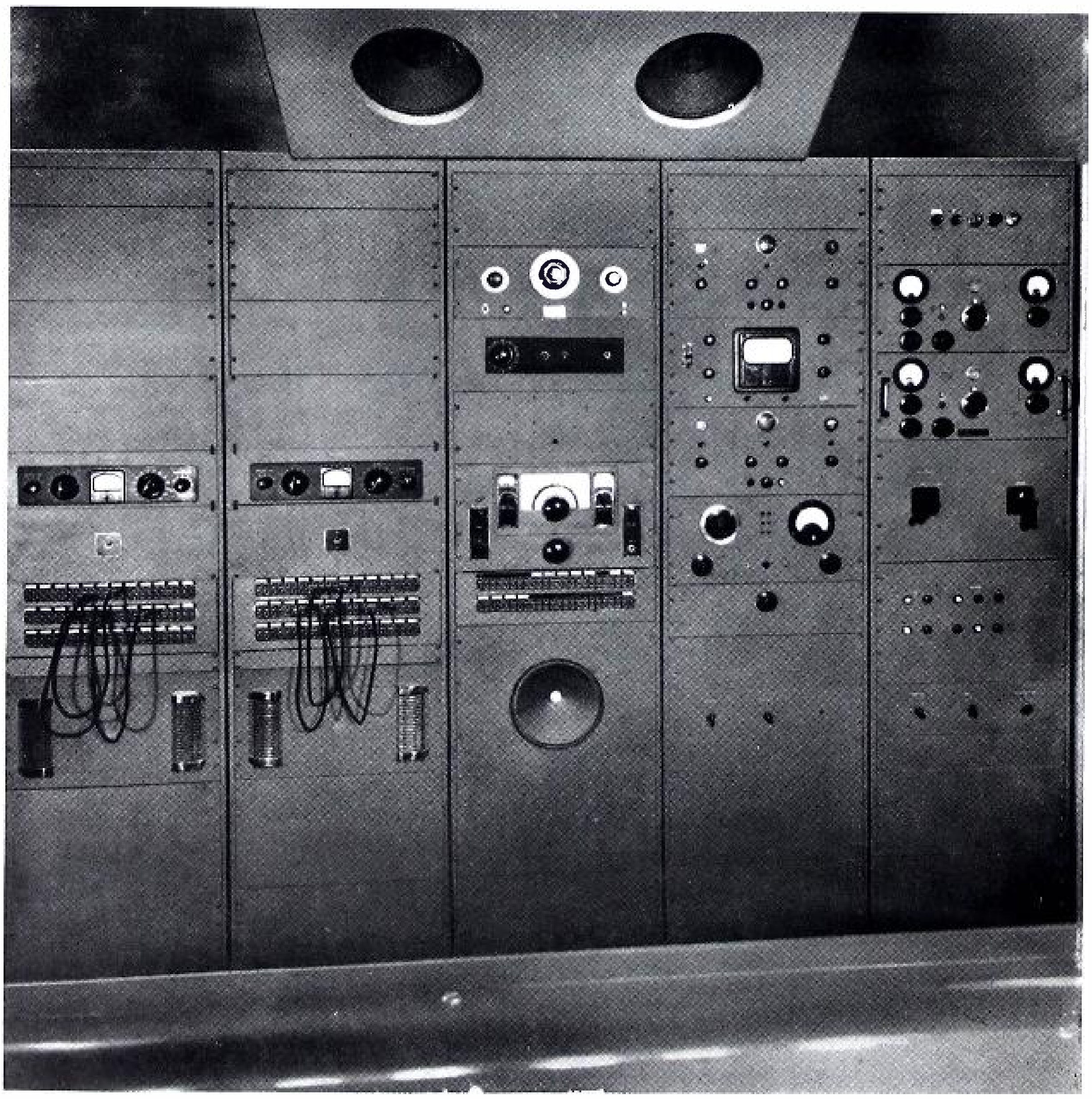


FIG. 9. *Audio and measuring equipment cabinet racks employed at shortwave station WOOC and WOOW. Five racks are shown. Three of these house the audio and the monitoring equipment, and the remaining two are used to mount various measuring equipment and control panels.*

BUY MORE WAR BONDS

ELECTRONIC TELEVISION IS AN RCA DEVELOPMENT

This is the first of a series of advertisements which will show that RCA engineers developed the basic essentials of the electronic television system — *including tubes and circuits.*

RCA built the first all-electronic television transmitters and receivers—the first commercial television station — established the first television relay system — presented the first electronic theatre television — was the first to televise a baseball game, and a Broadway play; and was first to televise from an airplane.

RCA is, and will continue to be, the leader in practical, successful commercial television. You may expect the best of all kinds of television transmitting and receiving equipment from RCA.

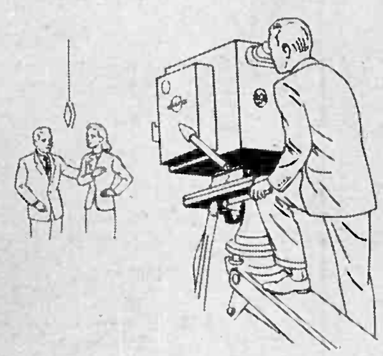
1. THE ICONOSCOPE

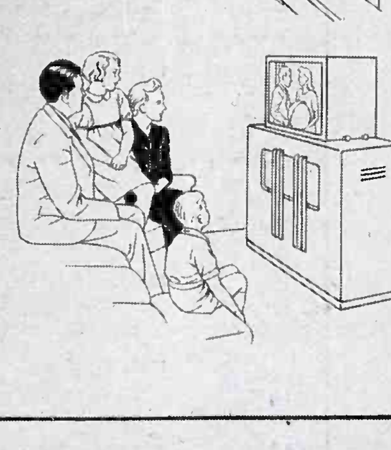
PRACTICAL TELEVISION began when television became all-electronic. ALL-electronic television began with the RCA Iconoscope.

The desirable possibility of displacing mechanical scanners by an all-electronic system was recognized very early. However, a practical electronic television pick-up device required a sensitivity that no ordinary tube possessed.

The Iconoscope, developed by Dr. V. K. Zworykin, Associate Director of RCA Laboratories, was the first electron tube to answer this need. By utilizing the now famous "storage principle," in which energy is stored up between successive scannings, the Iconoscope made electronic television a reality.

Under the direction of Dr. Zworykin, RCA engineers have brought the Iconoscope to its present high degree of perfection.





The Fountainhead of Modern Tube Development Is RCA

RADIO CORPORATION OF AMERICA

RCA VICTOR DIVISION • CAMDEN, NEW JERSEY

In Canada, RCA VICTOR COMPANY LIMITED, Montreal

HOW TO DETERMINE THE AREA AN FM STATION SHOULD SERVE

★

Details of the procedure to be followed in determining the "trade area" and "service area" of an FM station

by JOHN P. TAYLOR
RCA Victor Division

The first steps in planning an FM station are to decide on the type of station to be installed and the frequency for which to apply. When these decisions have been made, the next step is to determine, at least approximately, the area which the station will be required to serve. It is desirable that this be done before an attempt is made to choose a location for the transmitter since, as will be made evident later, the area to be served has an important bearing on the choice of a location.

The method of determining the service area of an FM station is described, in some detail, in the Rules and Regulations of the FCC and should be followed as closely as possible. Two procedures are described: one for the case where there are existing stations (or applications) in the community and another for the case in which the application in question is the first to be filed.

IF THERE ARE EXISTING FM STATIONS IN THE AREA

Rule 3.227 of the FCC states that: "*Stations located in the same city shall have substantially the same service area.*" Therefore, if an application is to be made for an FM broadcast station in a locality where one or more such stations are already operating (or have been granted construction permits), the new application should, as a rule, specify a service area approximately coinciding with that of the existing station or stations. In other words, the proper *service area* for that locality has (presum-

COMMERCIAL FM STATIONS

Call	State and City	Licensee	Frequency (*megs.*)	Coverage (*sq. mi.*)
	CALIFORNIA			
KHJ-FM	Los Angeles	Don Lee Broadcasting System	44.5	6,944
KTLO	*Los Angeles	M-G-M Studios	46.1	7,000
	CONNECTICUT			
WTIC-FM	Hartford	The Travelers B/C Service Corp.	45.3	6,100
WDRC-FM	Hartford	WDRC, Incorporated	46.5	6,100
	ILLINOIS			
WBBM-FM	Chicago	Columbia Broadcasting System	46.7	10,800
WDLM	Chicago	Moody Bible Institute of Chicago	47.5	10,800
WGNB	Chicago	WGN, Incorporated	45.9	10,800
WEHS	*Chicago	WHFC, Incorporated	48.3	10,800
WWZR	Chicago	Zenith Radio Corporation	45.1	10,800
	INDIANA			
WMLL	Evansville	Evansville On The Air, Inc.	44.5	8,400
WOWO-FM	Fort Wayne	Westinghouse Radio Stations, Inc.	44.9	6,100
WABW	*Indianapolis	Associated Broadcasters, Inc.	47.3	8,400
WSBF	South Bend	South Bend Tribune	47.1	4,300
	LOUISIANA			
WBRL	Baton Rouge	Baton Rouge Broadcasting Co.	44.5	8,100
	MASSACHUSETTS			
WBZ-FM	Boston	Westinghouse Radio Stations, Inc.	46.7	6,700
WMTW	Boston	The Yankee Network, Inc.	43.9	31,000
WGTR	Boston	The Yankee Network, Inc.	44.3	19,230
WBZA-FM	Springfield	Westinghouse Radio Stations, Inc.	48.1	2,500
WTAG-FM	Worcester	Worcester Telegram Pub. Co.	46.1	4,465
	MICHIGAN			
WLOU	Detroit	John Lord Booth	44.9	6,732
WENA	Detroit	Evening News Association	44.5	6,820
	MISSOURI			
KOZY	Kansas City	Commercial Radio Equipment Co.	44.9	4,410
KMBC-FM	Kansas City	Midland Broadcasting Company	46.5	6,700
	NEW JERSEY			
WFMN	Alpine	Edwin H. Armstrong	43.1	15,610
WAAW	*Jersey City	Bremer Broadcasting Corporation	49.5	6,200
	NEW YORK			
WNBF-FM	Binghamton	Wylie B. Jones Adv. Agency	44.9	6,500
WBAM	New York	Bamberger Broadcasting Service	47.1	8,500
WNYC-FM	New York	City of New York Municipal Broadcasting System	43.9	3,900
WABC-FM	New York	Columbia Broadcasting System	46.7	14,150
WQXQ	New York	Interstate Broadcasting Co., Inc.	45.9	8,500
WHNF	New York	Marcus Loew Booking Agency	46.3	8,500
WABF	New York	Metropolitan Television, Inc.	47.5	8,500
WGYN	New York	Muzak Radio Broadcasting Station, Inc.	44.7	8,500
WEAF-FM	New York	National Broadcasting Co., Inc.	45.1	8,500
WFGG	*New York	Wm. G. H. Finch	45.5	8,500
WHFM	Rochester	Stromberg-Carlson Company	45.1	3,200
WHEF	Rochester	WHEC, Incorporated	44.7	3,200
WBCA	Schenectady	Capitol Broadcasting Co., Inc.	44.7	6,589
WGFM	Schenectady	General Electric Company	48.5	6,600
	NORTH CAROLINA			
WMIT	Winston-Salem	Gordon Gray	44.1	69,400
	OHIO			
WELD	Columbus	WBNS, Incorporated	44.5	12,400
	PENNSYLVANIA			
WPEN-FM	Philadelphia	Wm. Penn Broadcasting Company	47.3	9,352
WIP-FM	Philadelphia	Pennsylvania Broadcasting Co.	44.7	9,300
WLBG	*Philadelphia	Seaboard Radio Broadcasting Corp.	46.5	9,300
WCAU-FM	Philadelphia	WCAU Broadcasting Company	46.9	9,300
KYW-FM	Philadelphia	Westinghouse Radio Stations, Inc.	45.7	9,300
WFIL-FM	Philadelphia	WFIL Broadcasting Company	45.3	9,300
KDKA-FM	Pittsburgh	Westinghouse Radio Stations, Inc.	47.5	8,400
WTNT	Pittsburgh	WWSW, Incorporated	44.7	8,400
	TENNESSEE			
WSM-FM	Nashville	National Life & Accident Insurance Company	44.7	16,000
	UTAH			
KSL-FM	*Salt Lake City	Radio Service Corp. of Utah	44.7	700
	WISCONSIN			
WMFM	Milwaukee	The Journal Company	45.5	8,500
WDUL	Superior	Head of the Lakes Broadcasting Company	44.5	407

*—Construction Permit only.

FIG. 1. *Commercial FM stations as of February 1, 1945. Note that stations in the same area are assigned the same "Coverage" area.*

ably) been determined by the previous application. In this case, the new applicant should consult the files of the FCC to find out what this area is, and (unless there are good reasons for doing otherwise) use it in planning the station as outlined in the following sections (Figure 1).

It should be noted that while this "freezes" the area to be served by stations in a given locality, it does not necessarily result in the use of the same power by these stations. Because of differences in antenna elevation and antenna gain, the power required by two stations serving the same area may be quite different. This will be true particularly in larger cities where one station may be successful in locating a tall building while late-comers may have to use much lower buildings.

IF THE APPLICATION IS THE FIRST IN THE AREA

If there has been no previous application for an FM broadcast station in the area, then the proper *service area* must be determined by the method outlined by the FCC in the release entitled, "Concerning Applications for High Frequency Broadcast Stations" (Form 43759). In brief, this method consists of two steps. The first step is to make up a *composite* map on which are drawn the boundaries of the *trade area* as given by several authorities. The second step is to draw on this map an *average boundary* which is then considered as the area which the station should (at least theoretically) be planned to serve. The procedure is outlined in detail below.

OBTAINING THE "TRADE AREA" MAPS

There are a number of economic authorities who produce maps showing "retail shopping" or "trade" areas which may be used for this purpose. The FCC rules mention four of these, as follows:

1. RETAIL SHOPPING AREAS (J. Walter Thompson)
   Available from American Map Co., 16 East 42nd Street, New York City—also contained in Market Data Handbook of U. S. Domestic Commerce Service, No. 30, obtainable from Supt. of Documents, Government Printing Office, Washington, D. C.

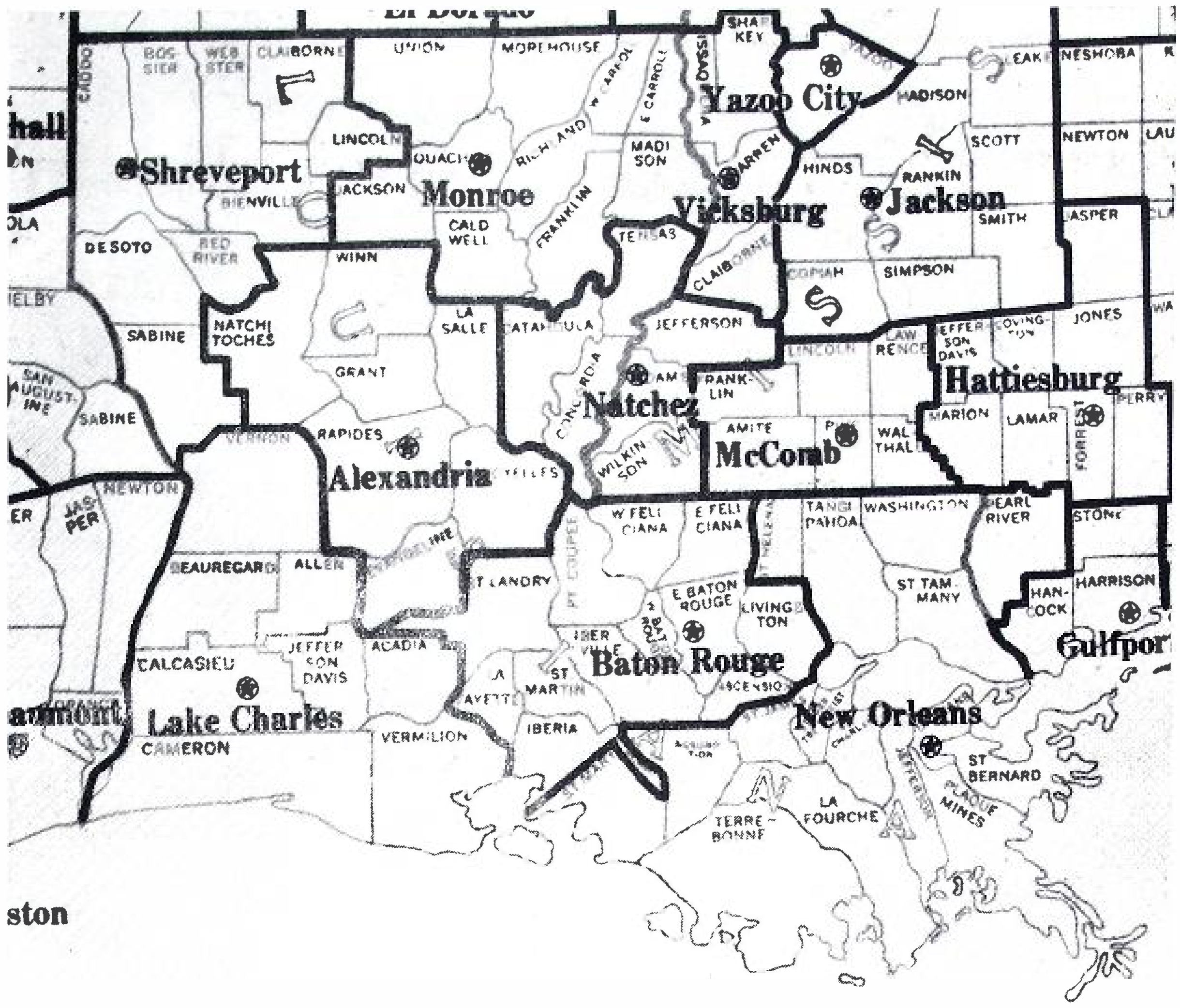


FIG. 2. *A section of one of the "Trade Area" maps suggested for use in determining the service areas of FM stations. The "Trade Areas" surrounding "Principal Cities" are shown by heavy lines.*

FIG. 3. *Map of the State of Louisiana on which has been plotted the boundary of the Baton Rouge "Trade Area" as shown by the map in Figure 2.*

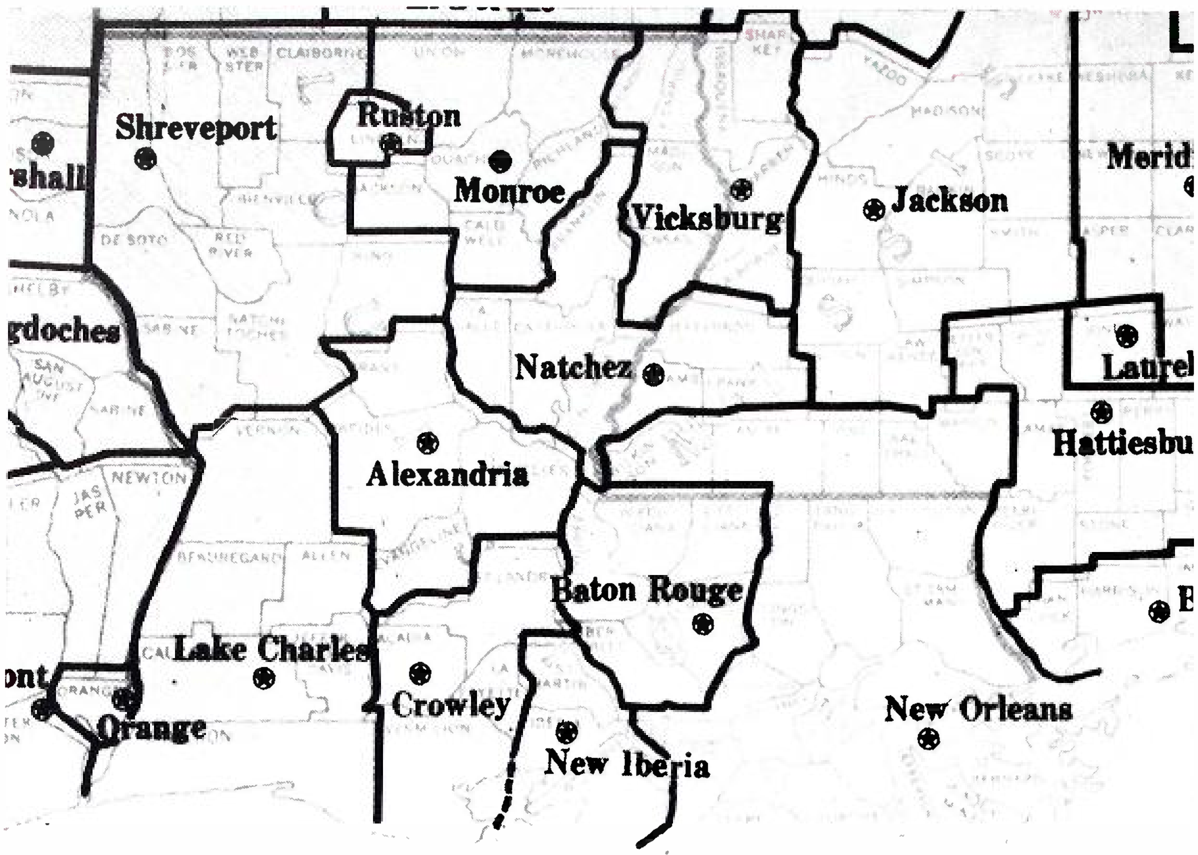


FIG. 4. *A section of another "Trade Area" map for the same general area. It will be noted that the boundaries of the individual "Trade Areas" vary somewhat from those shown in Figure 1.*

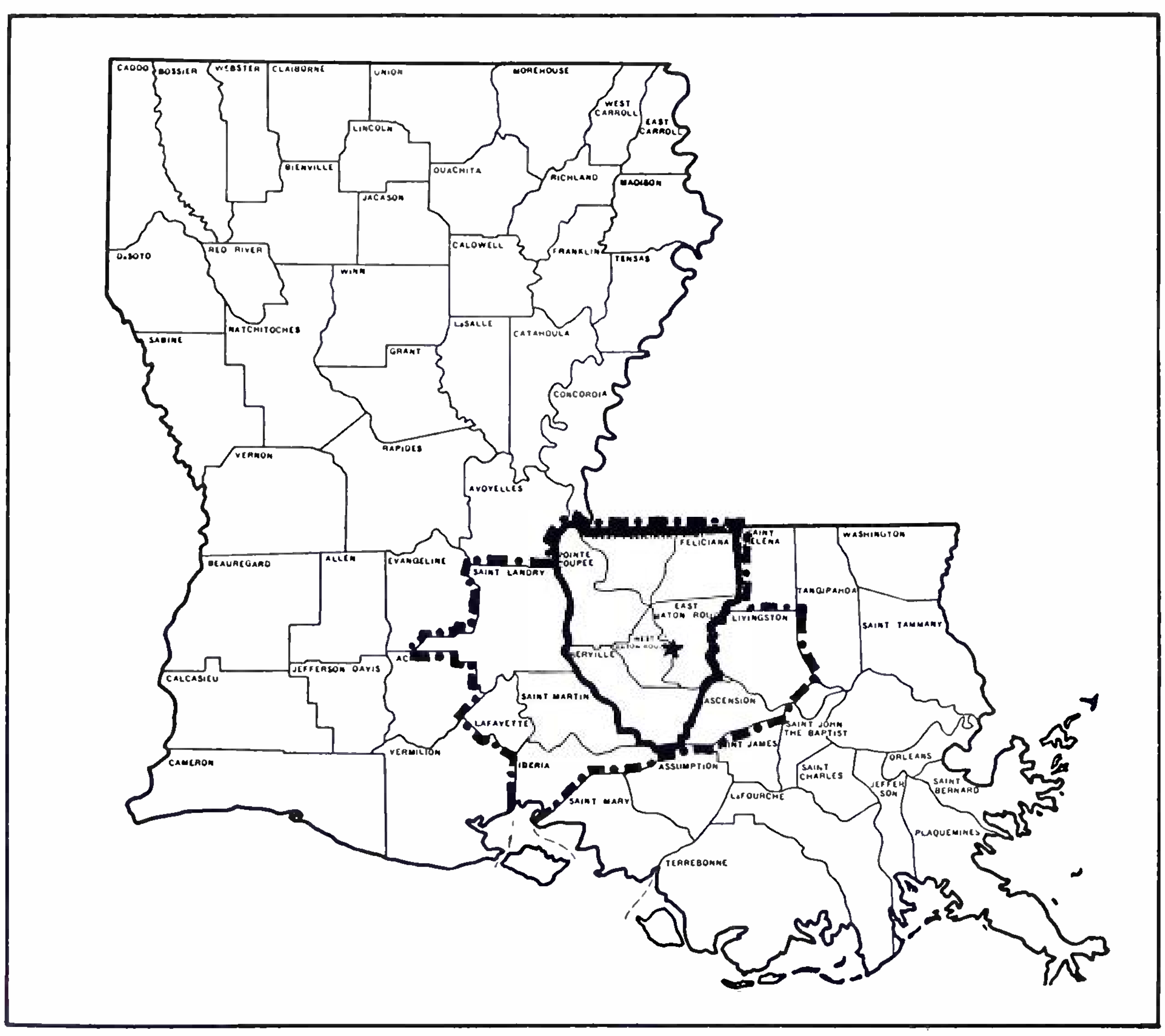


FIG. 5. *Map of the State of Louisiana on which have been plotted the boundaries of the Baton Rouge "Trade Area" as shown by the maps of Figure 2 and Figure 4.*

2. CONSUMER TRADING AREAS (Hearst Magazines, Inc.)
   Available from Hearst Magazines, Inc., Marketing Divisions, 57th and 8th Avenue, New York City—also contained in Market Data Handbook. (See 1, above.)

3. TRADING AREAS (Rand McNally Map Co.)
   Available from Rand McNally Map Co., 536 South Clark Street, Chicago, Illinois.

4. FOUR-COLOR RETAIL TRADING AREA MAP (Hagstrom Map Co.)
   Available from Hagstrom Map Co., 20 Vessey Street, New York City.

The FCC rules also state that other sources of information may be used when available.

USING THE MAPS

The method of using the maps in determining a particular service area can be best shown by a specific example. The example used will be that of a *basic trade area* station located at Baton Rouge, La. Figure 2 shows a part of one of the trade area maps listed above. As the first step, the trade area shown on this map for Baton Rouge is transposed to a map of the State of Louisiana as illustrated in Figure 3. In Figure 4 is shown a part of another of the trade area maps mentioned above. It will be noted that on this map the trade area indicated for Baton Rouge is somewhat different from that shown in Figure 2. This area, therefore, is also plotted on the State map, as illustrated in Figure 5. This same procedure is followed with each of the other two maps until the areas outlined on all four have been noted on the one map as shown in Figure 6. Since most of the mapping authorities follow county lines in delineating the trade areas, this is not hard to do. After the four boundary lines have been drawn in this way, a sort of *average* boundary can be drawn by simple inspection. The best way to do this is by placing a piece of tracing paper over Figure 6 and sketching in the boundary. The result will have the appearance of the heavy line of Figure 7.

It is desirable, of course, that the boundary be nearly circular, so that the required coverage pattern can be obtained with a standard antenna. In the case of WBRL, it was found that a circle of 50 mile radius was a satisfactory *average.* The area enclosed within the boundary drawn in this manner is the area which, by the FCC's rules, the FM station should provide with service. Stated in another way, the 50-microvolt/meter contour of the station (which is the boundary of the area receiving the required minimum signal) should coincide as nearly as possible with the *average* trade area boundary as determined by the above procedure.

IF APPLICATION IS FOR "LIMITED TRADE AREA" STATION

The method of determining trade area as above described applies directly only to stations of the *basic trade area* type. In the case of limited trade area stations, it is also necessary to establish a *service area.* For this purpose, the FCC suggests the Hagstrom Four-Color Retail Trading Area Map mentioned above. This particular map shows the shopping areas for smaller cities and towns as well as *principal cities* and is, therefore, particularly useful for this purpose. In many cases, it will be possible to supplement this with information from other sources, particularly those with direct local contact.

OTHER CLASSES OF STATIONS

For stations designed to cover *large rural areas.* the criterion in the establishment of a *service area* is coverage of the maximum area that is practical, considering the elevations available in the region. This must, in any event, be not less than 15,000 square miles. In such cases, the *service area* map will usually be left for determination after the site, antenna, and power have been decided on.

For stations designed to cover *unusual areas,* the service area will also probably be determined by practical transmitting considerations, together with, as a rule, data or information to show the need for special consideration.

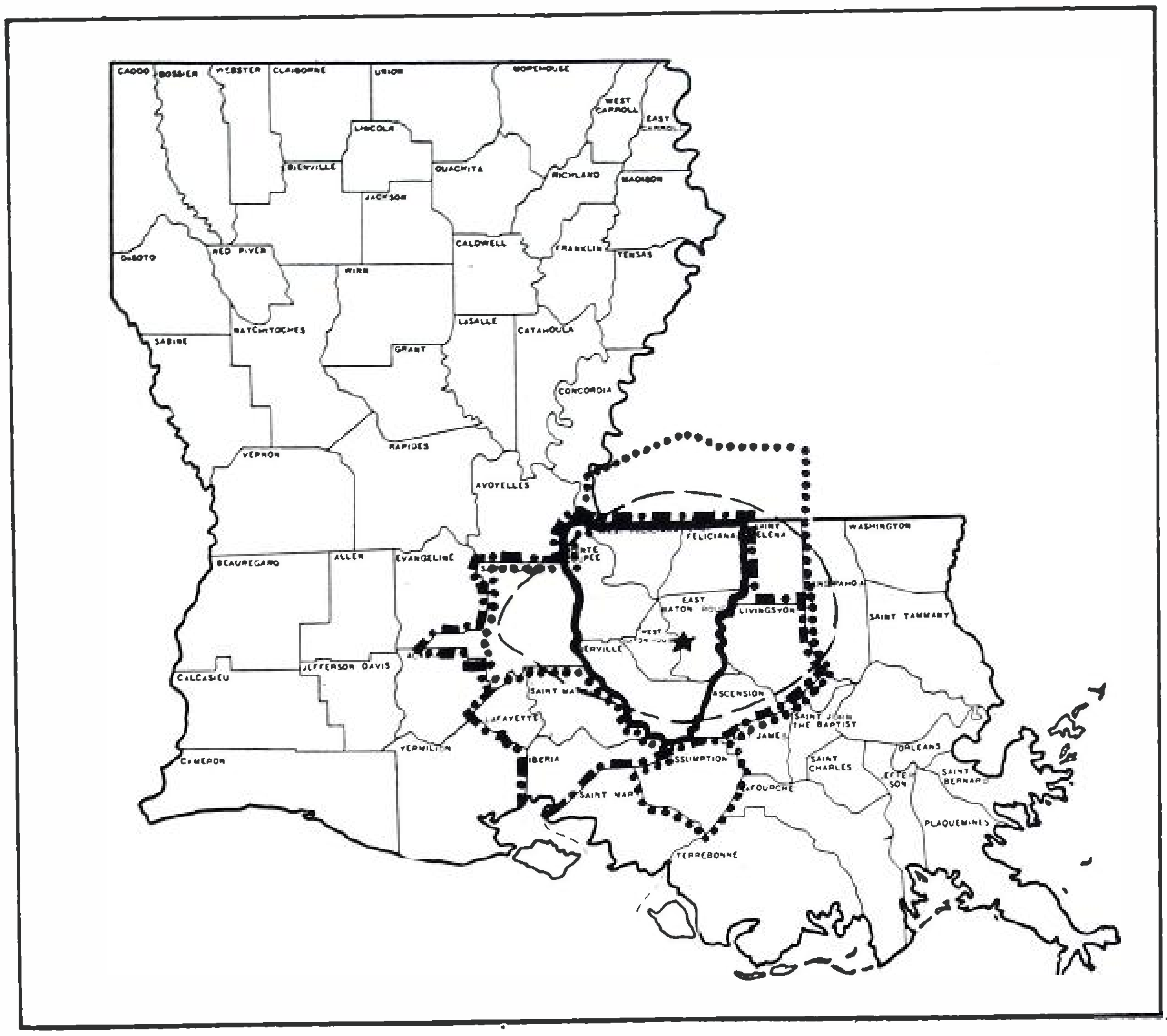


FIG. 6. *The same map after the boundaries of the Baton Rouge "Trade Area" as given by the form authorities (mentioned in the text) have been plotted.*

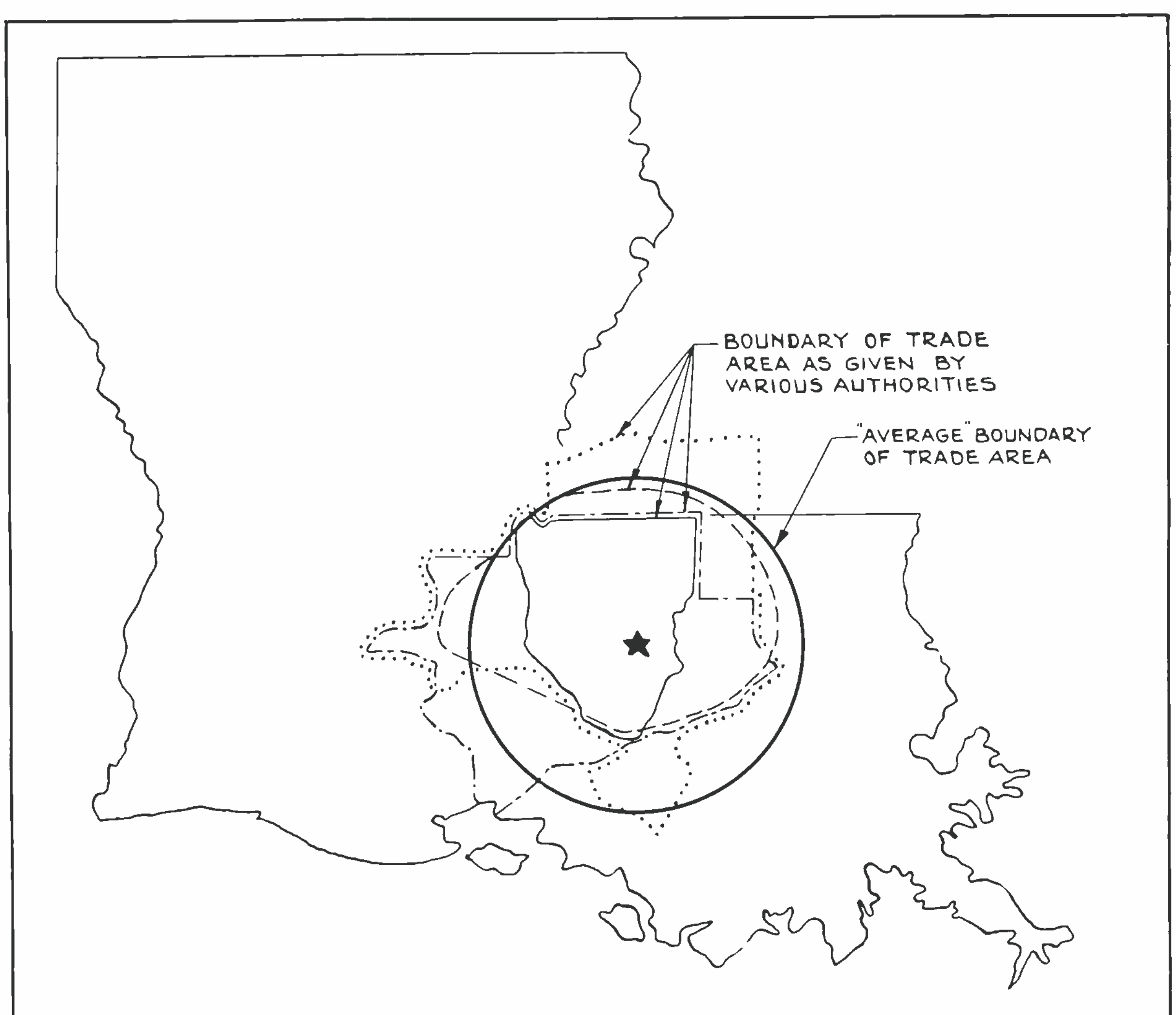
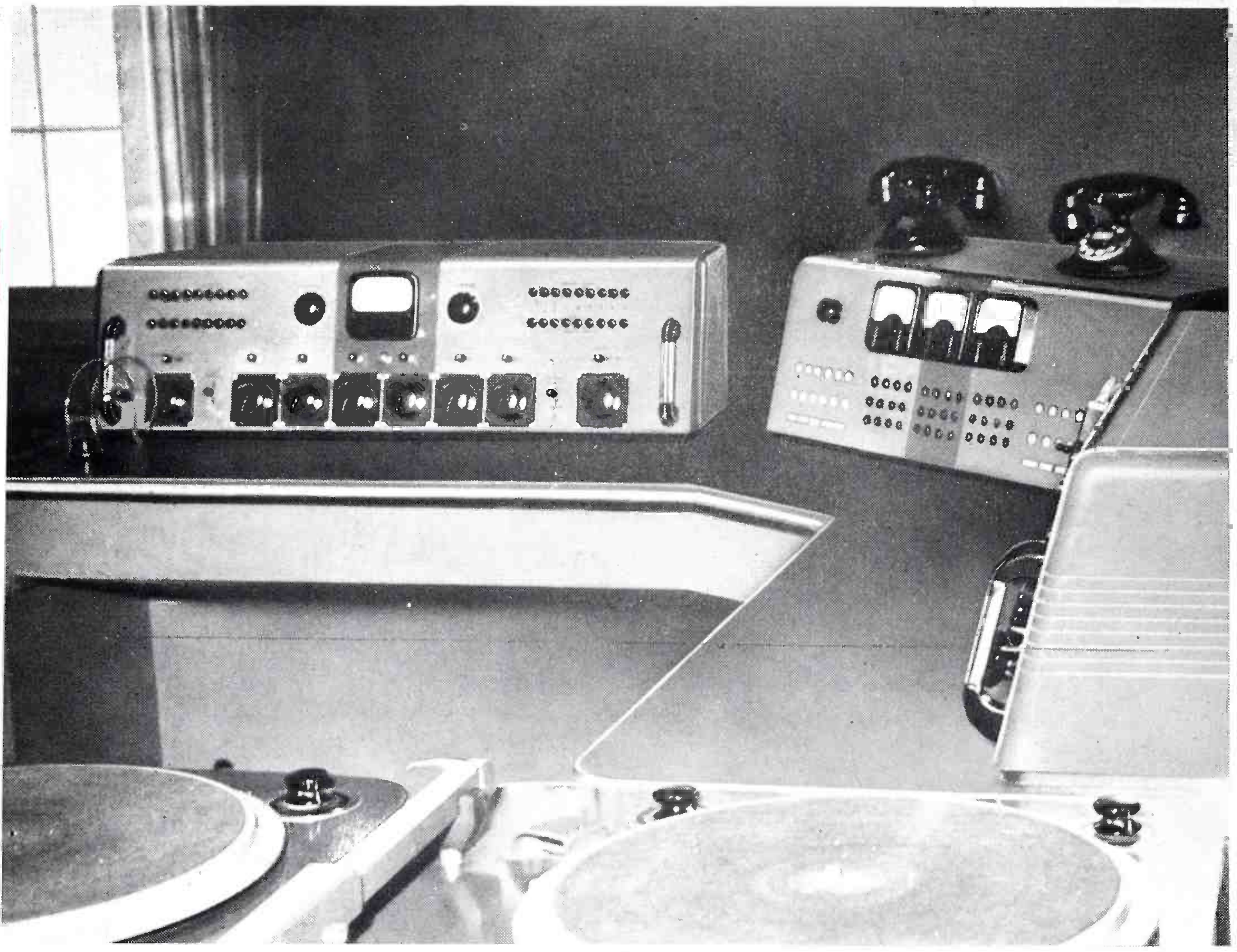


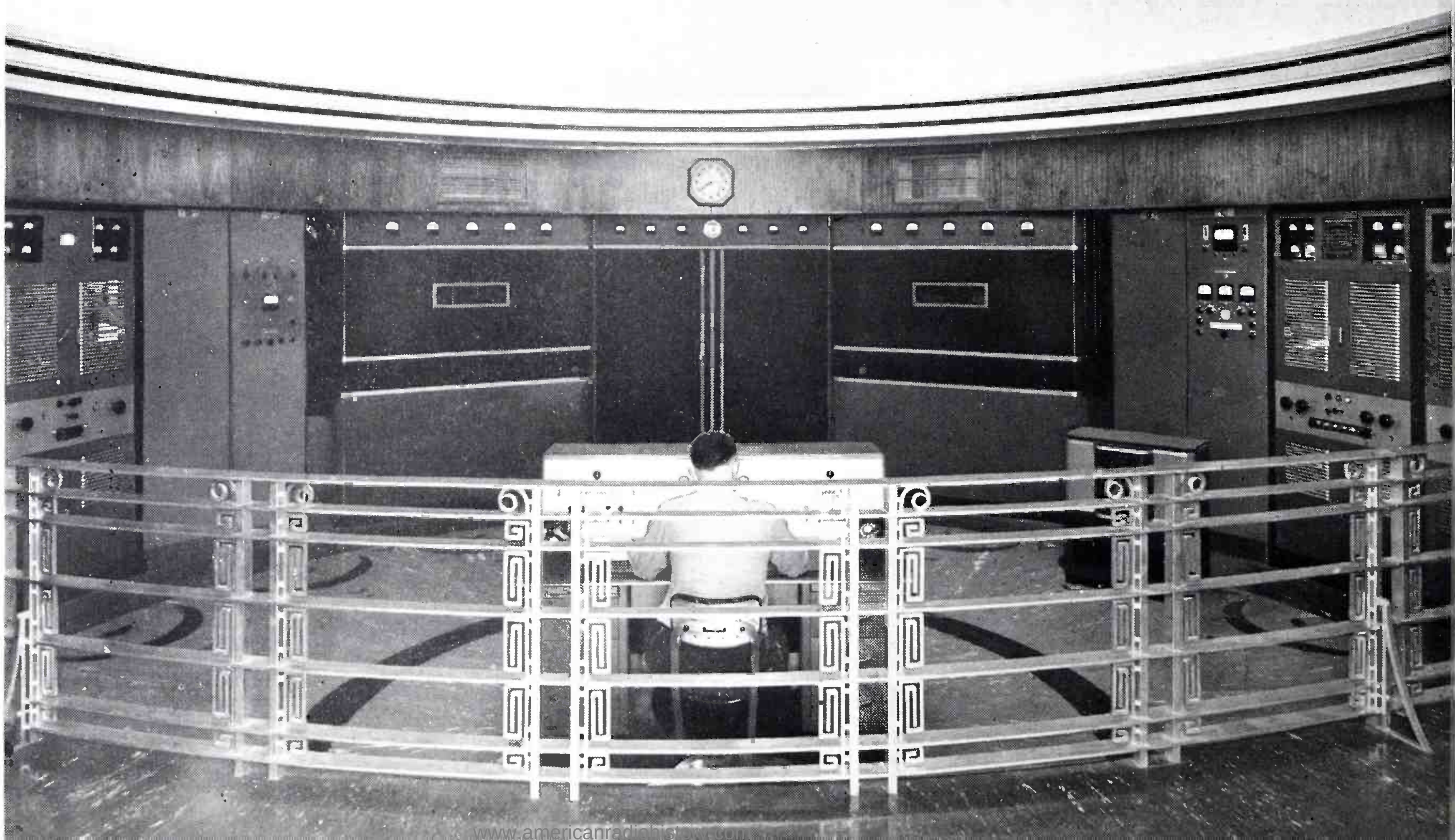
FIG. 7. *Outline map made by tracing the important boundaries of the map in Figure 6 and drawing in a curve corresponding approximately to the average of the four trade area boundaries. This "average boundary" is the area which the station should be designed to serve.*

FM Station WSBF uses from



Left — The control room in the studios shared by FM station WSBF and AM station WSBT. Two RCA 76-B2 Consolettes handle the output of two studios. A master control console (center) provides monitoring and switching of outgoing lines to the two transmitters. The RCA 70-C Turntables may be seen in the foreground. In the studios RCA 44-BX Microphones are used.

Below—The FM-10-A Transmitter at WSBF is installed in the center of the operating room. This 10 KW Transmitter, presently operated at reduced power, will resume operation at full-power rating as soon as wartime restrictions are lifted. To the left and right of the FM transmitter are racks containing the AM and FM monitors; and beyond them, at either end, are the main and standby transmitters of WSBT.



RCA Equipment Microphone to Antenna

WSBF, the FM station of the South Bend Tribune, uses RCA equipment throughout. In the studios are RCA 44-BX Microphones; in the control room are RCA 70-C Turntables, RCA 76-B Consolettes and a special RCA-built master control console. At the transmitter building are an RCA FM-10-A Transmitter and RCA frequency and modulation monitors. The antenna is an RCA-developed four-bay turnstile using concentric feeders.

WSBF is a sister station of WSBT, the AM station operated by the South Bend Tribune. It is interesting to note that WSBT, like hundreds of other AM stations is also completely RCA equipped. Operators of AM stations know the meaning of "RCA all the way." And they know that in RCA FM equipment they will find the same dependability and the same advanced design features that they have come to expect in RCA AM equipment.

Operators of both AM and FM stations—and station applicants—can make reservations right now for early delivery of RCA postwar broadcast equipment. For information on our Broadcast Equipment Priority Plan write Broadcast Equipment Section, Radio Corporation of America, Camden, N. J.

BUY WAR BONDS

RADIO CORPORATION OF AMERICA

RCA VICTOR DIVISION • CAMDEN, N. J.

In Canada, RCA VICTOR COMPANY LIMITED, Montreal

Below—The transmitter building and antenna system of the South Bend Tribune's dual installation. This building houses the 10 KW FM Transmitter of WSBF, the 1 KW AM Transmitter of WSBT, an auxiliary AM transmitter, audio and monitoring equipment for both AM and FM systems and necessary maintenance facilities. The 4-bay turnstile of WSBF is mounted on the top of one of the towers of WSBT's 3-tower directional array.

HOW TO DETERMINE THE REQUIRED TRANSMITTER POWER OF AN FM STATION

★

Method of calculating the transmitter power required to provide coverage of a specified service area when the antenna elevation and gain are known

by JOHN P. TAYLOR
RCA Victor Division

The regulations of the Federal Communications Commission state, in effect, that the actual operating power of an FM station must be that power which will provide a signal of 50 microvolt/meter to an area which coincides as closely as possible with the *service area* as determined by the method previously described ("How to Determine the Required 'Service Area' of an FM Station"). For example, if the *service area* is roughly bounded by a circle having a radius of 40 miles, then the transmitter power must be such that the 50-microvolt contour line is as nearly as possible a circle with a radius of 40 miles (Figure 1).

If the power required to do this comes out to be 3215 watts then that is the power at which the transmitter must be operated. As a result, FM operating powers are, in general, odd numbers rather than the round figures encountered in AM broadcasting. Also, they do not as a rule coincide with the maximum capability of the transmitter which is installed (since transmitters are manufactured in a relatively few power categories, whereas there will be almost as many operating powers as there are stations).

The FCC when granting an FM station construction permit does not specify the operating power, but instead specifies a *service area* (in square miles) with the understanding that the proper power to cover it will be used. However, one question on the application form requires that the proposed operating power be specified. Moreover, it is of course necessary to know this power, at least approximately, in planning the installation and deciding on the type and power of the transmitter and accompanying equipment. The calculation of operating power, therefore, is a necessary and important step in the overall planning of an FM station. Unfortunately, it is a rather complicated procedure (particularly in cases of rugged terrain) and one which will ordinarily have to be done by an engineer who has had allocation experience. But, whether or not a consultant is to make the final computations, it is likely that the station manager and engineer will want to understand the procedure in order to make their preliminary plans in an intelligent way.

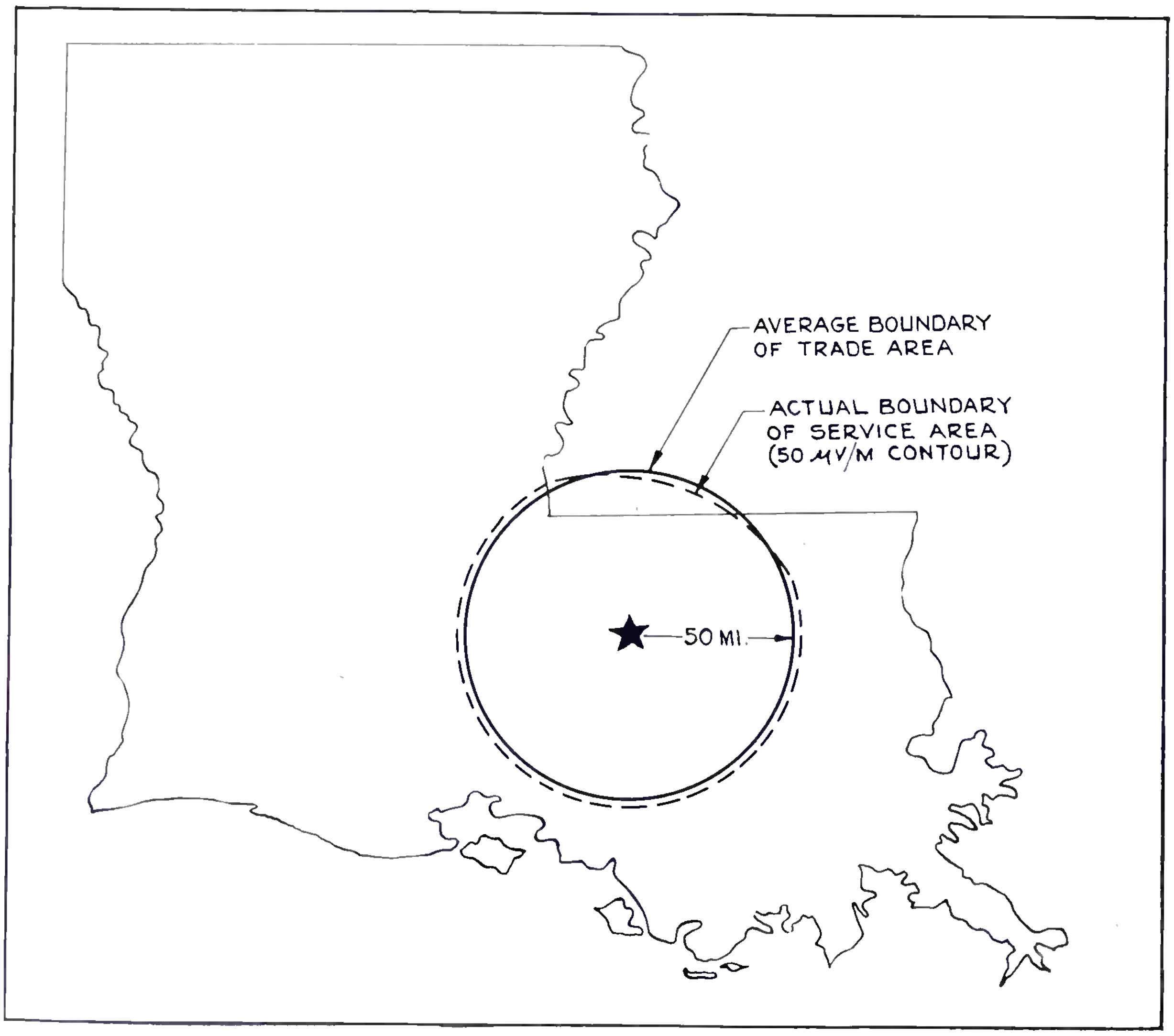


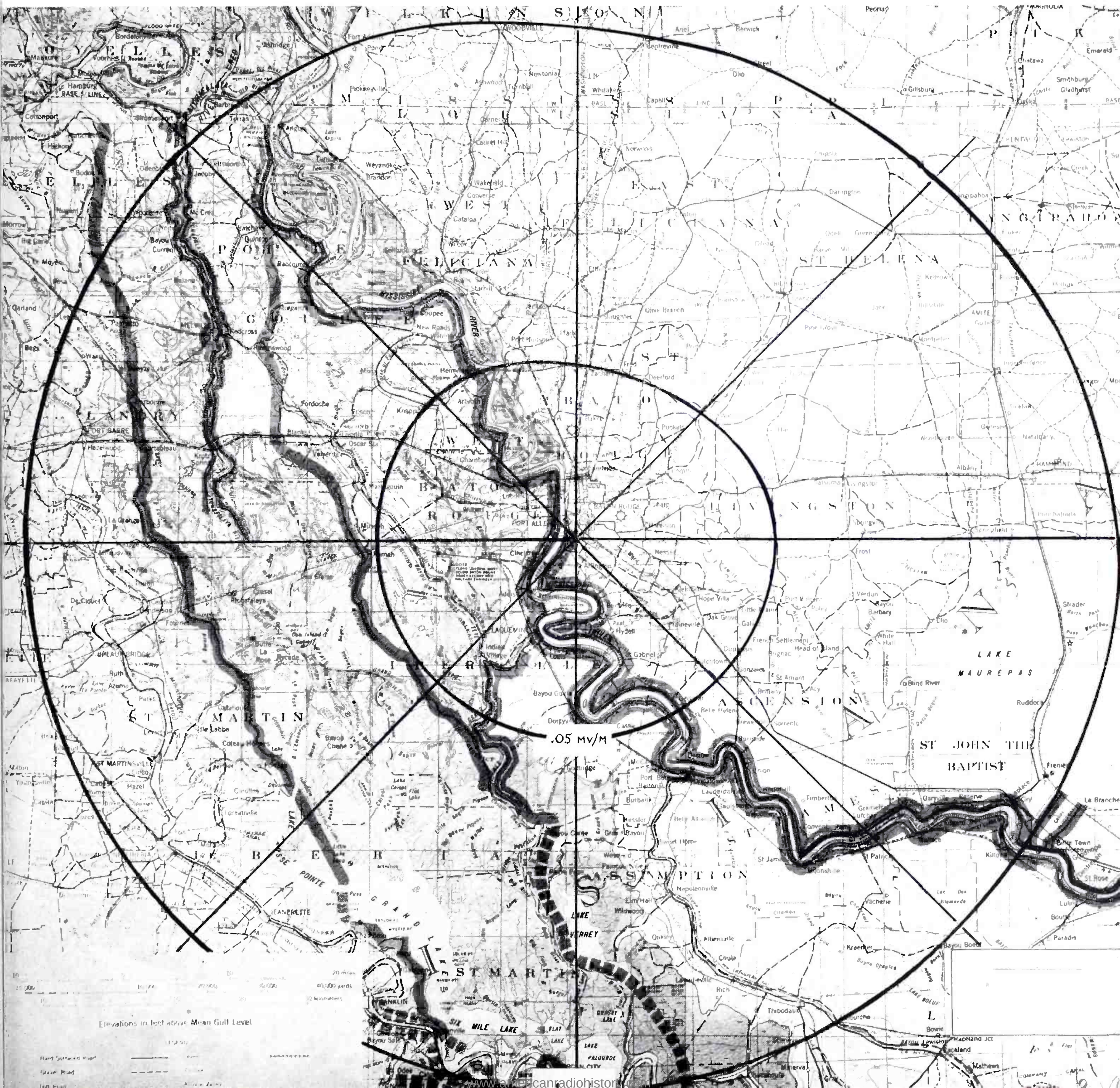
FIG. 1. ***The power and location of an FM station should be such that the 50 microvolt contour coincides as nearly as possible with the "service area."***

The approximate area to be covered, the location of the transmitter, the height of the antenna, and the power gain of the antenna will have a great effect on the power required and, therefore, must be known before the power can be calculated. Assuming that this information is available, what is the method to be followed in calculating required operating power? The answer is to be found in the Standards of Good Engineering Practice (FCC Form 41831) Section I, and the discussion which follows is essentially an elaboration of the material published therein.

AN EXAMPLE

In order to help those unacquainted with allocation procedures to understand and visualize the steps in calculating power, it will be best to use a specific station installation as an example. The station in this case is WBRL, the FM broadcast station of the Baton Rouge Broadcasting Company (WJBO) at Baton Rouge, La. The various maps and figures used as examples here are reproduced from exhibits filed with the application of this station which was granted a CP in 1941 and which has now been on the air more than four years.

FIG. 2. *On a topographic map of the area, the transmitter site is carefully plotted and eight radials (spaced 45° apart) are drawn. Contour levels along these radials are tabulated and plotted as shown in Figure 3.*



There is, of course, considerable danger in using a specific example since local conditions may make any particular case quite different from the example. However, the advantages of following one study through the consecutive steps will outweigh possible disadvantages, providing the reader keeps in mind that modifications of the method are sometimes required.

THE STARTING DATA

As already noted, it is necessary to know the following:

(a) the area to be served

(b) the location and height of the antenna

(c) the gain of the antenna.

Since WBRL was to be a *trade area* station, the first step was to draw the *composite* map showing the trade area as given by the various authorities. This is reproduced in Figure 1. The heavy solid line is a sort of *average boundary* which is considered to be the approximate area which the station should serve. In this particular case this area is a circle with a radius of about 50 miles. This is part (a) of the required starting data. Next the site: since the 490-foot tower of WJBO (the applicant's AM station) was the highest point in the area, it was decided to locate the FM station at the AM site. This gives additional needed data, viz., (b) the antenna location and height (i.e., 490 feet plus ground level at the site of 20 feet, giving an overall elevation of 510 feet). After some consideration a six-layer square-loop antenna was decided on. This antenna was assumed to have a power gain of 6.0 times, which gives the final part (c) of the starting information.

OBTAINING TOPOGRAPHIC MAPS

The next step is to obtain a topographic map of the area to be served, that is, a map which shows the actual contours of elevation over the area. The best maps of this kind are the Quadrangle Charts prepared by the U. S. Geodetic Survey Service. These can be obtained from the Geological Survey, U. S. Department of the Interior, Washington, D. C. and in many localities from city, county, or state engineers' offices. Unfortunately, the whole United States has not been thus mapped as yet and there will be many places where they are, therefore, not available. In such areas other maps equally good may often be found. These are the topographic maps prepared by waterway, flood control, soil conservation and other similar public authorities. Another type of map which the FCC mentions is the Aeronautical Charts, available from the Civil Aeronautics Authority, Washington, D. C. (also at many airports). These show only the 1000-foot interval contours, which generally is not considered sufficient. However, they may be acceptable where nothing else is available. In the case of WBRL a map prepared for a Mississippi River flood control project was found to give the desired contours for most of the area concerned.

DRAWING THE RADIALS

On the topographic map selected the site of the station is carefully plotted and from this point eight radials, spaced approximately 45° apart, are drawn. Figure 2 shows the WBRL map with these radials drawn. (The 1000 microvolt and 50 microvolt contours shown on this map should be disregarded for the moment as they are drawn on later.)

By following along one of the radials and noting the distance at which it crosses the various elevation contours a "profile graph" of elevation vs. distance can be drawn as shown in Figure 3. This is done for each radial in turn. Usually, the complete set of graphs is plotted as shown in Figure 3. These profile graphs indicate at a glance the nature of the terrain in each of the eight directions from the station and they form the basis for estimating the signal range in these directions.

OTHER SOURCES OF ELEVATION DATA

It will be noted that the map illustrated in Figure 2 does not show contour lines all the way to the edge of the area in several directions. This was because such data was not available for that part of the area—a condition that will probably be met with frequently. In such cases the proper procedure is to use the next best information as to elevation. There are many such secondary sources, most of them of a local nature. In most cases there will be at least a few benchmarks available. Occasionally it will be found that maps showing location and elevation of wells are available in county offices. In other cases surveyors may be able to furnish useful information. Such data is collected, tabulated, and where necessary interpolated to provide as many points as possible along each radial. In Figure 3 the parts of the "profiles" determined by this means are shown dotted.

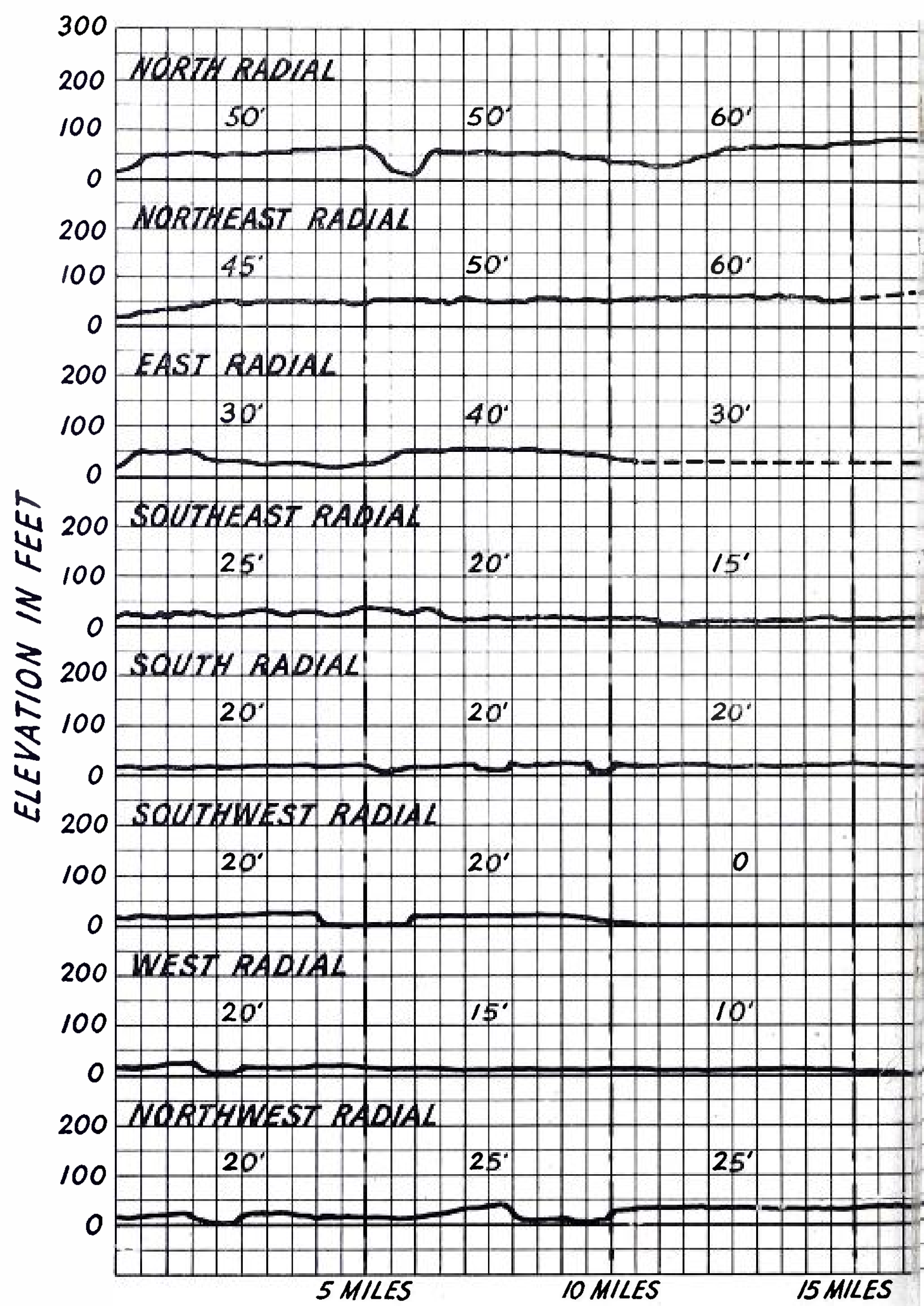


FIG. 3. *Elevations in each of eight directions are plotted as shown here. Average elevations for each five mile sector are determined by "counting squares" or planimetering. Data is tabulated as shown in Table No. 1.*

DIVIDING INTO SECTORS

Assuming that the profiles have all been drawn, the next step is to divide these into sectors; after which the average elevation of each sector is determined and used in figuring coverage. The division into sectors is by miles along the radial. Thus, in Figure 3, 0 to 5 miles is one sector, 5 to 10 miles another, etc. There should be at least ten sectors on each radial between the site and the proposed 50 microvolt line. Since the distance for the expected WBRL coverage was 50 miles, each sector was made five miles long. Had this distance been 30 miles, each sector would have been three miles. Had it been 65 miles, 13 sectors each of five miles would have been required.

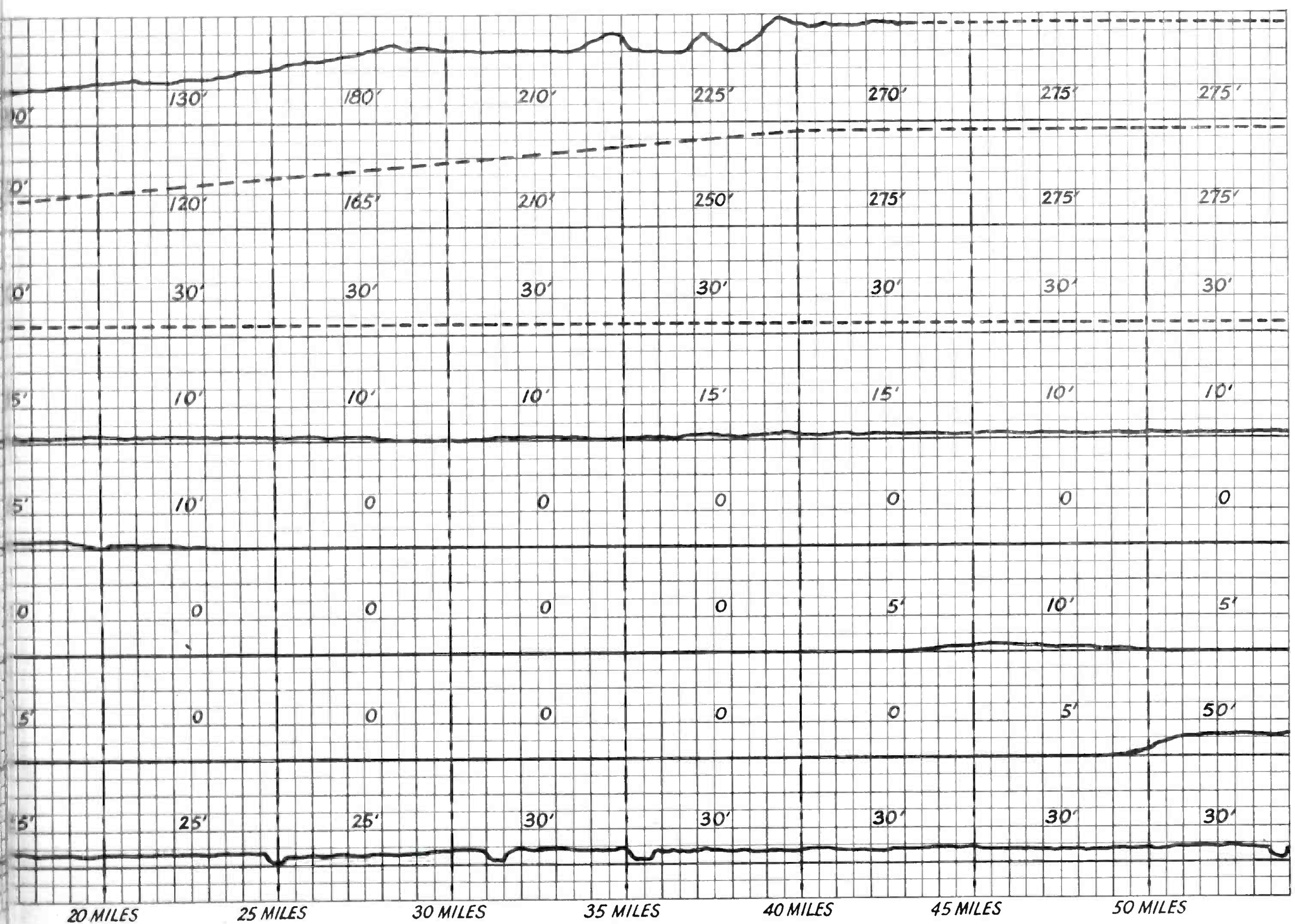
After the profiles have been divided into sectors the elevations throughout each sector should be averaged by counting squares or plainimetering. (In Figure 3, the average elevation of each sector is marked directly on the graph sheet.) These elevations are tabulated as shown in Table No. 1 and this information is used in figuring the coverage in each direction.

DETERMINING COVERAGE FOR A GIVEN POWER

The next step is to assume a certain transmitter power and, from the curves relating power, height and distance, determine the coverage in each of the radial directions. To illustrate, in the WBRL case, a 1 KW transmitter was tentatively planned. From this 1000 watts at the transmitter it was, of course, necessary to subtract the expected transmission line loss. Available tables indicated that 500 feet of 7/8" concentric line would introduce a loss of 1.6 db., or 300 watts. Thus, 700 watts would enter the antenna proper. Multiplying this by the power gain of six (for this type antenna) gave a figure of 4200 watts for the "effective power radiated" if the full power of the transmitter were used. Assume for the moment that it would be.

For elevation there must be used in each instance the figure obtained by subtracting from the antenna elevation (above sea level) the average elevation over the area to the 50 microvolt line. As a start, the "average" over the ten sectors should be used. For WBRL the antenna height was 510 feet. The average elevation along Radial A (on Table 2) was 155 feet. Thus, the relative antenna elevation to be used in entering the curves was 355 feet.

The curves used for this purpose may be either those given in the chart entitled, "Signal Range For High Frequency Broadcast Stations" (which is a part of Annex I of the FCC Standards of Good Engineering Practice, part of which is reproduced in Figure 4) or the set worked out by Mr. R. D. Duncan, Jr. (see "Coverage Curves for FM Antennas"). The latter are derived from the FCC curves, but are spread out for easier reading and



are particularly useful when a turnstile antenna is to be used.

Assuming the FCC curves are to be used, a start is made by noting the point corresponding to 355 feet on the scale at the left (Figure 4). From this point a line is drawn horizontally across the chart until it intersects the slant line corresponding to the "effective power radiated" as calculated above. Since there is no slant line shown for 4.2 KW, the point where the horizontal line intersects the next nearest power category (in this case 5 KW) is marked and from this a vertical line is dropped to the bottom of the chart. This is illustrated by the line marked "A" on Figure 4. The abscissa of the chart is called θ. From the way this chart was drawn it is known that θ varies as the square root of the power, thus:

$$\frac{\theta_{4.2\ Kw}}{\theta_{5\ Kw}} = \sqrt{\frac{4.2}{5.0}}$$

and,

$$\theta_{4.2\ Kw} = .92 \times \theta_{5\ Kw} = .92 \times 800 = 736$$

Using this new value of θ, the chart is re-entered and a vertical line continued upward to the curved line corresponding to the height (in the case illustrated, the 500-foot curve is used since no lower ones are shown). From this point, a line is followed horizontally to the left and the distance read as 47 miles. This whole procedure is shown graphically by the heavy solid line with arrows.

By this means it is determined that the coverage for the assumed power is 47 miles, providing the average elevation is 355 feet. But this was the elevation as averaged over 50 miles. It is necessary, therefore, to check the average elevation over 47 miles and this is where the elevations by sectors become useful. In this particular case it can be seen at a glance that the elevation averaged for 47 miles would not be very different from that for 50 miles and the 47 miles is, therefore, allowed to stand as the final figure. However, had the coverage come out appreciably different (say 40 miles, so that the average elevation was markedly changed) it would have been necessary to enter the curves again and determine a new distance corresponding to the changed elevation. In a very bad case it might be necessary to go back and forth several times, each time reducing the error by cut-and-try until the coverage comes out to correspond closely to the distance represented by the average elevation used.

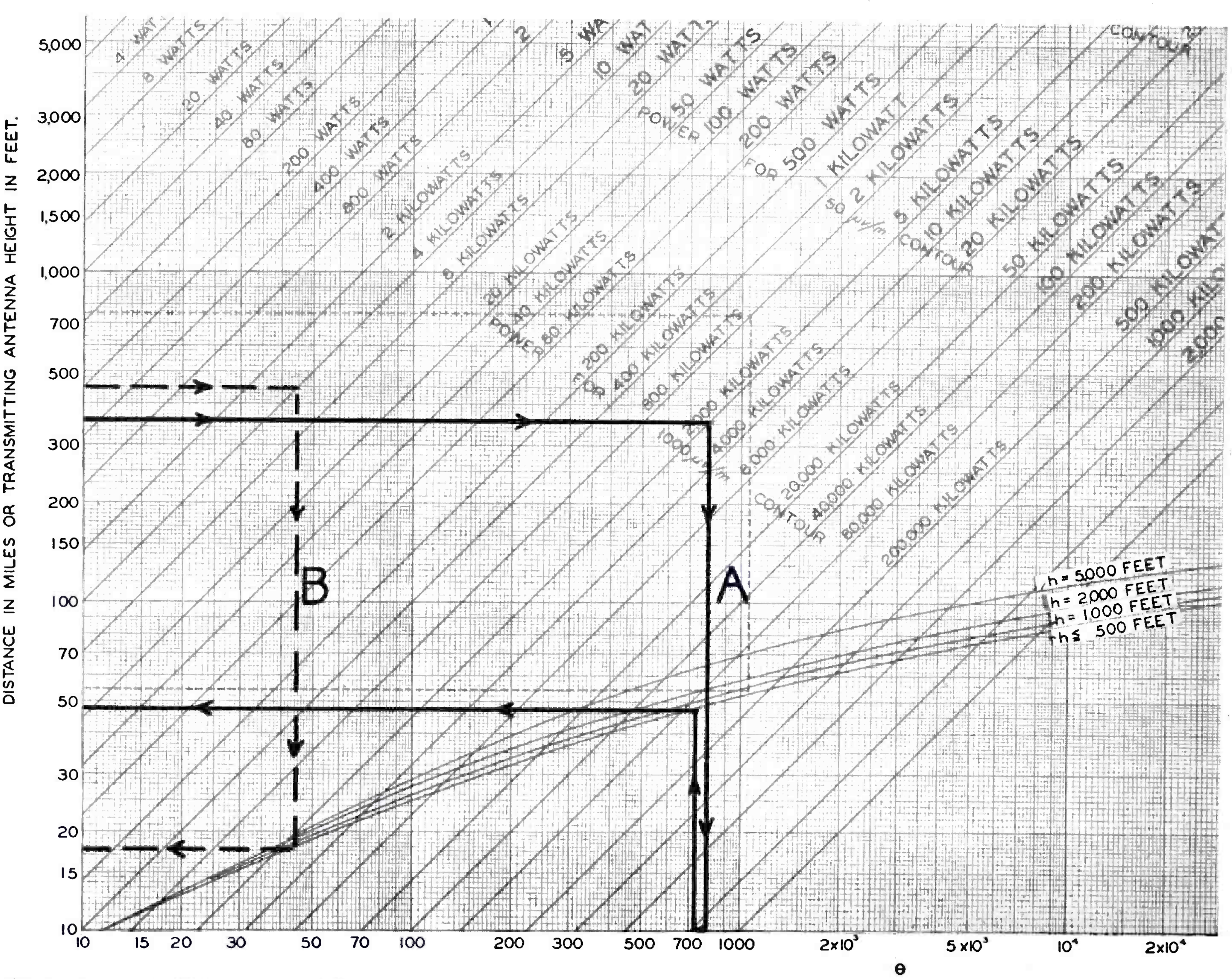


FIG. 4. *Part of the FCC chart "Signal Range for High Frequency Broadcast Stations." Using this chart the distance to the 50 microvolt line for a given elevation and power can be determined as shown by the solid line with arrows (see text). Distance to 1000 microvolt line is determined as shown by the dotted line with arrows.*

COVERAGE IN EIGHT DIRECTIONS

The procedure above outlined for determining the range for a given elevation profile must be carried through for the profile graphs which correspond to each of the eight radials. This data is collected and tabulated as shown in Table No. 2. After this has been done, the same procedure is followed in determining the distance to the 1-millivolt/meter contour. In this case, however, the markings "Power For 1000 uv/m Contour" are followed. Since there is a curve for 4 KW—which, within the limits of accuracy of the method, can be used for a calculated power of 4.2 KW—there is no need to determine an equivalent θ as was done before. Instead, a vertical line is dropped from the point where the horizontal line corresponding to the elevation (445 feet for Radial A) and the slant line marked 4 KW intersect. This line is then drawn to the curved line marked 500 feet, and a horizontal line is drawn from this point to the scale at the left. This course is illustrated on the graph by the heavy dotted line marked "B". The distance to the 1000 microvolt contour is thus determined as 18 miles. The same procedure is followed for each radial direction and the data tabulated as in Table No. 3.

From the data in Tables No. 2 and No. 3 we can now plot the 50 microvolt and 1000 microvolt contours which establish the "actual service area" for the assumed power of the transmitter. This is done by laying out on the topographic map (Figure 2) the distances to these contours in each of the eight directions and drawing through the eight points a smooth line. This line may or may not be a circle, depending on the slope of the terrain in the several directions.

In the case of WBRL, the terrain was fairly even so that the distances to the 50-microvolt contour varied from a minimum of 47 miles to a maximum of 52 miles. Thus the contour is a circle slightly squashed in on one side.

Referring to Figure 2, it will be noted that the heavy line corresponding to the 50 microvolt contour (which was determined as described above for an assumed power of 4200 watts) corresponds fairly well with the *average* trade area, as shown by the broken line which is a circle of 50 mile radius. Since this represented a coincidence as good as could be practically achieved, the figure of 1000 watts was confirmed as the required operating power. Suppose, however, that the *service area*, as so determined, had fallen well outside the *trade area* boundary. In that case, it would have been necessary to assume some lower power, go through the whole process as above outlined and again check against the trade area. In theory it might be necessary to go through this cut-and-try process a number of times until the exact power is decided. In practice it is usually possible to come near enough on the second or third try.

THE EFFECT OF AVAILABLE TRANSMITTER POWER

Supposing that in the above case of WBRL it had turned out that not 1000 watts, but for instance, 1100 watts appeared to be required. The next available transmitter size is 3 KW—obviously an uneconomical alternative. What should be done? There are several possibilities. One would be simply to let the *service area* remain a little smaller than the optimum: as a rule there is enough leeway in interpreting the *average trade area* to allow this to be done within the present rules. Another

TABLE NO. 1

Sea-level elevations by sectors in eight radial directions

	Interval of Sector	Radial A N 0° E	Radial B N 45° E	Radial C N 90° E	Radial D N 135° E	Radial E N 180° E	Radial F N 225° E	Radial G N 270° E	Radial H N 315° E
1.	0 to 5 mi.........	50	45	30	25	20	20	20	20
2.	5 to 10 "	50	50	40	20	20	20	15	25
3.	10 to 15 "	60	60	30	15	20	0	10	25
4.	15 to 20 "	100	80	30	15	15	0	5	25
5.	20 to 25 "	130	120	30	10	10	0	0	25
6.	25 to 30 "	180	165	30	10	0	0	0	25
7.	30 to 35 "	210	210	30	10	0	0	0	30
8.	35 to 40 "	225	250	30	15	0	0	0	30
9.	40 to 45 "	270	275	30	15	0	5	0	30
10.	45 to 50 "	275	275	30	10	0	10	5	30

TABLE NO. 2

Average elevation and distance to 50 microvolt contour

Average elevation to 50 miles...........	155	153	31	14	8	5	5	24
Elevation relative to antenna height	355	357	479	496	502	505	505	486
Distance to 50 micro-volt contour	47	47	51	52	52	52	52	51.5

TABLE NO. 3

Average elevation and distance to 1000 microvolt contour

Average elevation to 20 miles...........	65	59	32	19	19	10	12	24
Elevation relative to antenna height	445	451	478	491	491	500	498	486
Distance to 1000 micro-volt contour	18	18	18.5	19	19	19	19	19

RCA ENGINEERS WIN PROMOTIONS

DR. C. B. JOLLIFFE, formerly Chief Engineer of the RCA Victor Division, has been elected Vice President of Radio Corporation of America in charge of RCA Laboratories.

A native of Morgantown, West Virginia, Dr. Jolliffe was graduated from West Virginia University, receiving a B.S. degree in 1915 and the M.S. degree in 1920. In 1922 he was awarded a Ph.D. by Cornell University.

From 1922 to 1930, Dr. Jolliffe served as physicist in the radio section of the Bureau of Standards, resigning to become Chief Engineer of the Federal Radio Commission, which shortly thereafter became the Federal Communications Commission. In 1935 he joined the Radio Corporation of America as Engineer-in-Charge of the RCA Frequency Bureau and in September 1942, was appointed Chief Engineer of the RCA Victor Division.

MR. D. F. SCHMIT, formerly Assistant Chief Engineer, has been appointed Director of Engineering of the RCA Victor Division, thereby taking over the post vacated by Dr. Jolliffe.

Mr. Schmit has held important engineering posts in the RCA Victor organization and its predecessor companies for more than fifteen years. A native of Port Washington, Wisconsin, Mr. Schmit was graduated from the University of Wisconsin with an electrical engineering degree. He joined the RCA Radiotron Company in Harrison, N. J., in 1930. A few years later he was placed in charge of tube design and application. His next position was as Manager of Research and Engineering at the Harrison plant. In 1939, he was named Manager of the New Products Division of the company and in 1943 became Assistant Chief Engineer of the RCA Victor Division.

MR. G. L. BEERS, formerly on the Engineering Administrative Staff of the RCA Victor Division, has been appointed Assistant Director of Engineering in charge of advance development for the Division.

Mr. Beers, a graduate of Gettysburg College, began his engineering career with Westinghouse Co. in 1921. From 1922 to 1930 he was in charge of Superheterodyne Receiver development. In 1930 he joined RCA and from that date until 1940 he was a Section Engineer in the Research Department. From 1940 to 1942 he was in charge of the Advanced Development Division; from 1942 to 1943, Manager of the Engineering and Manufacturing Service Division; and since 1943, he has been on the Engineering Administration Staff. Mr. Beers is well-known in the industry for his development of the locked-in oscillator circuit used in RCA FM receivers.

(Continued from preceding page)

alternative is to consider means of increasing antenna gain by adding layers. A third possibility is to try to reduce line losses. The one expedient that is not allowed (under present rules) is to increase the output of the transmitter above the manufacturer's rating.

SIMULTANEOUS CONSIDERATION OF POWER AND LOCATION

The possibility that the required power will come out an odd figure, as above noted, shows one of the difficulties encountered when power determination is left to the last (as it normally would be in the procedure described here). It is even possible that the required power will come out some impossibly large figure so that the entire location must of necessity be shifted and, possibly, even the classification of the station must be changed. As a result, practical planning of an FM station usually requires a more or less simultaneous consideration, not only of location, height and antenna type, but also of required power. The usual procedure is: first, study the curves to get some general idea what can be done; second, pick a tentative site; third, check through the calculations roughly to see if the arrangement will permit an approach to a practical solution; and, fourth and finally, go through the detailed calculations as described above. The power so determined is used in answering question No. 21 (e) of Form 322. It is also used in making the initial adjustments of the actual installation.

Finally the Regulations of the FCC also require that, within one year after start of operation, the station shall make, or have made, a field intensity survey. If this survey shows the actual 50 microvolt contour to be approximately the same as the predicted contour, then the power, as determined above, becomes the permanent operating power. If the actual contour lies some distance beyond (or short of) the predicted contour, power must be reduced (or increased) in whatever degree required to make the actual area served as similar to the predicted area as possible. The new power then becomes the permanent operating power.

ASSOCIATED BROADCASTERS INSTALL 50KW SHORTWAVE AND EQUIPMENT

For New International Studios

by **ROYAL V. HOWARD**
Vice President in Charge of Engineering
The Associated Broadcasters, Inc.
The Universal Network
San Francisco, Calif.

ROYAL V. HOWARD

Sometime before Pearl Harbor, it was realized that facilities for disseminating truth about America via international short wave were inadequate in the Pacific area. In the fall of 1941, the Associated Broadcasters, Inc.. operators of Standard Broadcast Station KSFO, San Francisco, was asked by the Government to install a 100 kilowatt short wave transmitter, and a construction permit was granted by the Federal Communications Commission. The Associated Broadcasters, who maintained a dominant position in the broadcasting industry on the Pacific Coast, immediately started their Engineering Department to work on the designs for this super-power station.

With the advent of the war, the urgency of such a voice in the Pacific theatre was magnified many fold and immediate steps were then taken to secure a transmitter. At that time, only one transmitter was available, a 100 kilowatt model. Contracts were rushed for its purchase and construction of the antennas and building was started.

On May 5, 1942, eleven weeks after start of construction, nine months to a year ahead of schedule, 100 kilowatt KWID was placed in operation. Since that time, the Corporation, in cooperation with the Office of War Information, has expanded its facilities to include the very fine RCA Type 50 S-W, 50 kilowatt international transmitter KWIX. This transmitter, one of more than twenty-five of this type now being used by the Office of War Information, the Coordinator of Inter-American Affairs and the Armed Forces Radio Service, was described in detail in BROADCAST NEWS.[1]

The additional facilities imposed a very large studio production problem and new studios were constructed, at Pine and Mason Streets atop Nob Hill in San Francisco. This large studio structure, one of the few to be constructed in wartime, was completed in the spring of 1943.

Taking advantage of improvements in the art and experience gained from previous studio construction[2] by the Engineering Department of the Associated Broadcasters, Inc., the studios represent the latest word in modern American design principles. Thirteen studios are included in the building. Also included is a large recording laboratory which, due to the almost universal use of delayed program material in international broadcasting, turns out many hundreds of sixteen inch sides a month for various Government offices. This heavy load constitutes a fine endorsement of the reliability and ruggedness of the RCA 73-A recording lathes and associated equipment.

STUDIOS

The new studios were built as an addition to the world-famous Mark Hopkins Hotel high above San Francisco and from the offices a fine view overlooking the city is obtained. It is of modern, fireproof construction. While an addition to the Mark Hopkins Hotel, it has a separate and distinct entry way. The major portion of the studios, recording laboratory, Master Control room and kindred offices are a part of the main hotel building. Being built on the side of Nob Hill, the design of the building is such that all working offices and the lobby receive direct daylight, with southern exposure, by windows running from floor to ceiling. This building handles the major studio and business activities of the Corporation.

The principal operational studios and booths, eight in number, are grouped around the Master Control room. The planetary placement enables the engineer in charge at the RCA Master Control Desk to readily view the operations occurring in each of the studios. Some of these studios are of the announce and play-back type and are intended for simultaneous separate programming in multi-station operation. International broadcasting differs mainly from standard broadcasting in that practically all programs are recorded. These programs may be released simultaneously or separately and oftentimes may be repeated on different beams and different frequencies to different countries. The booths surrounding Master Control are primarily for this purpose while other small studios are used for the recording of small shows, i.e., commentaries, news and small cast features.

---

1 BROADCAST NEWS, January 1944, "The 50 SW, A New Transmitter For International Broadcasting."

2 BROADCAST NEWS, January 1939, "One of America's Most Modern Radio Stations," by James L. Middlebrooks and Royal V. Howard.

The larger, secondary studios, two of them located within view of Master Control, are used for the production and recording of programs requiring larger facilities. These may also be used for live direct shows where required.

Located directly behind the Master Control operator is the equipment room. This room is a development that should prove of interest to all stations. Open racks, that is to say, racks without separate enclosures, are lined up in two parallel rows with equipment fronts out to form two walls. The enclosure is completed by a wall at the far end. The other end, with a suitable door, is closed over, thus making a room with the equipment control panels on the outside and accessible by a short hall. Into the interior of this room is brought filtered, refrigerated air so as to keep the equipment at the desired temperature. All movement of air is out through the louvres and jack holes. With a slight positive pressure prevailing, no dirt or dust enters the

FIG. 1. (Top left) *Master Control Room. From his position at the control desk, the engineer can view the operations going on in the eight studios which are grouped around the master control room.*

FIG. 2. (Center left) *Another view of the master control desk. The equipment room can be seen directly behind the operator. The equipment is completely enclosed behind and is "pressurized" with filtered, refrigerated air.*

FIG. 3. (Bottom left) *The Recording Laboratory. International broadcasting entails a large amount of recording. At KWIX, six RCA Type 73-A Deluxe Recorders installed in special room handle all requirements.*

FIG. 4. (Below) *One of the control booths associated with the smaller "announce and play-back" studios. RCA 70-C Turntables and special control consoles are used.*

FIG. 5. *Interior of the control room for the large studio which is separate from Master Control Group.*

room. Such a scheme, pioneered by the Associated Broadcasters, has cut maintenance requirements to an amazing extent. The keeping of the equipment and tubes at the proper temperature has extended the life of the equipment several hundred percent.

It should be noted that such a system makes the wiring readily accessible for maintenance and repair in addition to the obvious installation advantage afforded. A centralized grouping of the studios and equipment around the Master Control console makes practical the use of troughs to all points thus allowing ample room for future expansion. Further, such a design permits very short runs for all equipment.

With the exception of the equipment for the large type studio all the usual studio amplifiers and associated facilities are mounted on the main equipment room bay-frames. This system eliminates the need for the extra space usually required in such small studios for the apparatus. Their operation is entirely a-c, and special emergency thrown-on relays to other sources provide for power failures. Small low consoles are the only equipment installed in the operational booths, with the exception of microphone, turntables RCA 70-C1 and the loudspeakers. These consoles, in addition to the usual attenuators, have transcription "run in" positions on the loudspeaker for checking before playing.

A loudspeaker amplifier input selector, of the rotary type, enables the operating personnel to select the next program source or to listen for special cues. Also, on the console in these studios, is located the output feed interlocked selector system. The operating personnel, by the use of these buttons, may select their correct outgoing feed to any group of transmitters, or whatever is desired, by means of a pre-select system located on the Master Control console. Such a system permits Master Control to operate over long periods of time relatively unattended. Original plans called for an automatic dialing communication system, but due to war conditions this has been postponed until equipment is available. A standard PBX switchboard is employed for the communication to program origination points.

The program production studios are of standard "room within a room" type constructed with acoustical material of the rock wool and perforated board type. The lighting of these studios is attained by recess glass reflectors thus assuring ample illumination without glare or shadows. The lighting units themselves are recessed into the ceiling so that no direct glare is produced to either the control room personnel or the talent. The studios are equipped with the usual number of microphone, utility and telephone outlets. A-C convenience outlets are distributed throughout.

A large studio is separate from the Master Control grouping and is of the same general design with the exception that, in this case, the control and observation rooms are placed eight feet above studio level so as to provide an unobstructed view. Below these is located a storage room for chairs, sound effect and other miscellaneous equipment normally required for production of feature programs. This studio's equipment is placed in standard racks in the control room. Also provided is the equipment for the studio sound reinforcing system used on audience shows.

RECORDING LABORATORY

The recording laboratory is located adjacent to the Studio Master Control group and consists of six RCA Type 73-A recording lathes. These six lathes have their equipment mounted

FIG. 6.
The RCA Type 50 S-W Transmitter at KWIX.

FIG. 7.
Another view of the KWIX Transmitter.

in a dust proof enclosure under the tables themselves and between each pair of lathes is located their control panel. This panel has input selector rotors and instantaneous switch buttons so arranged that each lathe may cut separate and distinct programs or, if desired, all lathes may record the same program. Thus set up, each pair of lathes acts as its own little master control. Such a system further simplifies the operation of the Master Control dispatcher as usually an entire day's recording schedule is either normalled through or set up in advance and will require no further attention. These lathes are kept running twenty-four hours a day. Standard NAB recording characteristics are employed.

OFFICES

The offices and business administration section of the building are of modern functional design and the office furniture, also styled in the modern manner, is of bleached Philippine mahogany. The offices are grouped in such a way as to reduce traffic within the building and are generally adjacent to the activities with which they are most strictly connected.

TRANSMITTERS

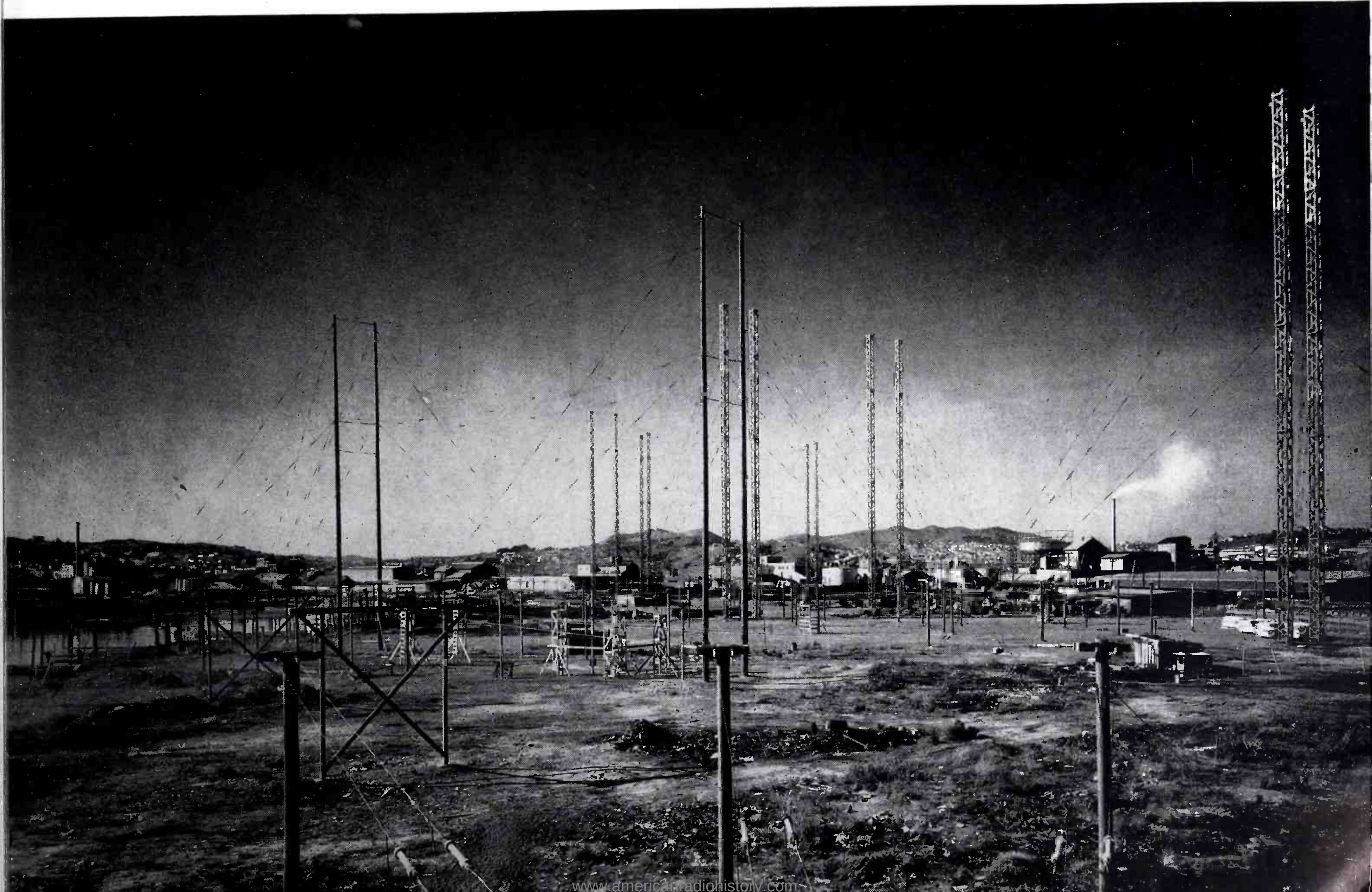
The transmitters are located in the San Francisco Bay area. The building design, like the studios, is modern American functionalism. A technical description of the transmitters employed will not be gone into as the details have been previously published in various periodicals. The transmitter installation is straight forward and, due to a very rigorous system of preventative maintenance, an exceptionally fine record of "on-air" performance has been attained. Many of the details of these installations will undoubtedly be disclosed when security permits.

The antenna systems employed may be generally classified as being of the colinear curtain type although one antenna, designated the BHT, employs new developments which enable it to operate over a frequency range of three to one. It is reversible and its beam can be electrically steered to almost any inhabited portion of the world. Both 100 kilowatt KWID and 50 kilowatt KWIX can be, and are, used simultaneously on one antenna on two different frequency bands! No attempt will here be made to describe the details of this antenna developed by Associate Engineers, Mr. F. Richard Brace, the author, and A. E. Towne, for these details will be disclosed in a technical article at a later date.

However, it should be said these antennas are currently producing concentrations of energy, in both the vertical and horizontal, of equivalent powers never before realized. In some cases at the maximum of the beam the effective radiated carrier energy is equivalent to ten million watts. This type of operation is indicative of how far shortwave engineering has progressed in the last few years.

The Associated Broadcasters, Inc. are also preparing for the post-war world having filed applications with the Federal Communications Commission for both FM and television stations. The President of the Associated Broadcasters, Inc. and The Universal Network is Mr. Wesley I. Dumm; Mr. Allan A. Kees is Chief Audio Engineer; and Mr. Alfred E. Towne, Chief Transmitter Supervisor.

FIG. 8. *Colinear curtain type antennas employed at KWIX to obtain high-gain in direction of transmission.*



HOW DOES IT FEEL TO BLOW UP A RADIO STATION?

FIG. 1. *The Heacock Building after Manila was bombed.*

FIGS. 2 and 3. *KZRH's Control Room and Studio.*

by JUDY J. ALESI
Assistant Editor

"Blowing up Station KZRH was one of the saddest events of my life. I suffered a deep personal sense of loss." That was the answer Bert Silen, NBC's Manila correspondent and manager of Radio Station KZRH, gave interviewers during a recent visit to the Camden plant of RCA. Mr. Silen is back in the United States after fifteen years in the Philippines and visited RCA with Mr. John A. Malcolm, Vice President of the Heacock Company, to make arrangements for the purchase of new equipment so that "The Voice of the Philippines" can speak again.

To go back to the night of the fireworks (which, ironically, occurred on New Year's Eve, 1941) there wasn't much time for reminiscences and regrets when Mr. Silen and some fellow radio men destroyed this radio station. The progress of Japanese troops was being checked from a second floor window of the Heacock Building, where the studios of KZRH were located; however, since they advanced so rapidly, Mr. Silen and his men were given only five hours notice in which to destroy their equipment. It was an especially painful task since just the previous month they realized a long-standing ambition when they converted the station from 5 KW to 10 KW.

While Mr. Silen's group blew up their new RCA 10-DX transmitter and their RCA 1 KW shortwave transmitter with five cases of dynamite, the Japanese troops were taking care of the studios with a thorough bombardment of the entire city. Only the bare walls of the Heacock Building and one other building remained intact. All that was left of this station, which represented an investment of approximately $100,000, were the two 325-foot grounded towers which had supported the flat-top antenna (it had been found that this type antenna gave the best coverage for their particular problem).

As soon as the Japs took over Manila, Mr. Silen was arrested and accused of sabotage. The declaration of Manila as an Open City meant that, according to International Law, anyone destroying something so vitally important would be tried for sabotage. He was questioned for several days and would probably have been executed, had it not been for a receipt, scribbled on the back of an old envelope, which had been given him by a United States Army officer just before our troops pulled out of Corregidor. This, and some fast talking, led the Japs to believe that the station had been destroyed by our Army demolition squads.

Bert Silen and his family spent the following three years in the Jap prison camp of Santo Tomas where they saw many of their close friends killed or wounded by Jap soldiers. The Silen family, along with the other more fortunate internees, were released on January 9, 1945, when returning United States forces reached Santo Tomas. On February 7, a mother's prayers were answered when Mrs. Silen, listening to her radio in San Francisco, heard her son as he delivered his now famous broadcast to the States over the Army shortwave station—which began, "Hello, NBC. As I was saying, when I was so rudely interrupted over three years and a month ago . . ."

Mr. Silen, who flew back to the United States, arrived in New York on April 3rd. He hopes that by the time he goes back to San Francisco, where he will cover the San Francisco Conference for NBC and where he will be reunited with his family who left the Philippines by boat, he will have made all the necessary arrangements for a new and bigger Station KZRH.

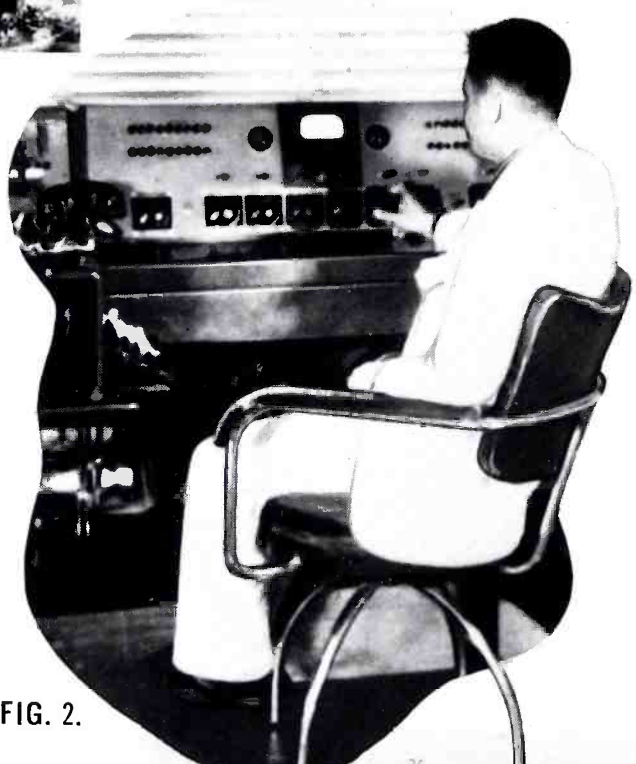
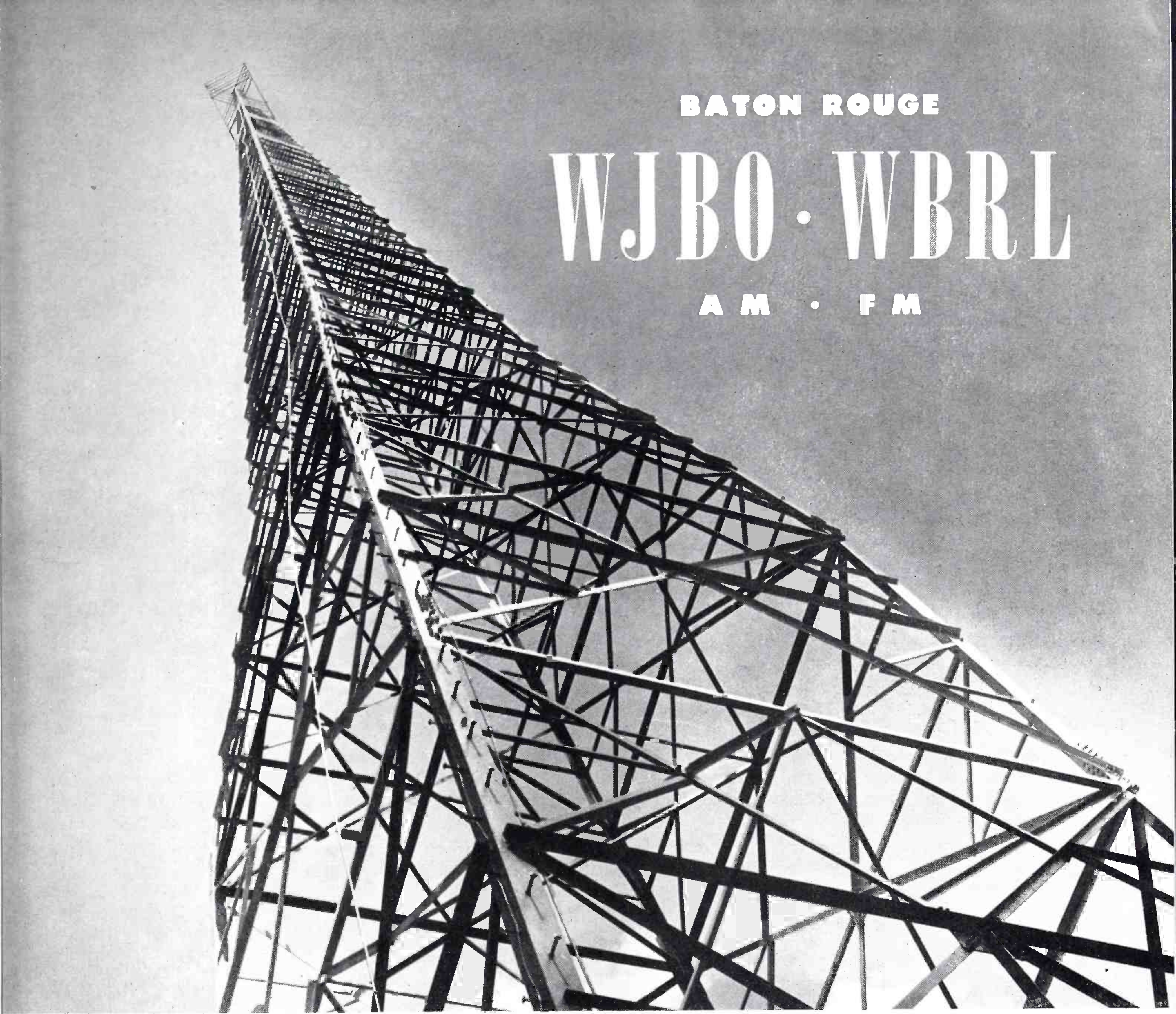


FIG. 2.

FIG. 3.



BATON ROUGE

WJBO · WBRL

AM · FM

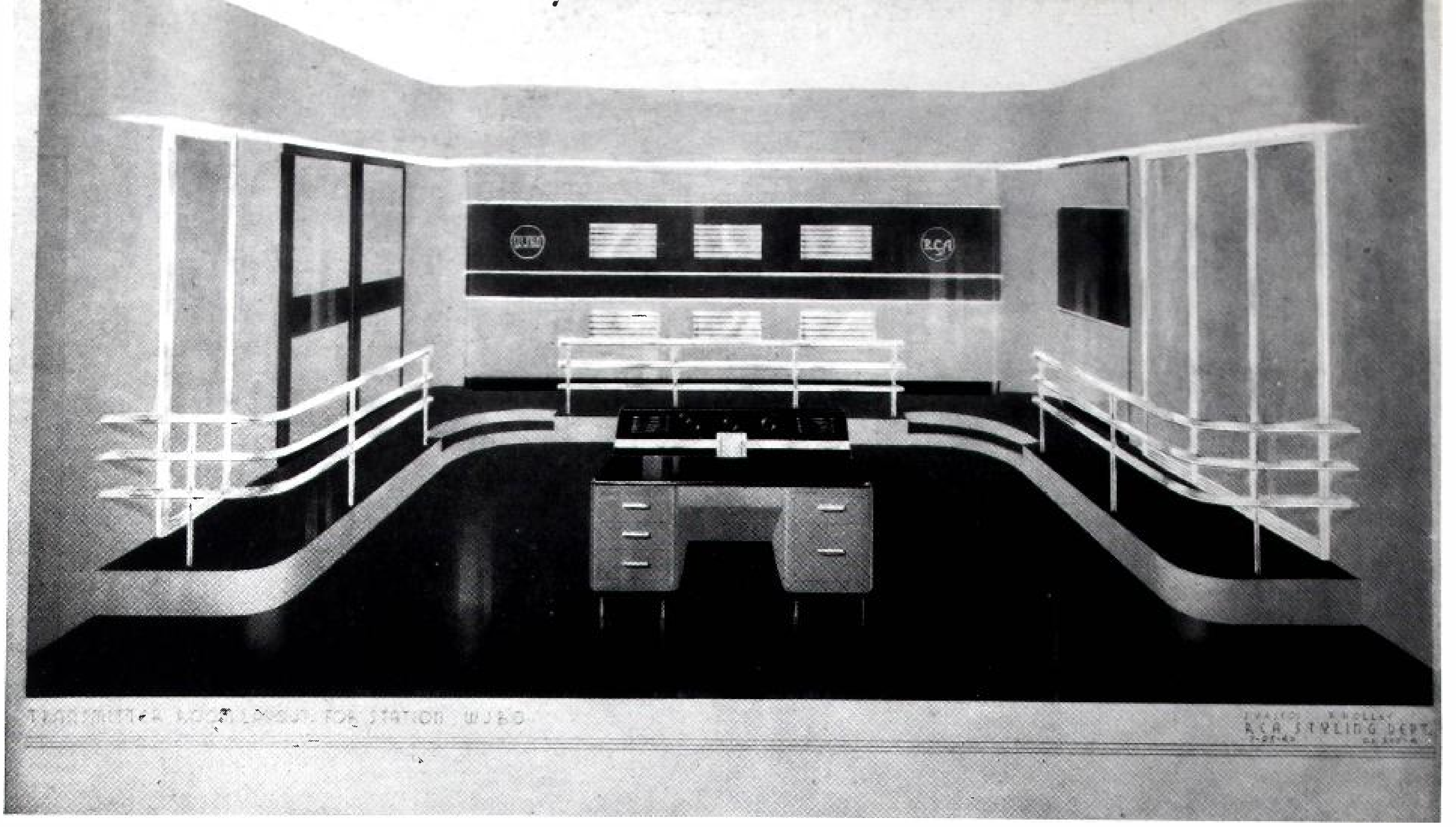
The "dual" transmitter installation of the Baton Rouge Broadcasting Co.—which comprises a 5 KW AM station (WJBO) and a 1 KW FM station (WBRL)—should be of considerable interest to the many present AM station owners who are making plans to install FM equipments.

This installation has a number of unusual and interesting features, not the least of which is the fact that the two transmitters are located in the same room and are operated at times by a single engineer. This, together with the use of one of the AM towers as a support for the FM antenna, makes for an operation which is economical, convenient and easy to maintain. While such an arrangement may not be "ideal" for FM in its eventual state, it does represent one way of keeping down operating expense during the "transition" period.

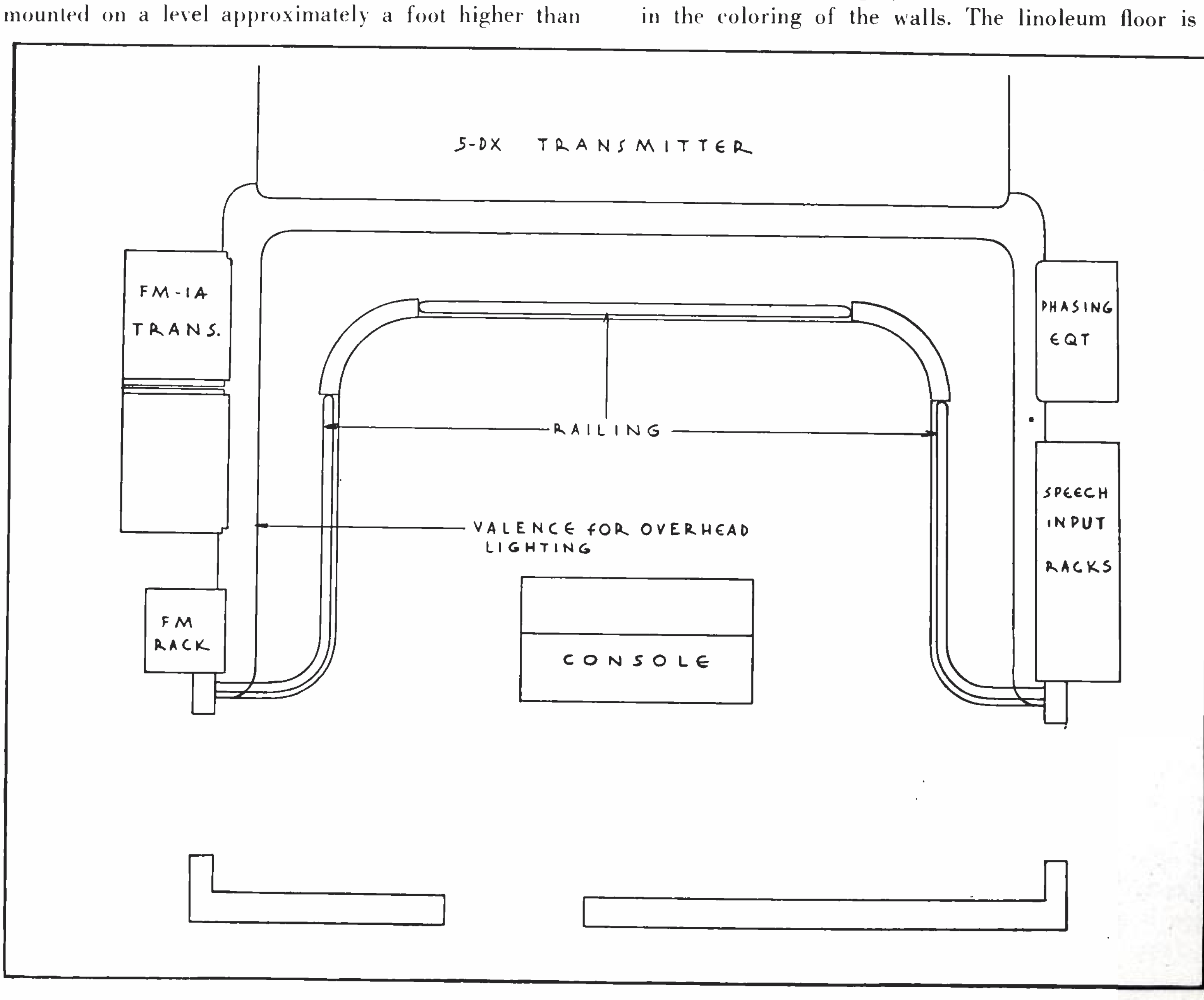
WBRL was the first FM station in the "deep South"; the second anywhere in the South (the first was WSM). That such pioneering should have been done by a relatively medium-sized station is due to the foresight and vision of Mr. H. V. Anderson, then manager of WJBO, and Mr. Charles P. Manship, President of the Baton Rouge Broadcasting Co. and of the Baton Rouge Advocate and State-Times. Having closely followed early FM tests they decided in 1940 to file an application for an FM station in Baton Rouge. A construction permit for this station was granted early in 1941.

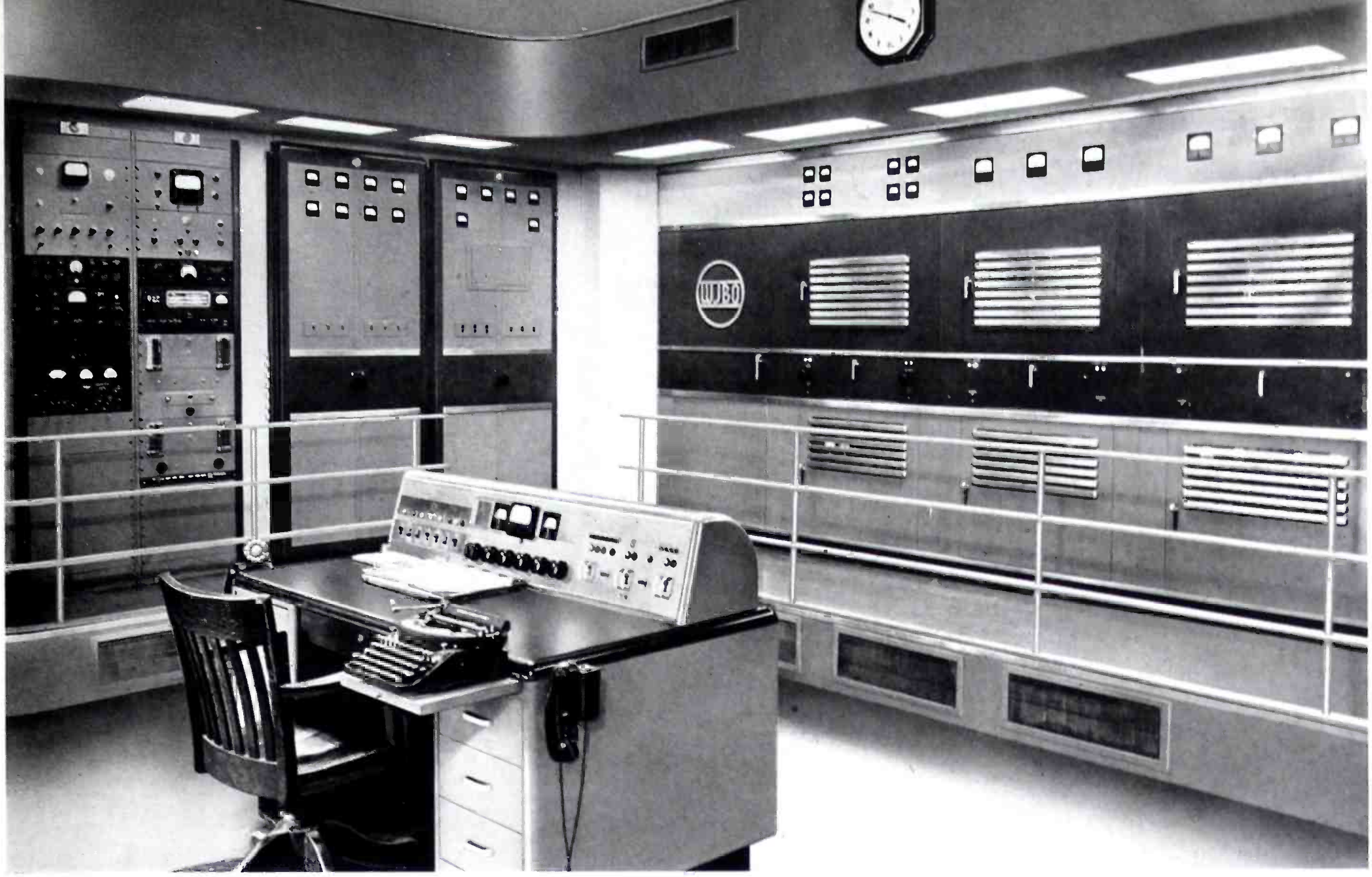
General plans for the station were drawn by Mr. Anderson. Details were worked out by the station's staff and RCA engineers. The fortuitous circumstance that the AM station was being increased from 1 KW to 5 KW at nearly the same time (and a new transmitter being installed) made it possible to plan an all-new AM-FM installation. Bob Holley of the RCA Styling Department helped the project along by sketching designs for an ultra-modern, streamlined transmitter room. Working from his suggestions, the local architect and the building contractor achieved a transmitter building which for simplicity, efficiency and attractiveness is hard to beat.

The main features of the WBJO-WBRL transmitter installation proper are illustrated on succeeding pages. The antenna of the FM station (WBRL) was very briefly described in the last issue of Broadcast News (No. 39, Pg. 12). This antenna, the antenna coupling system and the WJBO-WBRL studios will be described at further length in future issues of Broadcast News.

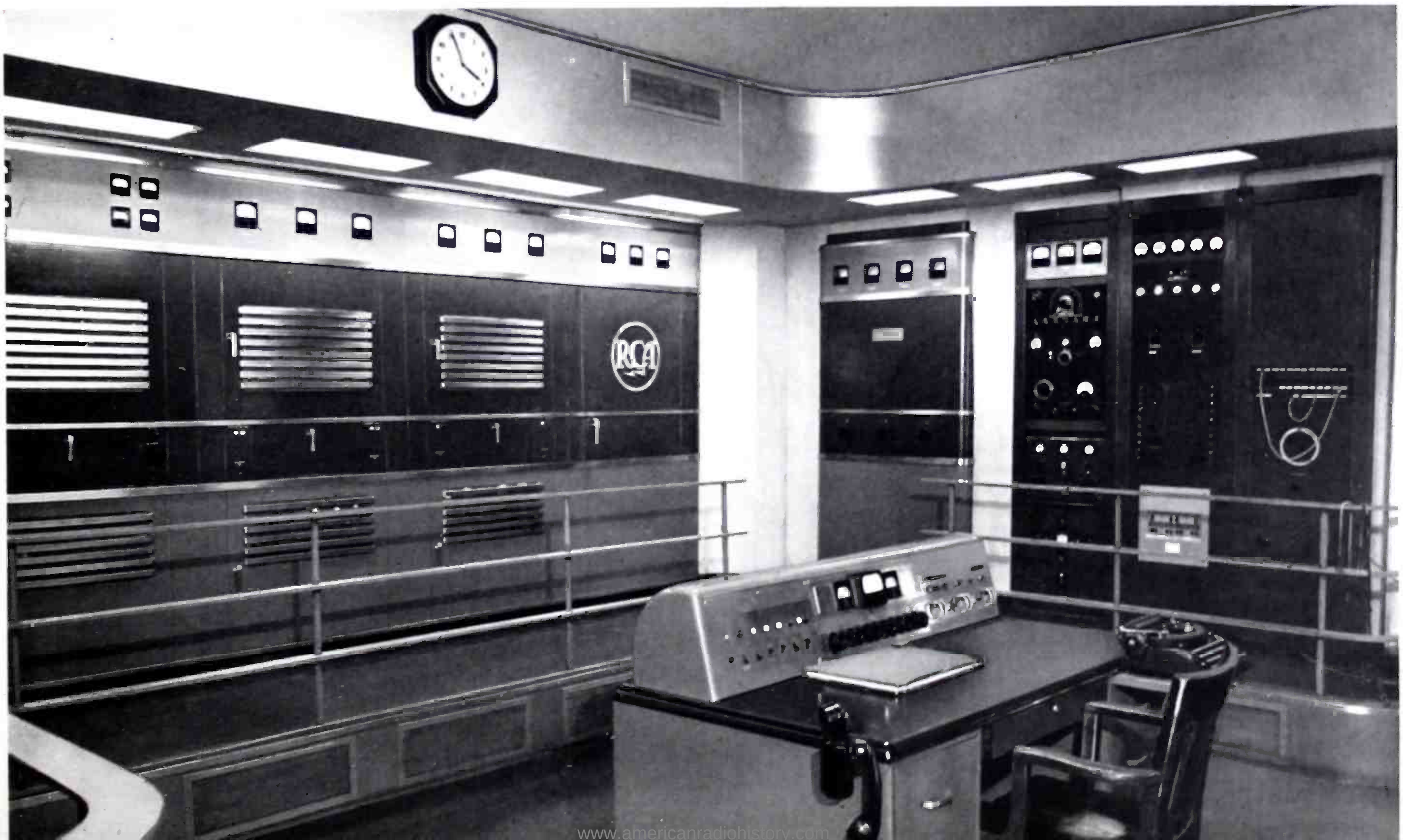


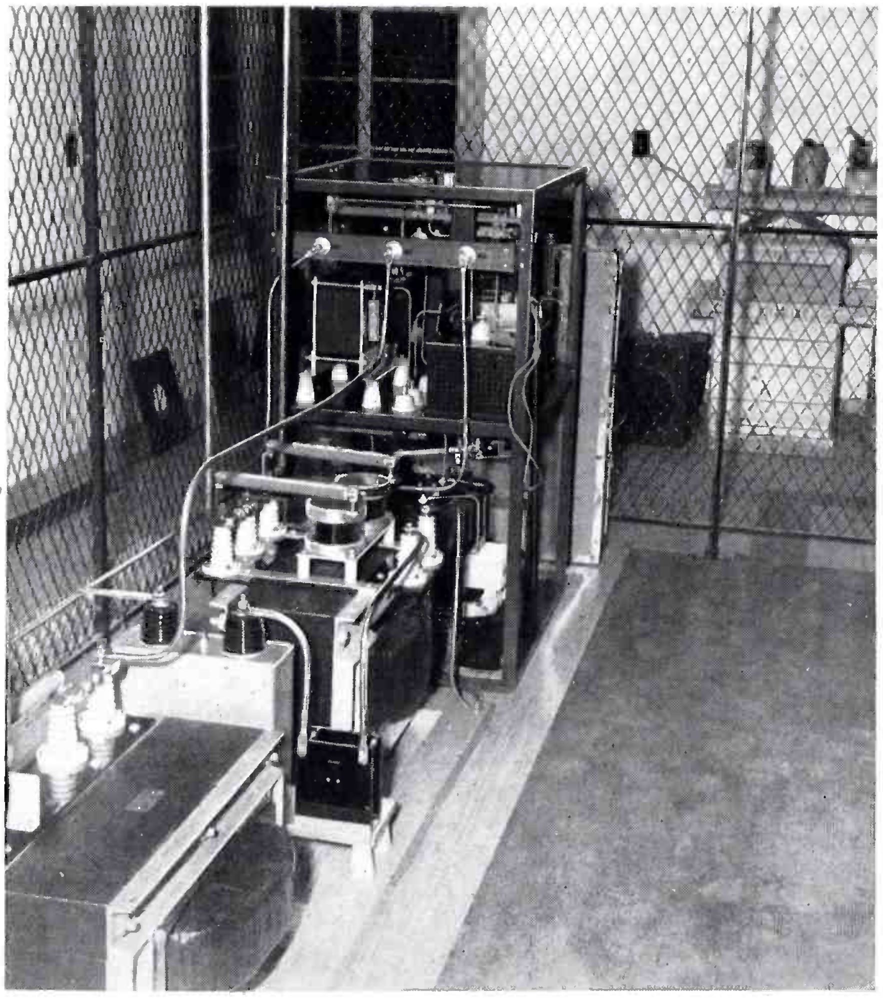
THE ORIGINAL PLAN for the WJBO-WBRL transmitter installation is shown in the two styling sketches reproduced on this page (Figs. 2 and 3). To enable single-operator control of both stations, all of the equipment was arranged in a U-shape with a control console conveniently located in the center space. This equipment includes AM and FM transmitters, audio input equipment and monitoring for both transmitters, AM phasing equipment and over-all power control for the installation. All of these units are mounted on a level approximately a foot higher than the floor of the center room and a walkway of the same height and 3 feet in width extends all the way around the room. This added height provided a space in which wiring and ventilating ducts could be conveniently placed. Together with a valence in which are recessed overhead lights it adds measurably to the professional appearance of the installation. Use of chrome-plated railings around the edge of the platform heightens this effect. The two-tone umber-grey colors of the transmitters are followed in the coloring of the walls. The linoleum floor is dark blue.



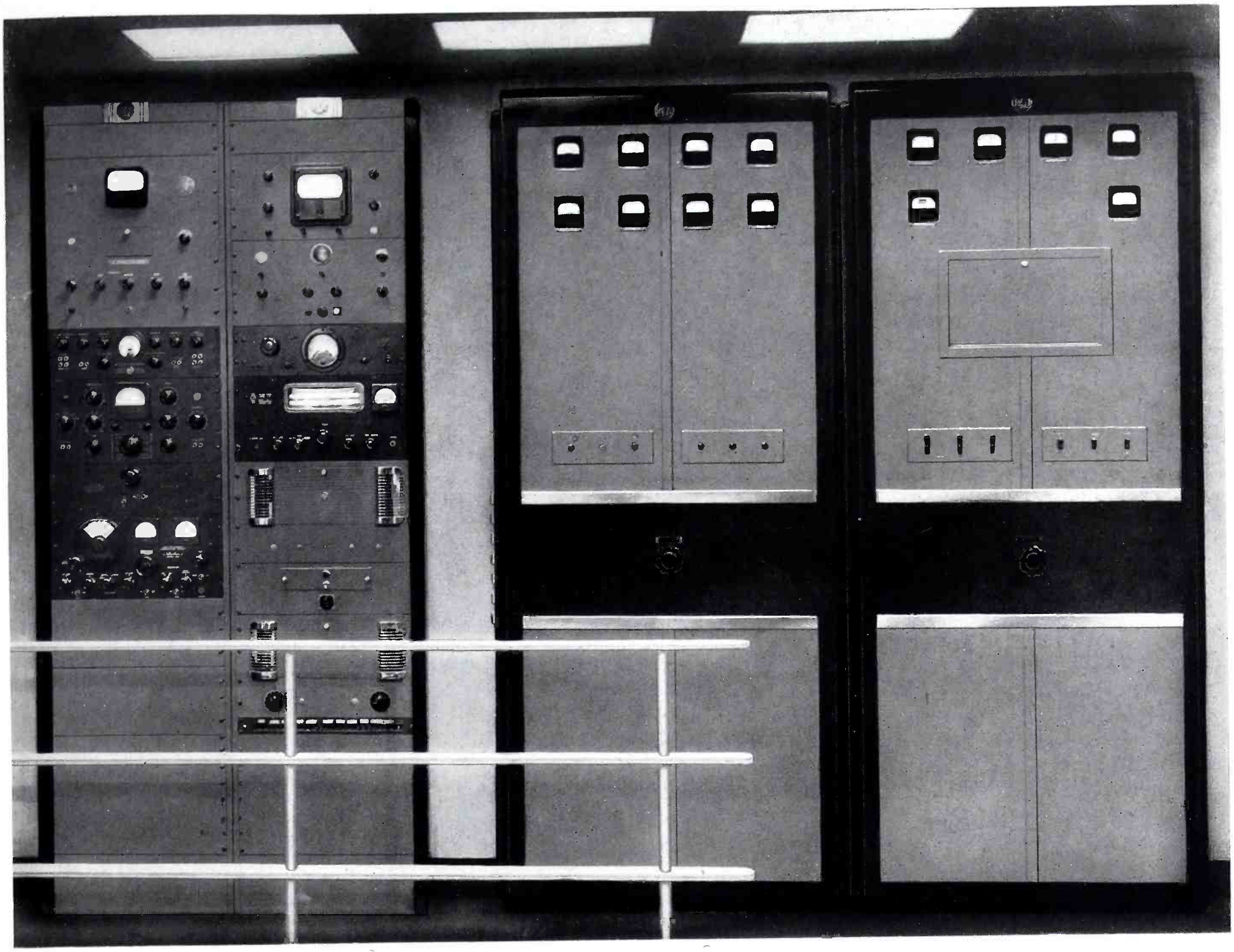


AS CONSTRUCTED the transmitter room of WJBO-WBRL actually looks very much as envisioned in the artist's sketches. Unfortunately, the fact that this room is shallow and rather wide, made it impossible to get all of the equipment in a single photograph. However, a good idea of the appearance can be obtained by mentally visualizing the two views on this page (Figs. 4 and 5) joined together in proper perspective. The equipment units are arranged as shown in the floor plan on the preceding page with the exception that two racks, instead of one, are provided for the FM auxiliary equipment. These racks (at the very left of the U) contain the FM audio input and monitoring amplifiers, the FM monitors, the distortion and noise measuring equipment and AM and FM receivers. Next to these racks is the RCA FM-1-B Transmitter. In the center of the U is the RCA 5-DX AM Transmitter. On the right side of the U are the AM phasing equipment cabinet and three standard relay racks. One of these racks contains the RCA 300-A Phase Monitor, the 300-B Meter Panel, the AM modulation and frequency monitors and the AM audio input. The other two racks contain a-c power controls, jack panels for line terminations and a monitoring system.

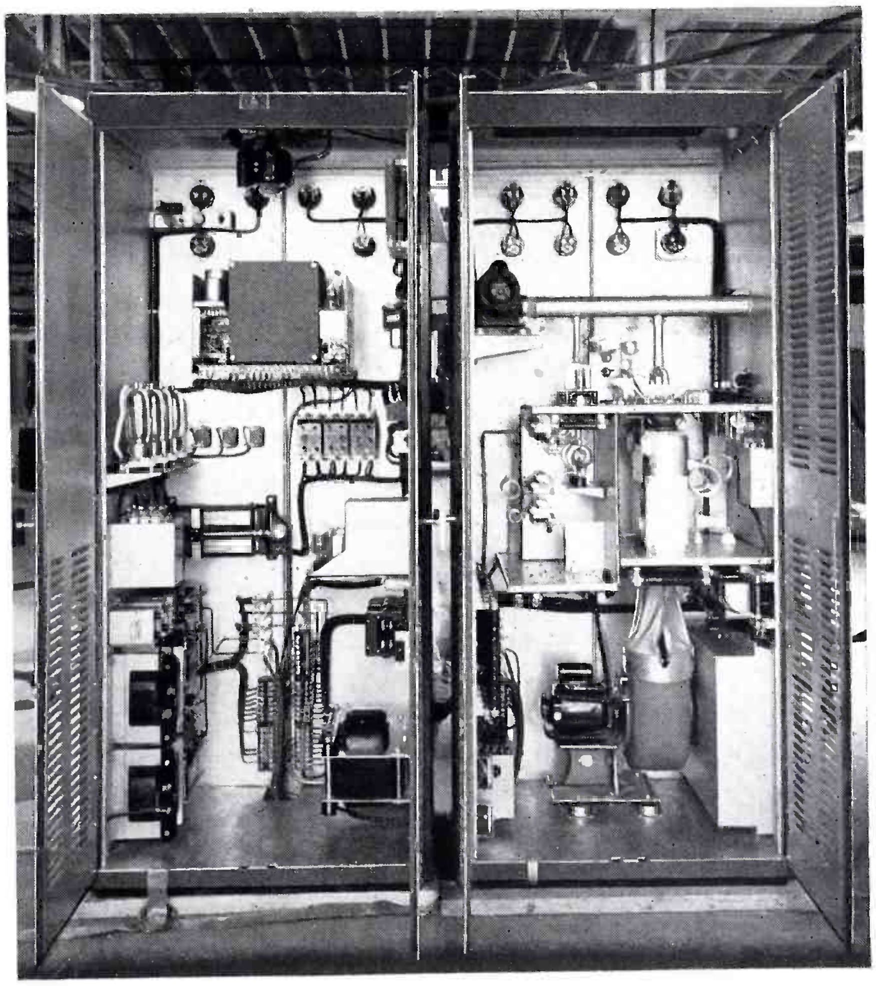




THE AM TRANSMITTER of WJBO is shown above and the high-level modulation transformers and reactor and high-voltage filter components of this transmitter in the photograph at the left (Figs. 6 and 7). This rear view shows a part of the fenced-in space immediately behind the transmitter. This space is approximately 6 feet deep and extends the full length of the AM transmitter. The fence is provided with an interlocked gate near one end. Outside the fence is a corridor about 4 feet wide which extends all the way around the U. It is reached by doors in both sides of the transmitter room proper. Since the FM transmitter and the phasing cabinet have interlocked doors, no fence is necessary along the rear of these. To provide easy accessibility to wiring between units, a metal duct 8 inches wide and 6 inches deep runs all the way around the U at a distance of about a foot behind the equipment units. Branches from this run under each equipment. All wiring except the low-level input connections and the leads to the control console and high-voltage transformer (located outside) are run in this duct. R-f leads from the AM phasing unit and the concentric line from the output of the FM transmitter are run overhead. Telephone and power lines entering the building are run underground from some distance away. The ventilating system includes louvers around the base of the raised platform which admit cool air to the transmitter room in warm weather, and louvers over the AM transmitter which admit warm air from the transmitter during cool weather.

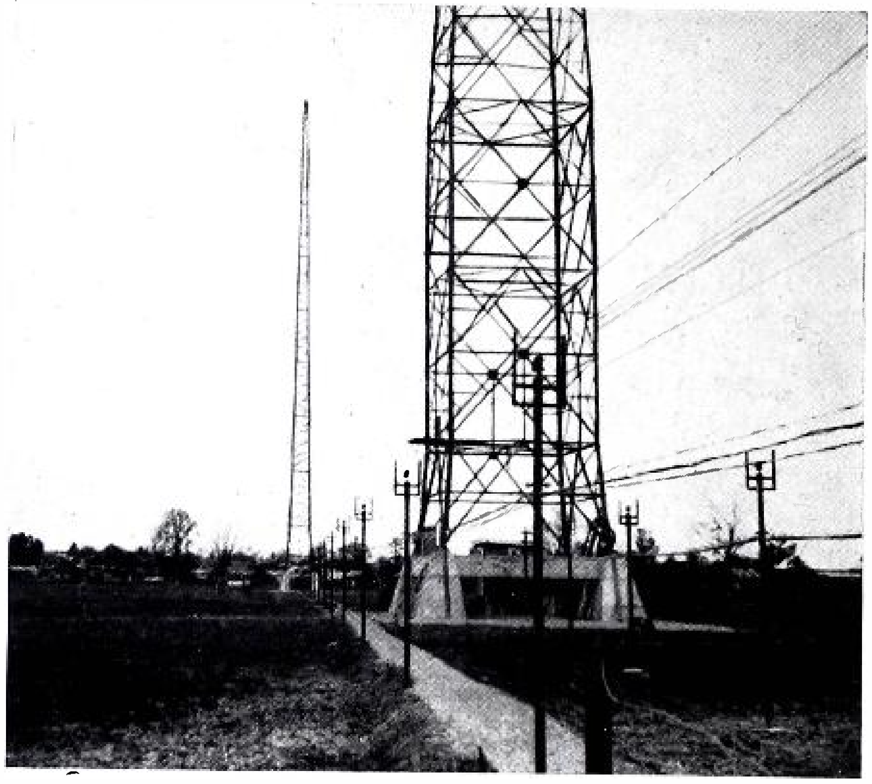


THE FM TRANSMITTER of WBRL is shown above and a rear view of this transmitter at the right (Figs. 8 and 9). This transmitter is constructed in two sections, each about 36 inches wide. The left-hand section (viewing it from the rear) contains the FM exciter unit (the shelf-mounted unit in the upper center), the high-voltage power supply (on left wall), and a low-voltage and audio input unit (right wall). In the right-hand cabinet are located the r-f amplifier stages which raise the FM modulated output of the exciter unit to the 1 KW final output. These stages consist of an 807 tripler, a pair of 809's as a second tripler, a pair of 8001's as an intermediate power amplifier and the final stage consisting of a pair of RCA 872-R's in push-pull. The latter, which are beam-power tetrodes, are a unique feature of the RCA 1 KW transmitter. Forced air-cooled (by a small blower just beneath) these tubes have a high plate dissipation. A modification of the power supply is all that is required to obtain up to 3 KW from the same r-f lineup. The arrangement of the r-f circuits is such that they are very stable and seldom need retuning. Even initial adjustments are relatively easy. Since the low-power stages act as triplers and the IPA is well shielded, no neutralizing is needed. The final stage is also well shielded due to the unique construction of the 827-R tube. Small tabs are provided for neutralizing, but the adjustment is not critical and is easily made.

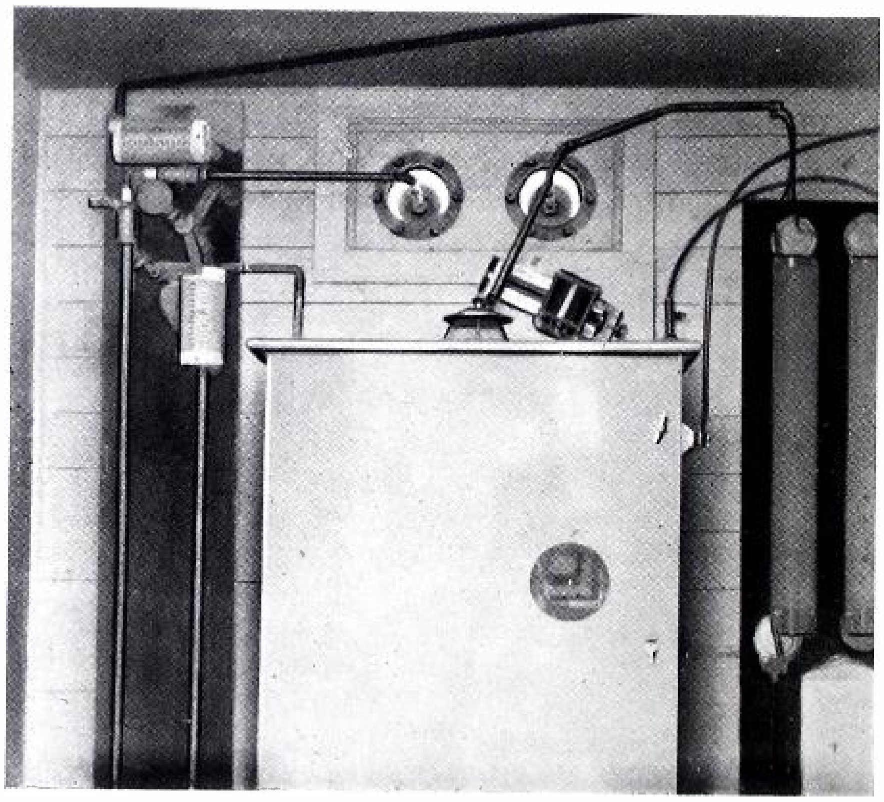


TRANSMISSION LINES emerge from the building at a central point and run to the three towers which make up the directive antenna system of AM station WJBO (Fig. 10). The FM antenna of station WBRL is mounted at the top of the 500 foot tower which forms the center tower of this array. The transmission lines for both the AM and FM radiators are supported by metal poles spaced 30 feet apart. A rather unusual feature is the fact that there are no lines of any kind underground. The six-wire open wire lines feeding the AM radiators are mounted at the top of the transmission line poles. Some 3 feet below these are messenger cables which carry (1) the small concentric lines which feed back r-f from a pickup coil in each antenna house to phase monitor in the transmitter room, (2) the twisted pair line feeding the remote-reading antenna meter in the main building, (3) the supply line (220 volts) for the tower lights and (4) the intercom lines. In the case of the center tower, the ⅞ inch concentric line feeding the FM antenna system is also supported by one of the messenger cables. This arrangement of the various lines was easier to erect than underground lines, it is easier to service and has been very satisfactory in every way.

THE ANTENNA SYSTEM of the AM station, WJBO, consists of three self-supporting towers. The center tower, of which the lower part is visible in the view at the right (Fig. 11), is 490 feet above the insulators, while the two end towers, of which one is visible in this picture, are 315 feet in height. All three towers are used at night (directive operation), but only the center tower is fed during daylight hours (non-directive operation). The three towers are mounted on reinforced concrete abutments approximately 10 feet high. This was done in order to insure that the insulators would always be well above water level—a necessary precaution inasmuch as the ground on which the transmitter stands is occasionally flooded. Separate transmission lines run from the main building to each tower. Two of these can be seen in this picture. Spacious "dog-houses" are located within the supporting abutment of each tower. The floors of these are elevated and the phasing units and lighting equipment mounted well above any likely water level.



ANTENNA COUPLING EQUIPMENT in the center tower doghouse is shown at the right (Fig. 12). In the large box in the center of this picture is mounted the AM antenna matching and phasing unit (the antenna ammeter may be seen through the hole). The lead from the top of this unit is a piece of ⅞ inch copper pipe which passes out through the window and ties on to the tower at a point immediately above. At the right of the picture are the lighting chokes and condensers. These are double-wound coils through which passes the 220 volt a-c for tower lights and beacon. The leads from the top of these are passed through the copper-pipe antenna lead to a junction box on the tower. Just above the large cabinet in the center is the small bakelite-enclosed coil which picks up a small amount of r-f from the antenna lead and passes it back through a small concentric line to a phase monitor in the main building. At the very left of the picture is the FM coupling unit. The purpose of this unit is to pass the FM feed line "around" the AM tower insulators. The operation of this unit will be the subject of a later article.



"SINGA PAMBA" . . . . "BUNCH OF WIRES"

Through RCA Radio Belgium Speaks from the Banks of the Congo

by L. A. THOMAS

RCA International Division

From deep inside fallen France in June of 1940, the refugee Belgian radio four times sounded the Brabançonne, Belgium's national anthem, and then fell silent. Less than two years later the voice of Belgium spoke again, but this time from Leopoldville in the Belgian Congo. Chanting natives helped erect "Singa Pamba" or "Bunch of Wires" as they called the RCA transmitter that became the new voice of Belgium. By means of this powerful 50 kw short wave transmitter, the message of Belgium was lifted from the shores of famed Stanleypool and carried over the continents and seas to the invaded homeland and to all the world.

Today the original purpose for which this broadcast station was erected, the freeing of Belgium from the invaders, has been accomplished. Radio Leopoldville is a potent liaison agent between Belgium of today and Belgium of tomorrow. The story of how this radio voice of Belgium was created is one in which RCA has taken an important and stirring part.

This station is a link in what might be called the United Nations network, for which RCA has built and installed more than twenty 50 kw transmitters to help radio in its global war missions.

The radios of invaded Belgium had scarcely signed off before plans were being made to get on the air again. In London, plans were made for the installation of a powerful station on free sovereign Belgian territory so that the Belgian government could speak directly to its people and to the world. Leopoldville was chosen for the location of the new equipment because it was the capital of the great Belgian Congo territory, because much broadcasting experience had already been gained there, and because a staff of technicians was already on the spot. However, several of the staff, caught by the invasion while at home on vacations, were never able to return. As a result the radio set-up at Leopoldville was undermanned during the whole war period.

EARLY RADIO SERVICE IN BELGIAN CONGO

Radio first came to the Belgian Congo in 1910 when the Belgian Colonial office began to install radio stations in that territory. By 1914, thirteen cities were linked by radio. The first short wave link between Belgium and the Congo Colony was inaugurated in 1925, and in 1927 bilateral communication between Belgium and Leopoldville was established.

In 1929, four key stations, in Leopoldville, Elizabethville, Stanleyville, and Coquilhatville were in operation. Since then radio-telephone service between Belgium and the Congo has been established. Also a network of 37 telegraph and telephone stations, interconnecting all the chief cities of the colony, was gradually developed. The airports of the Belgian Congo are, of course, radio equipped, in most cases with RCA radio beacons and other types of RCA transmitting and receiving equipment. Many private companies now also have their own radio-telephone communication systems.

In 1941 the first high powered broadcasting and communication transmitter was installed. This was a 7.5 kw RCA ET-4750 and is still used daily to broadcast programs to all parts of Africa. Before the new 50 kw station was installed the 7.5 kw equipment was also used to broadcast daily news and information to Belgium.

RCA 50 KW SHORTWAVE TRANSMITTER ORDERED

B. W. Moldowsky, now a technical adviser of the staff of the Belgian Embassy in New York City, was responsible for planning the new station and making all arrangements for installing it. He selected the standard RCA type 50SW transmitter for the job. This equipment has been described in detail in the January 1944 edition of BROADCAST NEWS. The equipment was built at Camden and then the decision as to how to ship it safely to Africa, through the submarine menace, had to be made. It was decided that each unit should be shipped separately on different ships, in which case, if one unit were lost it could then be replaced. All units, fortunately, arrived safely.

Welden Shaw of the RCA Service Company preceded the shipment to the Congo. With the help of the local staff he was on hand to install the equipment as fast as it arrived.

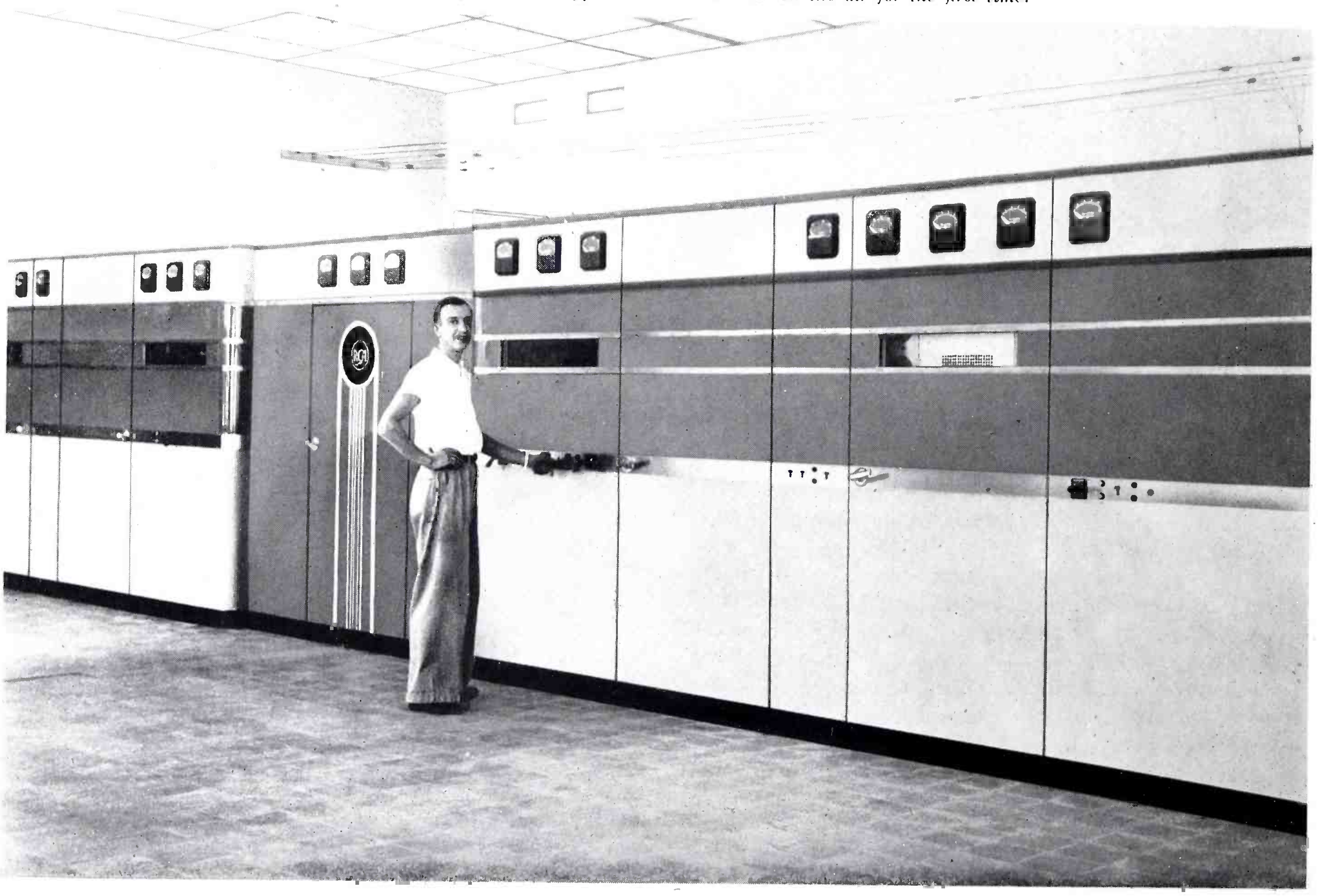
INSTALLATION CALLED FOR INGENUITY

According to Shaw, the unpacking of the transmitter equipment was remindful of the Christmas season then being observed back home. All boxes were opened and the contents inspected with the zeal of curious youngsters on Christmas morning. The equipment had landed in Africa in almost perfect condition, an insulator on one of the rectifier transformers having been the only part needing replacement, due to damage in transit.

The installation at Leopoldville is divided into three main locations—the transmitter building and antennas called the "beam", the studios near the center of town, and the receiving station, including antennas, at N'gili.

Because of the pressure of routine work and maintenance of all the existing communication equipment and the shortage of help due to constant attacks of malaria, there were usually but one man plus two or three native boys available at any one time for assembly and wiring work. In spite of the apparent slow progress, the complete assembly was finished in a little over a month, the first broadcast being made February 3, 1943, six weeks after the arrival at the "beam" of the equipment.

FIG. 1. *Putting the RCA Type 50-SW Transmitter on the air for the first time.*



As construction of the studio building was behind schedule, studio racks were stored as received in a warehouse for several months. Some worry was caused regarding the effects of the high humidity, which was present at all times, on this equipment. However, as a precaution, electric light bulbs were installed and turned on in the racks for several days in order to dry them out before power was to be applied. This apparently was successful, for practically no trouble developed during the tests or since.

The chief installation problem was the moving of heavy equipment. This was accomplished by getting as many native boys as could possibly cluster around the unit to push the equipment, along greased metal sheets used as rails, to the rhythmic chanting of the natives which assured teamwork. Everything was successfully moved into position.

Distilled water for the transmitter cooling system was obtained, not from the coffee colored Congo River nearby, but from the local brewery. The installation of the transmitter and transmitting antennas, of the studio equipment, and the receiving equipment was accomplished with little trouble and with great speed, due in large part to the zeal and training of the Belgian technicians. Many of those were refugees from the Nazis and many had families whom they have not seen or heard from for several years. All of the Belgians in the Congo city took great pride in seeing this modern, impressive 50 kw broadcast station rise to fight the Nazis. About mid-June 1943, a report from occupied Belgium stated that as early as the first of June, transmissions from Leopoldville station were being heard clearly by the Belgian underground.

To the many visitors of all nationalities to Leopoldville, this RCA equipment stands out as a monument of the modern age, sharply in contrast to what one naturally expects to find in the Congo region. Standing before the transmitter console or the control panel in the air-conditioned studio, they have the feeling of being suddenly transported far from the steaming tropics of Africa to a center of technical civilization.

Among the many accessories which have been assembled to complete this broadcasting station in Africa, is a great library of Victor records. These served, particularly at various times during the period of installation, to entertain small groups of Americans who got a lift from listening to familiar symphonies and other music while sitting in the air- and sound-conditioned studio.

Weldon Shaw passes along the credit for Radio Leopoldville to others. Shaw says that,

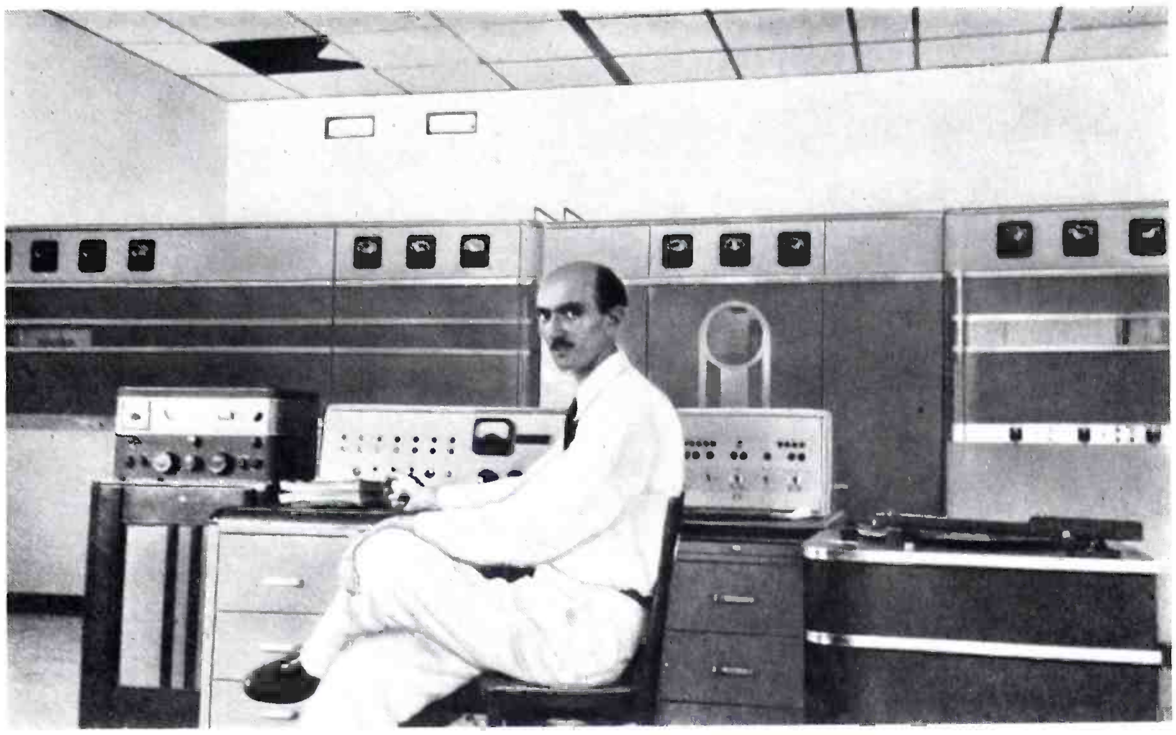


FIG. 2. *Chief Engineer, Jean Joulet, director of tele-communications, Belgian Congo.*

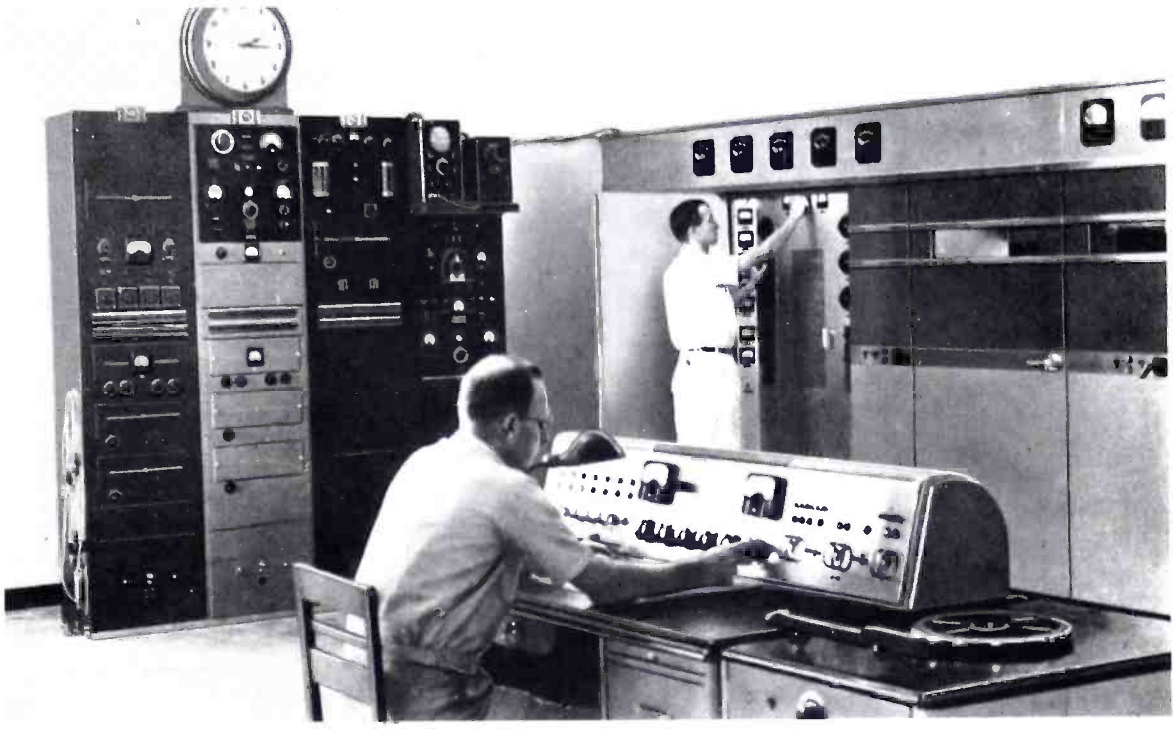


FIG. 3. *RCA operating console, r-f section of RCA 50 KW transmitters and RCA test equipment racks.*

FIG. 4. *Program Director's Offices. Twenty hours a day of programs, in seven or eight languages, are planned here.*

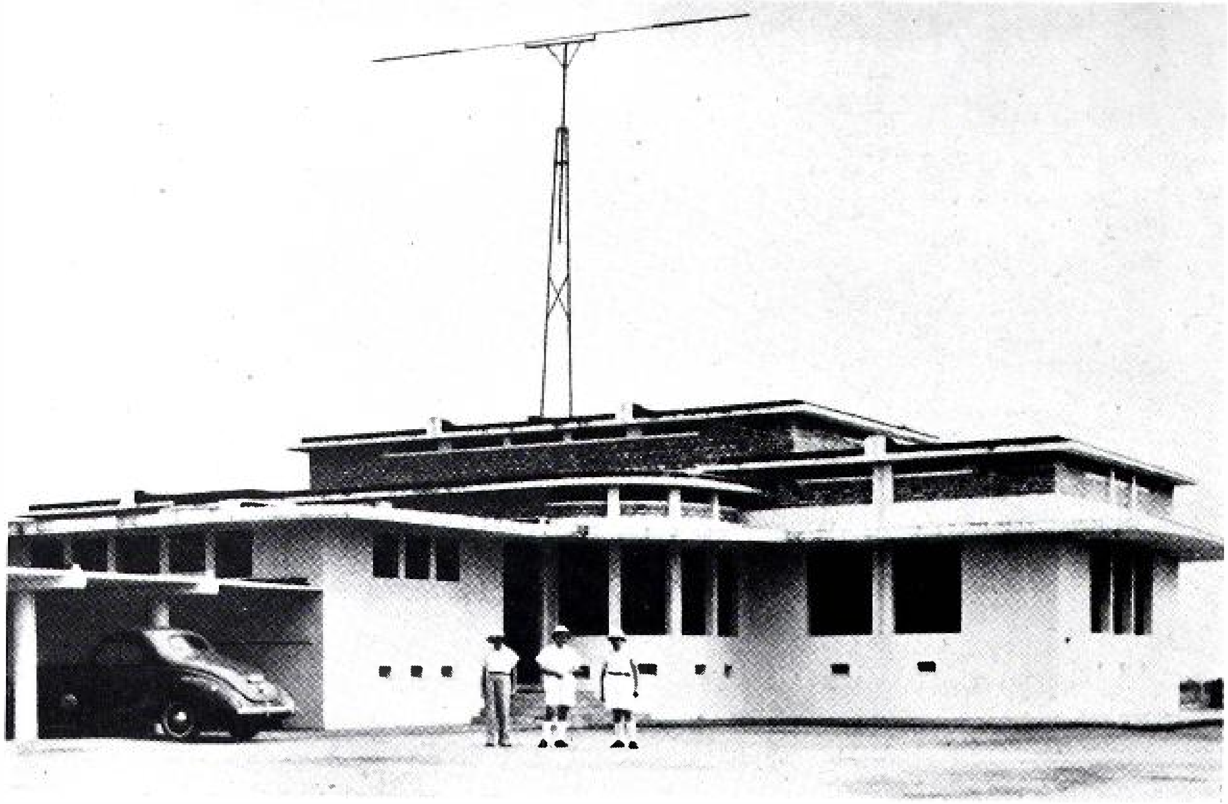


FIG. 5. *Receiving Station at N'Gili. AR-77 and RCA AR-88 Receivers are principally used.*

according to those who have seen the station in action, much of the success of the installation at Leopoldville is due to the Chief Engineer, Jean Jonlet, who is in charge of the complete communications network of the Belgian Congo. His ability as a radio engineer, his knowledge of propagation characteristics, his skillful handling of his men and varying war situations deserve high praise.

MODERN AIR-CONDITIONED STUDIOS

The building for housing the studios at Leopoldville was designed especially for its purpose. There are four air conditioned studios and two more are planned to accommodate the ever growing services. The building which houses the transmitter is not air conditioned but it has been found that almost no difficulty and no serious trouble has been experienced on this account.

PROGRAMS IN MANY LANGUAGES

The station has been on the air every day since its opening. It is now broadcasting about twenty hours a day. Its programs originate in London and New York, as well as in Leopoldville and are given in the following languages: French, Flemish, English, Portuguese, Afrikander, Luxemberger, Turkish and German. Two wave lengths are used on all broadcasts, 19.78 and 25.71 meters.

WIDE COVERAGE

With the opening of this station, Belgium became the only country at that time able to broadcast from three continents. Belgian programs originally were regularly broadcast from BBC London, from New York, set up by the Belgian Broadcasting Services and broadcast through the facilities provided by the New York Office of War Information, and from Leopoldville. It was soon found that the Leopoldville station was able to reach the Near East and South Africa better than any station then on the air outside of Africa. As a result arrangements were made with the British Broadcasting Company and with the U. S. Office of War Information to rebroadcast programs to these areas of Africa and the Near East which could not be reached successfully from England or America directly.

The effective coverage of Radio Leopoldville has been much greater than it would have been reasonable to expect. Reports of high signal strengths have been received from large numbers of listeners all over the world. It is especially strong when beamed to North and South America, to Europe, the Near East, as well as all over the Atlantic and, of course, Africa.

INVASION OF BELGIUM ANTICIPATED

An interesting sidelight has been recently revealed on the vitality and energy of the people of Belgium during the invasion and liberation as related to radio. Years ago it was expected that invasion woud again occur and plans for maintaining radio broadcasting during a possible occupation were made, thanks to the foresight of the General Director of the Belgian Broadcasting Services, Mr. Theo Fleischman. As a result, as soon as the Germans appeared all broadcasting equipment in the regular locations was destroyed, but immediately the hidden portable sets went into operation to aid in the resistance which continued until "V" day. Conversely, plans were also made to restore normal broadcasting on the day when the Germans should leave. Old equipment was hidden. New equipment, too, was sent into Belgium by air. This was all ready for operation on D day, except for tubes which arrived on schedule with the army of liberation.

BELGIAN PATRIOTS RESTORE RADIO SERVICE

Thus, on the very day that the Germans left, apparently destroying all existing radio equipment, Belgium was ready to resume broadcasting with equipment built, in many cases in America, shipped through the submarine packs to England, then dropped by parachute to Belgian patriots. These assembled, within a stone's throw of the enemy, their precious radio equipment for the great day ahead. Thus eight complete broadcasting stations were ready on the day of liberation to begin operations. Nothing can better illustrate the value which people who love freedom put upon the ability to say what they want to say by means of radio. The Belgians, too, have demonstrated that no personal risk is too great or no money cost too large to insure the freedom of radio communications.

PLANS FOR FUTURE

In discussing the future service of this station, Richard Zondervan, General Manager of the Belgian Broadcasting Services, New York office, feels that Radio Leopoldville is strategically located to render service to America, for example, as a rebroadcast station for American short wave programs to Africa and the Near East. In addition, it will continue to serve, as it has in the past, as a most powerful radio voice making known the presence of Belgium again in the affairs of the world.

In summing up the value of the RCA 50 kw short wave station at Leopoldville, Richard Zondervan said that, "It has performed far beyond our own great expectations and its money cost is insignificant compared to the service it has rendered to Belgium freedom and to the allied cause as a whole." Not only Belgian and RCA engineers and service men, but radio men everywhere may justly be proud of the contribution Radio Leopoldville has made to the progress of Belgian freedom.

PRACTICAL DESIGN OF VIDEO AMPLIFIERS

by Elliott A. Henry
Engineering Department
RCA Victor Division

In the past few years many excellent articles and papers have been published in various technical magazines on the subject of video amplifiers and the many types of compensation used to extend the frequency range of resistance-capacity-coupled amplifiers. The majority of these articles have dealt with the mathematical analysis or have had primarily a theoretical approach. A few have presented a generalized introductory discussion of the subject. It seems that a wide gap exists in the published information on this subject. It is the intent of this article to attempt to bridge that gap by presenting practical design data for video amplifiers. The mathematics will be kept to simple algebra. Such other information as is pertinent to the subject, for example some data on vacuum tubes, will be included for the sake of completeness.

If the underlying causes of trouble or limitations of performance are thoroughly understood, it will be easier to comprehend the methods of overcoming these limitations. We shall, therefore, commence this article with a discussion of the factors limiting the frequency range of the conventional R-C (resistance-capacitance) coupled amplifier.

As pentode tubes are almost universally used in video amplifiers, the following discussion will be based primarily upon their use and on the assumption that the value of the grid resistor is much greater than the plate load impedance, as is the case in video amplifiers. However, as triodes are occasionally used, sufficient data are included to cover the compensation of triode amplifier stages also.

In order better to understand the frequency response limitations of conventional R-C coupled amplifiers, let us examine the plot of output voltage versus frequency, Figure 2, of a typical amplifier stage, Figure 1.

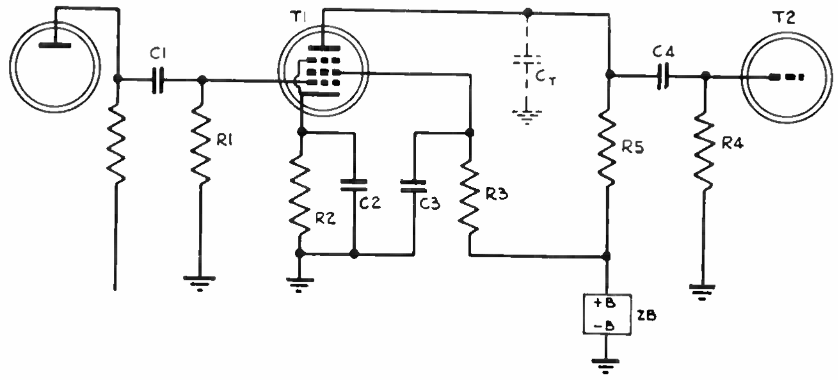


FIG. 1. *Conventional R-C coupled amplifier stage.*

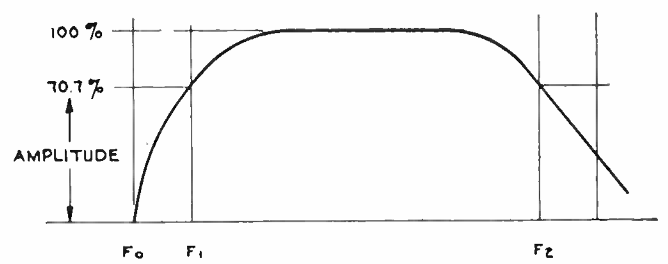


FIG. 2. *Gain-Frequency plot of Figure 1.*

At F_0, zero frequency, the output voltage is zero. As the frequency is increased, the output voltage rises to a maximum somewhat higher in frequency than F_1, remains essentially constant until the frequency is somewhat lower than F_2, and then continually decreases as the frequency is further increased. The two frequencies, F_1 and F_2, are considered the useful limits of the pass-band of an audio frequency amplifier and are the frequencies at which the output of the amplifier is 70.7% of the output at the mid-frequency range. This loss of response, or output, of the amplifier at F_1 and lower and at F_2 and higher both result from the change of reactance (X_c) of condensers with the change in frequency. Either the high or low frequencies will be attenuated, depending upon the location or function of the various condensers, including stray and circuit capacities. In order to demonstrate this more clearly, high and low frequency attenuation will be considered as separate problems.

Unequal gain in an amplifier is referred to as frequency distortion because a complex wave in passing through the amplifier will have its wave shape altered, or distorted, if all of its harmonic components do not receive the same degree of amplification. If the phase delay is not proportional to frequency, the wave may be further distorted. This is called phase distortion.

In the following discussion major emphasis has been placed on the frequency response rather than the phase characteristic of amplifiers. This has been done for two reasons: First, to keep the mathematics to simple algebra; second, an amplifier compensated in accordance with the design data herein presented will be corrected for both frequency and phase distortion and it is perhaps easier to visualize results in terms of frequency response rather than phase characteristic. The importance of the phase characteristic of a video amplifier cannot be over emphasized. For example, an amplifier stage with a response curve such as Figure 2 would not be suitable for video work as the phase angle would increase 45° at F_1 and decrease 45° at F_2 from the mid-frequency value and therefore a change in the phase angle of 90° over the operating range F_1 to F_2. General practice indicates that the frequency response should not drop more than 2% at F_1 and F_2 in a video amplifier if these frequencies are to be considered the limits of the useful pass band of the amplifier.

LOW FREQUENCY ATTENUATION

Low frequency attenuation, or low frequency distortion as it is sometimes called, may be introduced in any one of four places or any combination of the four. Referring to Figure 1, these four places or networks are: the grid resistor-condenser coupling network, R_1-C_1 or R_4-C_4; the cathode resistor by-pass condenser network, R_2-C_2; the screen resistor by-pass condenser network, R_3-C_3; and the internal impedance, Z_b, of the power supply. How the grid resistor-condenser combination acts to reduce the gain at low frequencies may be seen by referring to Figure 3.

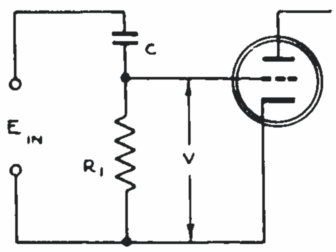


FIG. 3. *Grid coupling network.*

With E constant, the voltage, V, impressed across the grid to cathode may be expressed as $\frac{V}{E}$ and is equal to the resistance, R, divided by the impedance of R and C or:

$$\frac{R}{\sqrt{R^2 + X_c^2}} = \frac{V}{E} \qquad (Eq.\ 1)$$

As the reactance of a condenser is inversely proportional to frequency, the ratio of resistance to impedance, and thus $\frac{V}{E}$, decreases as the frequency decreases. This means the voltage available to drive the following stage is less at the low frequencies than at the high frequencies; and with the gain in the tube equal at both frequencies, the output voltage will be down in the same proportion as the input voltage. This ratio $\frac{V}{E}$, expressed in percentage, is the coupling efficiency of the grid resistor-condenser combination. For example, let us assign values to R and C, Figure 3, and with a constant voltage, E_{in}, see how V varies with frequency.

If $C = .05$ ufd.
$R = 250{,}000$ ohms
$E_{in} = 10$ volts

and the two frequencies are
$F_1 = 30$ cycles
$F_2 = 1000$ cycles

then at F_2: $X_c = \frac{1}{2\pi FC} = 3184$ ohms.

From Equation 1:

$$\frac{V}{10} = \frac{25 \times 10^4}{\sqrt{625 \times 10^8 + 10.1 \times 10^6}} = \frac{250{,}000}{250{,}020} \cong 1$$

Therefore, $V \cong 10$ volts or a coupling efficiency of practically 100% at 1000 cycles.

At F_1: $X_c = 10.6 \times 10^4$ ohms

$$\frac{V}{10} = \frac{25 \times 10^4}{\sqrt{625 \times 10^8 + 112 \times 10^8}} = \frac{25}{27.2} = .92$$

So $V = 9.2$ volts and the coupling efficiency is 92% at 30 cycles. Therefore, the output voltage of the stage will be 8% lower at 30 cycles than at 1000 cycles, other factors being equal.

Low frequency distortion may result from the cathode resistor-condenser combination, R_2-C_2 of Figure 1. This results from degeneration, as the impedance in the cathode circuit will vary with frequency, and the gain of a stage with cathode degeneration is reduced by the factor:

$$\frac{1}{1 + G_m Z_k} \qquad (Eq.\ 2)$$

In other words, the gain of a stage, other things being equal, is:

$$A = A_1 \times \frac{1}{1 + G_m Z_k} = \frac{A_1}{1 + G_m Z_k} \qquad (Eq.\ 3)$$

where A is the actual stage gain, and
A_1 is the stage gain without degeneration,
G_m is the mutual conductance in Mhos,
Z_k is the cathode circuit impedance (impedance of R_2-C_2 in parallel) in ohms.

This impedance, Z_k, is detailed in Figure 4 and is given by:

$$Z_k = \frac{R\ X_c}{\sqrt{R^2 + X_c^2}} \qquad (Eq.\ 4)$$

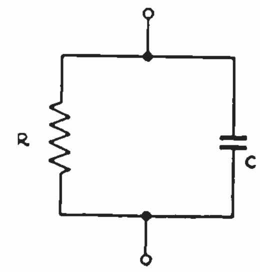


FIG. 4. *Equivalent cathode or plate load network.*

Thus if, in Figure 1, R_2 was 1000 ohms, C_2 was 10 ufd., G_m 5000 umhos, and the stage gain without degeneration 10, the actual gain at 1000 cycles would be:

$$X_{C2} = 15.9 \text{ ohms at 1000 cycles}$$

$$Z = \frac{1000 \times 15.9}{\sqrt{10^6 + 253}} = \frac{15{,}900}{1000.125} \cong 15.9 \text{ ohm}$$

$$A = \frac{10}{1 + .005 \times 15.9} = \frac{10}{1 + .0795} = 9.25$$

or a loss of gain at 1000 cycles of 7.5%. Now let's see what the gain of the same stage is for a frequency of 20 cycles.

$$X_{C2} \cong 800 \text{ ohms at 20 cycles}$$

$$Z = \frac{10^3 \times 800}{\sqrt{10^6 + 64 \times 10^4}} = \frac{8 \times 10^5}{\sqrt{164 \times 10^4}} = \frac{8 \times 10^5}{1280} = 625 \text{ ohms}$$

$$A = \frac{10}{1 + .005 \times 625} = \frac{10}{1 + 3.125} = \frac{10}{4.125} = 2.42$$

Thus, the output of the stage under these conditions will be only about one-fourth, at 20 cycles, of the output at 1000 cycles.

The effect of R_3-C_3, Figure 1, is similar in effect to the results of cathode degeneration mentioned above; but as the screen current is only about 10% of the plate current and the screen-plate transconductance only about 12% of the control grid, or cathode, to plate transconductance, the effect is much smaller and can usually be made negligible by making the time constant of R_3-C_3 at least three times as long as the period of the lowest frequency it is desired to pass.

$$\text{Or,}\quad TC = RC > 3\,\frac{1}{F} \qquad (Eq.\ 5)$$

where C is in farads,
R is in ohms,
F is the lowest frequency in the pass-band.

The total impedance of the screen circuit is essentially the reactance of C_3; and, whereas in the case of cathode degeneration, if the product of $G_m\ Z_k$ equals one, the gain will be reduced 50%, the effect of the screen is so much less that a reduction of gain, at the lowest frequency, of only 2% would result if $G_m\ Z_s$ equaled 2 (G_m being the control grid-plate transconductance).

For example, a 6F6 is desired to pass 30 cycles (Figure 1).

$Z_s \cong X_{C3}$ then $X_{C3} G_m = 2$

$$X_{C3} = \frac{2}{G_m} = \frac{2 \times 10^6}{2500} = 800 \text{ ohms.}$$

$X_{C3} = 800$ ohms at 30 cycles $= 6.64$ ufd.

We would use the next larger commercial size, or 8 ufd. To determine R_3:

$$RC = 3 \quad \frac{1}{F} = \frac{3}{F} = \frac{3}{30} = .1$$

$$R = \frac{.1 \times 10^6}{8} = \frac{10^5}{8} = 12{,}500 \text{ ohms}$$

Therefore, we would use a value of 12,500 ohms or larger for R_3.

In the event that the value of the screen voltage dropping resistor, R as determined above, should be too large to allow the proper screen current, R may be set by screen requirements and the by-pass condenser C, determined from equation 5 using R as selected and solving for C.

The fourth place for low frequency distortion is the internal impedance of the power supply, Z_b. Unless a regulated power supply of the electronic type is used, the impedance is essentially the reactance of the output filter condenser and will vary with frequency as outlined previously. A method for making the effect of this impedance negligible is the use of R-C filters. These filters, if properly designed, may also provide correction for either R_1-C_1 or R_2-C_2, Figure 1, but not both at the same time. Design data for these correction networks is given in the section on low frequency compensation.

LOW FREQUENCY CORRECTION

Of the four places or networks at which low frequency distortion may be introduced, two, R_3-C_3 and Z_b, can be made negligible by proper design. In addition to making negligible the internal impedance of the power supply, we may correct for either R_1-C_1 or R_2-C_2 by the addition of an R-C filter, C_5-R_6, Figure 5.

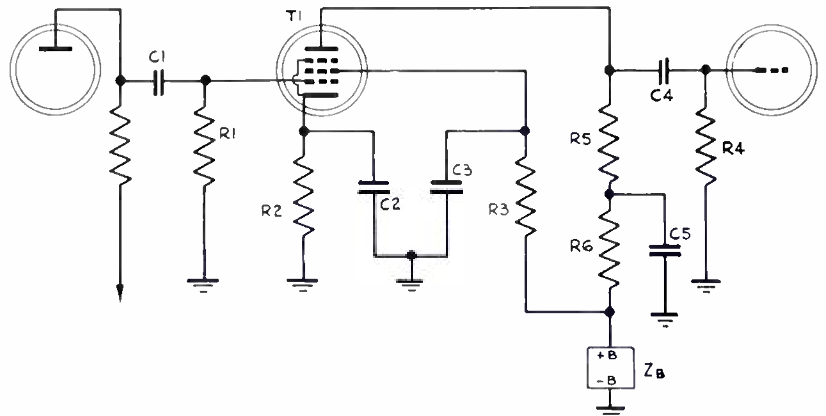


FIG. 5. *Amplifier stage with low frequency correction network (R_6-C_5).*

To correct for R_1-C_1 or R_4-C_4: Make the grid resistor (R_1 or R_4) as high as permissible; 500,000 ohms is a convenient value. Make the coupling condenser (C_1 or C_4) a nominal value such as .1 ufd. It is desirable to keep this value high but care must be taken to avoid making the capacity too large or trouble may be encountered from leakage and "hang over" effects. Now make the time constant of the grid resistor-condenser (R_1-C_1 or R_4-C_4) equal to the time constant of R_5-C_5 and make R_6 greater than 20 times the reactance of C_5 at the lowest frequency it is desired to pass. For example: If in Figure 5 we make R_4 equal 500,000 ohms, C_4 equal .1 ufd., R_5 equal 1000 ohms, and desire to provide correction to 30 cycles, then the time constant of R_4-C_4 will equal .05 seconds or 50,000 microseconds. Leaving the TC in us. will give our answer directly in ufds.

$$TC = RC = .1 \times 500{,}000 = 50{,}000$$

$$\text{and } C_5 = \frac{50{,}000}{1{,}000} = 50 \text{ ufd.}$$

and $R_6 > 20\, X_{C5}$ at 30 cycles $= 20 \times 106 = 2120$ ohms or greater.

What actually happens is that as the voltage across R_4 decreases, as a result of the rising reactance of C_4 (as the frequency is decreased), the reactance of C_5 also increases and as a consequence, the parallel impedance of C_5-R_6 is added to R_5 as part of the plate load impedance. Where the plate load is small in comparison to the plate resistance, the gain from grid to plate is given by:

$$A = G_m Z_p \qquad (Eq. 6)$$

where A is the stage gain,
G_m is the transconductance in mhos,
Z_p is the plate load impedance.

As we have made the time constants of C_4-R_4 and C_5-R_5 equal, the voltage across the plate load impedance will rise in proportion to the loss of voltage across C_4 and the voltage across R_4 will remain constant.

It might be pointed out that although at times it is expedient to make either C_4 or R_4 somewhat lower in value, such as to use a standard size capacitor for C_5, this should be done with caution. If the values of C_4 or R_4 are reduced, the amount of correction necessary is increased and errors become magnified. Good practice demands good design first so that minimum correction need be used.

If it is desired we may use C_5-R_6 to compensate for the frequency distortion of R_2-C_2 instead of R_1-C_1. To see how this can be done refer again to Figure 5. It has been previously shown that the impedance in the cathode circuit varies with frequency; and therefore, the AC voltage developed across this impedance will be, according to ohms law:

$$E = IZ \qquad (Eq. 7)$$

and, therefore, a function of frequency. This voltage will appear across the plate load resistor, R_5, amplified by the stage gain. Now the plate current flows through both R_2-C_2 and R_6-C_5, so the same kind of distortion will be generated in both circuits if the time constants are equal; but as the current flows through these networks in opposite directions, the distortion across R_5, resulting from R_2-C_2, will be cancelled by the distortion from C_5-R_6, if the distortion components are equal in magnitude. This condition is met when:

$$R_2\, C_2 = R_6\, C_5 \qquad (Eq. 8)$$

$$\text{and } \frac{C_2}{C_5} = \frac{R_6}{R_2} = A$$

where A equals the stage gain as defined in Equation 6 for pentodes and Equation 11 for triodes. For example, if we assign values of 200 ohms to R_2 (Figure 5), a nominal value of 100 ufd. to C_2, and a stage gain of 10, and wish to determine the value of C_5 and R_6, then:

$$\frac{C_2}{C_5} = \frac{100}{C_5} = 10 \text{ so } C_5 = 10 \text{ ufd.}$$

$$\frac{R_6}{R_2} = \frac{R_6}{200} = 10 \text{ so } R_6 = 2000 \text{ ohms}$$

The second condition may be checked by substituting in Equation 8:

$$200 \times 100 = 2000 \times 10$$
$$1 = 1$$

Therefore, both conditions have been met. There will be no frequency distortion from plate to ground resulting from R_2-C_2 and the phase delay will be proportional to frequency. However, more about the phase delay later.

We now find ourselves in the position of being able to make two of the four circuits causing low frequency distortion negligible and being able to compensate for either of the other two but not both. Now without compensating, as previously explained, the only way of minimizing the effects of the coupling efficiency of R_1-C_1 or R_4-C_4, Figure 5, is by increasing the values of either the resistor, condenser, or both. There are limits as to how far this can be carried, and generally the reactance of the coupling condenser cannot be kept low enough, at the lowest frequency, to give completely satisfactory results. So it is generally good practice to utilize C_5-R_6 to compensate for R_1-C_1 or R_4-C_4 and use other means to minimize the effects of R_2-C_2, Figure 5.

There are three methods generally used to accomplish this. First, eliminate R_2-C_2, ground the cathode directly, and apply fixed bias to the tube through the grid resistor. Second, eliminate the cathode by-pass condenser, C_2, and accept the consequent loss in stage gain. The gain will be reduced by the factor given in Equation 2; but the reduction in gain will be constant at all frequencies, so with other factors being equal there will be no low frequency distortion. The third method is to make C_2 very large and accept what comes out. This is not as bad as it sounds, since 1000 ufd. low voltage electrolytics are available at reasonable costs and certainly cost less than an additional stage which might be required to bring up the overall gain of the amplifier. The reactance of a 1000 ufd. condenser at 30 cycles is 5.31 ohms and in the average circuit will cause negligible distortion.

HIGH FREQUENCY ATTENUATION

As we have seen from the foregoing, there are four places, or networks, in the conventional amplifier at which the low frequency output may be restricted, and actually only one place that correction may be applied (the others however being made negligible). The opposite is true for the high frequency limitations. We have only one (or what may be summed up and treated as one) place, or network, responsible for the reduction of output at the higher frequencies (F_2 and higher in Figure 2), but we have a choice of several correction circuits. For an explanation, let's take another look at Figure 4. We have a resistance, R, in parallel with a capacity, C. The impedance of this network is given by:

$$Z = \frac{R \times X_c}{\sqrt{R^2 + X_c^2}} \qquad (Eq. 9)$$

and, therefore, the impedance Z will be a function of frequency. Now if we let R, Figure 4, represent the plate load resistance of an amplifier stage such as R_5 in Figure 1 and C represent the total shunt reactance across this load resistor such as C_T in Figure 1, we can calculate the effective load impedance for any frequency. Equation 6 shows that where the plate load impedance is much less than the plate resistance of the tube, the gain of the stage is directly proportional to the plate load impedance. In other words, if the G_m of a tube is 9,000 umhos and the load impedance is 1000 ohms, the gain would be 9; while if the load impedance were raised to 2000 ohms, the gain would be 18. It is this shunt reactance in parallel with the plate load resistor that limits the high frequency response of the amplifier. This reactance is composed (Figure 1) of the output capacity of T_1 plus the input capacity of T_2 plus the stray circuit capacity, and summed up as C_T.

CIRCUIT AND STRAY CAPACITIES

Before taking up the problem of compensating for this condition, methods for determining C_T should be discussed, as all systems of high frequency compensation depend upon accurate knowledge of this capacity.

The input capacity, C_{in}, of a tube is defined as the capacity from the grid to all other elements and the output capacity, C_{out}, of a tube as the capacity from the plate to all other elements. This is emphasized because of the usual practice in tube manuals of listing the static inter-element capacities of triodes and summing the capacities up into C_{in} and C_{out} for multi-grid tubes. A good reason for this is that the dynamic capacities of triodes are more subject to variations than screen-grid tubes. Therefore, when dealing with triodes, remember to add the grid-plate, C_{gp}, capacity to the plate-cathode, C_{pk}, capacity to determine the total output capacity, C_{out}; or for triodes,

$$C_{out} = C_{pk} + C_{gp}$$

In the case of a 6J5 where the tube manual lists C_{pk} as 3.6 uuf. and C_{gp} as 3.4, the output capacity will be $3.6 + 3.4 = 7.0$ uuf.

In determining the effective, or dynamic, input capacity of a triode, the "Miller Effect" must be considered. When a triode is acting as an amplifier, the grid and plate voltages are out of phase. That is, if the grid voltage is changed one volt in the positive direction and the gain is ten, the plate voltage will decrease ten volts. This gives a net change of eleven volts between the grid and plate and results in a capacity current in the grid circuit eleven times above the normal capacity current. This is known as the "Miller Effect," and from the above it can be seen that the dynamic input capacity is a function of the stage gain. The dynamic input capacity of a triode is given by:

$$C_{in} = C_{gk} + \left[C_{gp} (1 + A) \right] \qquad (Eq. 10)$$

where C_{in} is the dynamic input capacity,
C_{gk} is the capacity from grid to cathode,
C_{gp} is the capacity from grid to plate,
A is the stage gain.

From Equation 10 it is evident that the stage gain must be known before the dynamic input capacity can be determined. The gain of a triode is given by:

$$A = \frac{u Z_L}{Z_L + R_P} \qquad (Eq. 11)$$

where A is the stage gain,
u is the amplification factor of the tube,
Z_L is the plate load,
R_P is the plate resistance of tube.

For example, determine the stage gain and dynamic input capacity of a 6J5 working into a 20,000 ohm plate load. From the tube manual the plate resistance is 6700 ohms, u is 20, C_{gk} is 3.4 uuf., and C_{gp} is 3.4 uuf.

From Equation 11: $(Z_L = R_L)$

$$A = \frac{20 \times 2 \times 10^4}{2 \times 10^4 + 67 \times 10^2} = \frac{4 \times 10^5}{2.67 \times 10^4} \cong 15$$

From Equation 10:

$$C_{in} = 3.4 + \left[3.4\ (1 + 15) \right] = 3.4 + 54.4 = 57.8 \text{ uuf.}$$

which is quite an increase from the static capacities.

Where the load of a triode is in the cathode instead of the plate circuit, cathode follower stage, the dynamic input capacity is given by Equation 31 in the cathode follower section. The grid to cathode capacity C_{gk} of any amplifier tube is modified, where cathode degeneration exists, by the factor $1 + G_m R_k$ where the cathode is unby-passed, and $1 + G_m Z_k$ where the cathode is partially by-passed and Z_k given by Equation 4. This reduction factor is seen to be the same as for the reduction of gain with cathode degeneration.

$$C_{eff} \cong C_{gk} \frac{1}{1 + G_m Z_k} = \frac{C_{gk}}{1 + G_m Z_k} \qquad (Eq.\ 12)$$

where C_{eff} is the effective capacity grid to cathode, C_{gk}
C_{gk} is the grid to cathode capacity without degeneration,
G_m is the transconductance in mhos,
Z_k is the cathode impedance.

In a pentode if the screen is by-passed to the cathode the entire input capacity may be degenerated. This, however, reduces the effective shielding of the screen grid. For example, determine the dynamic input capacity of an 1852 with an unby-passed 160 ohm cathode resistor ($Z_k = R_k$).

From Equation 12:

$$C_{eff} = \frac{11}{1 + .009 \times 160} = \frac{11}{1 + 1.44} = \frac{11}{2.44} = 4.52 \text{ uuf.}$$

With the screen by-passed to ground the effective input capacity would be about 10% higher.

Determining the stray capacity is perhaps the hardest job. There are no hard and fast rules for determining these strays. Sometimes the capacity of individual components to ground are measured and summed up but generally they are estimated as close as possible, which may involve a bit of "cut and try." Nominal variations are usually compensated for in critical or very wide band amplifiers by making the "peaking coil" with a variable hi-permeability iron core and adjusting the inductance during alignment of the amplifier. A close approximation of the stray capacity is 10 to 15 uuf. in a well-designed layout.

Another method of determining C_T is by measuring the gain of an uncompensated amplifier stage, Figure 1, in the mid-frequency range (between F_1 and F_2, Figure 2) and then measuring the frequency at which the gain drops to 70.7% of the mid-frequency gain. This will be F_2 in Figure 2. In an uncompensated amplifier the magnitude of C_T that, with a given plate load resistor, will cause the gain of the amplifier to drop to 70.7% of the mid-frequency gain, F_2, Figure 2, is given by:

$$C_T = \frac{1}{2\pi F R} \qquad (Eq.\ 13)$$

where C_T is in farads,
F is in cycles,
R is in ohms.

Essentially this states that when the shunt reactance across the plate load resistor and the resistor are equal, the response will drop to 70.7% of the mid-range value (Equation 4).

For example, by using the circuit in Figure 1, with R_5 1000 ohms, and a wide range vacuum tube voltmeter connected from plate to ground. We could determine C_T by measuring the voltage across R_5, with a constant voltage input to the grid of T_1, around 2500 cycles and then increasing the frequency until the voltage was 70.7% of the initial value. This frequency can then be substituted in equation 13, and we can solve for C_T. The C_T thus determined will include the input capacity of the vacuum tube voltmeter and this vacuum tube voltmeter input capacity must be subtracted from the calculated C_T. In order to minimize errors on the input voltage to the grid of T_1, resulting from shunt reactance across the grid, R_1 should be made very low in value, 50 to 100 ohms, while making the measurements.

As a practical example, if we proceed as above and measure 10 volts across R_5 at 2500 cycles and 7.07 volts at 2mc., then substituting in equation 36:

$$C_T = \frac{10^{12}}{6.28 \times 2 \times 10^6 \times 10^3} = \frac{10^3}{12.56} = 79.6 \text{ uuf.}$$

But we must subtract from this capacity the capacity of the vacuum tube voltmeter and assuming the vacuum tube voltmeter capacity to be 22 uuf., C_T will equal 79.6 minus 22 or 57.6 uuf. This value will include all circuit and stray capacity, and may be used as the basis for calculating the high frequency compensation networks, as outlined later. When the peaking coil is added to the circuit, care should be used in its mounting to disturb the circuit as little as possible. A good practice is to have a peaking coil of the same physical size mounted in place *but shorted out* during the above measurements. If the peaking coil is placed as in Figure 6, the effect of the capacity to ground of the peaking coil is minimum.

HIGH FREQUENCY COMPENSATION

In low frequency compensation we found it necessary to make the plate load impedance, and consequently the voltage gain, rise in proportion to the loss in voltage across C_4, Figure 5. In high frequency compensation, however, it is necessary to keep the plate load impedance, and thus the stage gain, constant over the desired frequency range.

One way of accomplishing this is to add an inductive reactance to the plate load network to counteract the effect on impedance, of the change of capacitive reactance with frequency, of the shunt circuit and stray capacity. Such a network is shown in

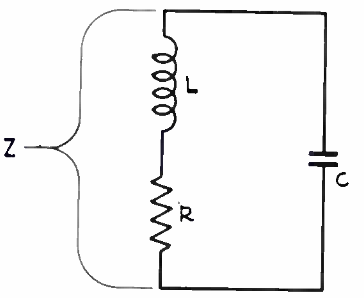


FIG. 6. *Basic shunt peaked network.*

Figure 6, and its impedance can be made essentially constant, from zero frequency up to any frequency where the network proportions are such that the reactance of C is equal to the resistance of R and twice the reactance of L. The impedance of this network is given by:

$$Z = X_c \sqrt{\frac{R^2 + X_L^2}{R^2 + (X_c - X_L)^2}} \qquad (Eq.\ 14)$$

Actually if a plot of impedance versus frequency is made, using the proportions above, it will be found that the impedance begins to rise at a frequency .2F where F is the chosen correction frequency and gradually rises as the frequency is increased to approximately .6F and then decreases, becoming equal to the low frequency impedance at F. The magnitude of this increase is about .5% at .2F and 3% at .6F. For example, if we assume F to be 5 mc., C to be 31.8 uuf., L to be 15.9 uh, and R to be 1000 ohms, the impedance, Figure 6, will be:

At 5 mc. $X_c = 1000$ ohms
$X_L = 500$ ohms

$$Z = 1000 \sqrt{\frac{10^6 + 25 \times 10^4}{10^6 \ (1000\text{-}500)^2}} = 1000 \sqrt{\frac{1.25 \times 10^6}{1.25 \times 10^6}}$$
$$= 1000 \sqrt{1} = 1000 \text{ ohms}$$

At 4.5 mc. $X_c = 1112$ ohms
$X_L = 450$ ohms

$$Z = 1112 \sqrt{\frac{10^6 + .2025 \times 10^6}{10^6 + (1112\text{-}450)^2}} = 1112 \sqrt{\frac{1.2025 \times 10^6}{1.43825 \times 10^6}}$$
$$= 1112 \sqrt{.834} = 1112 \times .913 = 1016 \text{ ohms}$$

At 3 mc. $X_c = 1668$ ohms
$X_L = 300$ ohms

$$Z = 1668 \sqrt{\frac{10^6 + 9 \times 10^4}{10^6 + (1668\text{-}300)^2}} = 1668 \sqrt{\frac{1.09 \times 10^6}{2.87155 \times 10^6}}$$
$$= 1668 \sqrt{.37966} = 1668 \times 616165 = 1027 \text{ ohms}$$

At 1 mc. $X_c = 5000$ ohms
$X_L = 100$ ohms

$$Z = 5000 \sqrt{\frac{10^6 + 10^4}{10^6 + 24.01 \times 10^6}} = 5000 \sqrt{\frac{1.01 \times 10^6}{25.01 \times 10^6}}$$
$$= 5000 \sqrt{.040384} = 5000 \times .201 = 1005 \text{ ohms}$$

This plate load network is a parallel resonant circuit of very low Q and we are actually working along the resonance curve. By increasing the correction frequency, F, the linearity over a desired frequency range can be made almost perfect at a sacrifice of gain. Design data for this is covered under "Shunt Peaking."

Generally speaking, high frequency compensation of amplifiers is based upon wave filter theory, and the more complex the filter used, the higher the gain. The more complex types of filters are usually used where highest possible gain or very sharp cut-off characteristic are of prime importance. The most widely used types of high frequency compensation are:

1. Shunt Peaking
2. Series Peaking
3. Combination or Series-Shunt Peaking

The gain of the different types are in the order listed above, with series peaking giving 50% more gain than shunt peaking and combination peaking giving 80% more gain than shunt peaking. Combination peaking is widely used as the best compromise between maximum gain and simplicity.

SHUNT PEAKING

Referring to Figure 7, there are three components which we are interested in, in order to extend the high frequency range of the stage.

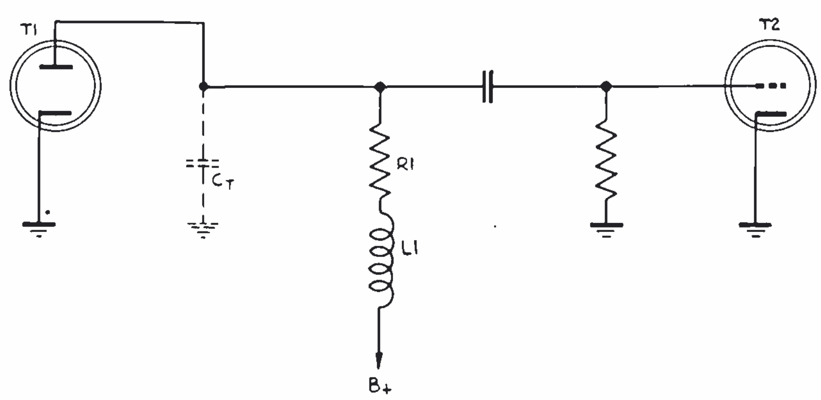


FIG. 7 *Shunt peaked stage.*

These are labeled C_T, R_1, and L_1. C_T can be determined by the methods previously outlined. R_1 is made equal to the reactance of C_T at the highest frequency of correction. Let us label this frequency F_c; then:

$$R_1 = X_{C_T} \text{ at } F_c \qquad \textit{(Eq. 15)}$$

And L_1 is such that its reactance at F_c is one-half of X_{C_T} at F_c, or:

$$X_{L_1} = \frac{X_{C_T}}{2} \text{ at } F_c \qquad \textit{(Eq. 16)}$$

or

$$L_1 = \frac{R_1}{4\pi F_c} \qquad \textit{(Eq. 17)}$$

For example, suppose it is desired to extend the bandwidth of the stage in Figure 7 to 5 megacycles and C_T was 25 uuf. Then:

$$X_{C_T} = \frac{1}{6.28 \times 5 \times 10^6 \times 25 \times 10^{-12}} = \frac{10^6}{785} = 1273 \text{ ohms}$$

Therefore, R_1 equals 1273 ohms (Equation 15) and:

$$L_1 = \frac{1273}{12.56 \times 5 \times 10^6} = \frac{1273}{62.8 \times 10^6} = 20.3 \times 10^{-6} \text{ henries}$$
$$L_1 = 20.3 \text{ uh.}$$

The stage gain, given by Equation 6, assuming T_1 to be an 1852, will be 1273 times .009 or 11.45. Equations 15, 16 and 17 are satisfactory for shunt peaking where only one or two stages are required. Actually the response, using these formulae, at F_c is the same as the low frequency response, but there is about a 3% rise in output somewhat lower in frequency than F_c. Shunt peaking can be made nearly perfect if F_c is made about 40% greater than the highest correction frequency desired. As this would result in a reduction in gain of 30%, an accepted compromise is to design for a reduction in gainof 15%.

If a conservative design is desired, or several stages are to be cascaded, the following formulae may be used. Still referring to Figure 6, Equation 15 may be replaced by:

$$R_1 = .85 \ X_{C_T} \text{ at } F_c \qquad \textit{(Eq. 18)}$$

and Equation 17 may be replaced by:

$$L_1 = \frac{.3}{(2\pi F_c)^2 C_T} \qquad \textit{(Eq. 19)}$$

If we recalculate the previous example, R_1 and L_1 would be:

$$R_1 = .85 \times 1273 \cong 1080 \text{ ohms}$$

$$L_1 = \frac{.3}{(6.28 \times 5 \times 10^6)^2 25 \times 10^{-12}} = \frac{.3}{(3.14 \times 10^7)^2 25 \times 10^{-12}}$$
$$= \frac{3 \times 10^5}{9.85 \times 2.5 \times 10^3} = \frac{300}{24.6} = 12.2 \text{ uh.}$$

and the stage gain will be $.009 \times 1080 = 9.72$.

SERIES PEAKING

The basic circuit of a series peaked stage is shown in Figure 8.

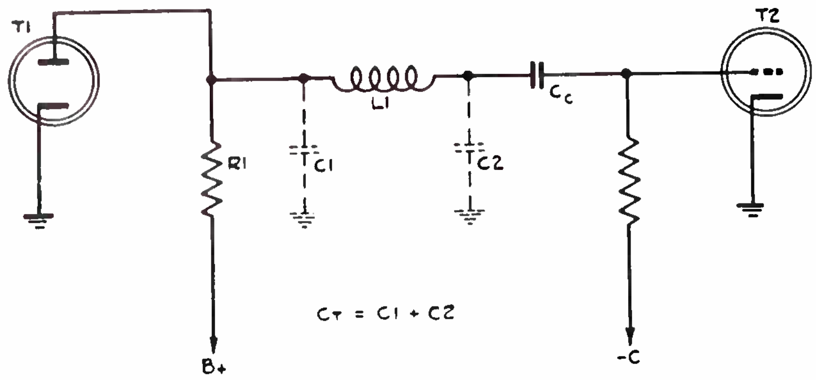


FIG. 8. *Series peaked stage.*

Here again we are interested in three components, L_1, R_1, and C_T, broken down into C_1 and C_2. C_T can be determined by the methods previously outlined; but in addition to knowing C_T, we want a 2/1 ratio between C_1 and C_2, although the ratio may be reversed by moving R_1 to the opposite side of the coil L_1, Figure 8. The rule is to keep the load resistor on the low capacity side of the filter. (See Figure 9.)

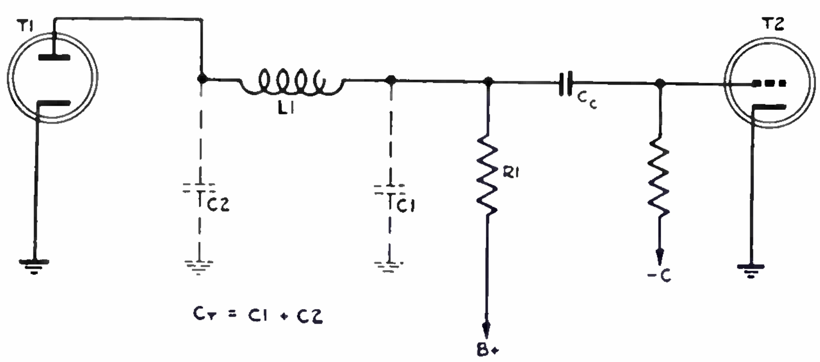


FIG. 9. *Series peaked stage.*

Usually, with a bit of juggling, the ratios may be kept close to 2/1. For instance, the coupling condenser, C_c, could be moved to the plate side of L_1, Figure 8, thus shifting the capacity to ground of C_c from C_2 to C_1. Referring to Figures 8 or 9:

$$C_T = C_{out} \text{ of } T_1 + C_{in} \text{ of } T_2 + C_{stray} = C_1 + C_2 \qquad \textit{(Eq. 20)}$$

$$C_2 = 2C_1 \qquad \textit{(Eq. 21)}$$

$$R_1 = 1.5 \times X_{C_T} \text{ at } F_c \qquad \textit{(Eq. 22)}$$

$$L_1 = \frac{1}{2(\pi F_c)^2 C_1} = .67\ C_T\ R_1^2 \qquad \textit{(Eq. 23)}$$

In using Equation 23, it is suggested that the second portion be used, that is, where C_T is used to determine L_1, because C_T is more important than the division of C_1 and C_2 in the compensation network and in all probability less error will be made in determining C_T than C_1.

For example let us calculate R_1, L_1, and the stage gain of Figure 8, assuming T_1 to be an 1852, F_c to be 5 mc., and C_T to be 30 uuf., with $C_2 = 2C_1$.

Then from Equation 22:

$$R_1 = 1.5\ X_{C_T} = 1.5 \times 1060 = 1590 \text{ ohms}$$

And from Equation 23:

$$L_1 = .67 \times 30 \times 10^{-12} \times 1590 = 51 \times 10^{-6} \text{ henries}$$
$$L_1 = 51 \text{ uh.}$$

And the stage gain will be:

$$A = G_m Z_p = .009 \times 1590 = 14.3$$

The series peaked network is characterized by a sharper cutoff and a more linear phase characteristic than the shunt peaked network.

SERIES-SHUNT OR COMBINATION PEAKING

Combination peaking, as its name implies, is a combination of shunt and series peaking and has a still sharper cutoff than series peaking. Here again our problem is similar to series peaking in that a 2 to 1 division of the capacity C_T is required for best performance of the stage. The same rule applies on the location of the load resistor; that is, place the load resistor on the low capacity side of L_2. (See Figures 10 and 11.)

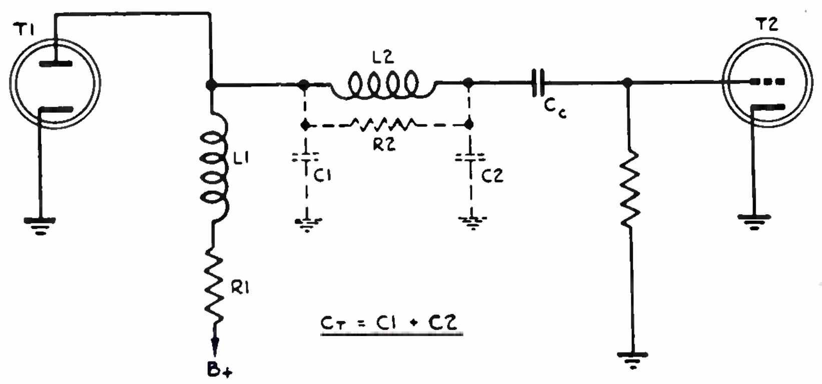


FIG. 10. *Combination peaked stage.*

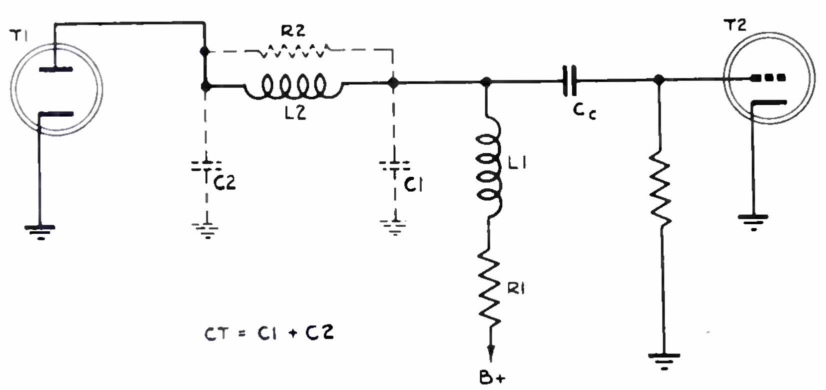


FIG. 11. *Combination peaked stage.*

R_1 and L_1 may be reversed, and usually it is desirable to do this as the stray capacity, which composes part of C_1 and C_2, would be smaller with a resistor connected to either side of L_2 than if L_1 were so connected (smaller physical size, primarily).

Referring to Figures 10 or 11, the design critera for combination peaking is:

$$C_T = C_1 + C_2$$

$$C_2 = 2C_1$$

$$L_1 = .12 \times C_T \times R_1^2 \qquad \textit{(Eq. 24)}$$

$$L_2 = .52 \times C_T \times R_1^2 \qquad \textit{(Eq. 25)}$$

$$R_1 = 1.8\ X_{C_T} \text{ at } F_c \qquad \textit{(Eq. 26)}$$

If required, start with $R_2 \cong 5R_1$ by experiment.

A high distributed capacity in coil L_2 or improper ratio between C_1 and C_2 may cause a rise in response in the higher frequency portion of the pass-band. This rise can usually be flattened out by the addition of the resistor R_2, Figures 10 and 11, to lower the Q of L_2. The exact value will have to be determined by experiment in each case. A good starting value is about five times the value of the plate load resistor.

As an example, suppose we use the same specifications we used in the example for series peaking, in calculating L_1, L_2, and R_1, Figure 10.

From Equation 26:

$$R_1 = 1.8 \times 1060 = 1908 \text{ ohms}$$

From Equation 24:

$$L_1 = .12 \times 30 \times 10^{-12} \times 3.64 \times 10^6 = 13.1 \times 10^{-6} \text{ H.} = 13.1 \text{ uh.}$$

From Equation 25:

$$L_2 = .52 \times 30 \times 10^{-12} \times 3.64 \times 10^6 = 56.7 \times 10^{-6} \text{ H.} = 56.7 \text{ uh.}$$

And the stage gain is: $A = .009 \times 1908 = 17.17$.

THE HIGH PEAKER STAGE

One problem usually encountered in transferring the video voltage output of an Iconoscope into the grid of the first amplifier stage is that of getting the maximum signal to noise ratio. The most satisfactory method for accomplishing this is to provide the highest possible signal input into the grid of the first amplifier stage without regard for frequency distortion, then carefully preserve this distorted signal while it is being amplified in one or two stages, and finally introducing a complementary network that gives equal and opposite distortion to that generated by the input network. With frequency components from 30 cycles to about 4 mc. in the output signal of an Iconoscope, developed across R_2 in Figure 12, it is readily seen that the shunt reactance of C_1 will severely limit the high frequency components.

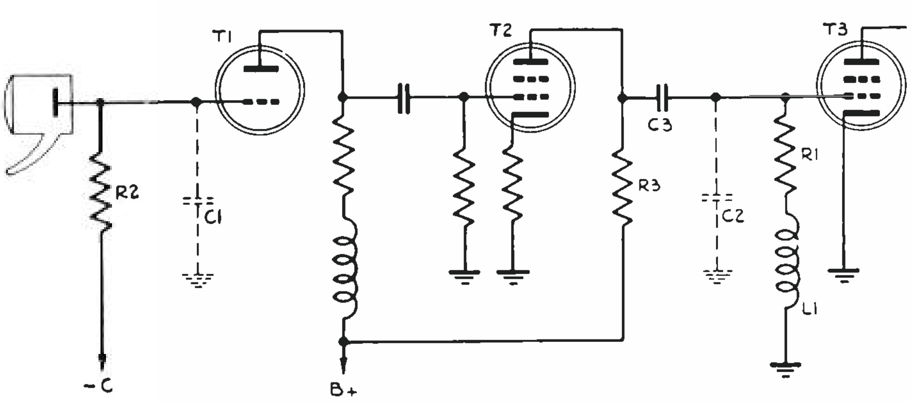


FIG. 12. *"Hi-Peaker" stage.*

If the linearity is preserved, that is, compensating as previously outlined between T_1 and T_2, to keep intact this distorted waveform, we can insert the network R_1-L_1 as the load for T_2. This network is complementary to the network R_2-C_1, and has the opposite impedance and phase characteristic, provided the time constants are equal. The time constants will be equal when:

$$R_2 \, C_1 = \frac{L_1}{R_1}$$

A stage with this type of correction is called a "High Peaker" stage, and the design data are:

C_1 = total ckt. and stray capacity (input stage)

C_2 = total ckt. and stray capacity (hi-peaker stage)

R_2 = nominally 100,000 ohms

$$R_3 > 10 \times X_{L_1} \text{ at } F_c \qquad (Eq. 27)$$

$$X_{C_3} < .1 \, R_3 \text{ at lowest frequency} \qquad (Eq. 28)$$

$$R_1 = \frac{L_1}{R_2 \, C_1} \text{ where R = ohms, L = uhenries, C = ufds.} \qquad (Eq. 29)$$

$$L_1 = \frac{25.33 \times 10^3}{(2 \, F_c)^2 \times C_2} \qquad (Eq. 30)$$

where L is in uh.,

C is in uuf.,

F is in mc.

Thus, with Equations 27, 28, 29 and 30, we can design a satisfactory compensating network. Equation 30 shows that the resonant frequency of L_1-C_2 is twice the cutoff frequency, F_c.

For an example let's determine L_1, R_1, R_3, and C_3 of Figure 12, assuming C_1 to be 12 uuf. and C_2 to be 30 uuf., F_c is 5 mc., and 30 cycles the lowest frequency.

From Equation 30:

$$L_1 = \frac{25.33 \times 10^3}{10^2 \times 30} = \frac{253.3}{30} = 8.43 \text{ uh.}$$

From Equation 29:

$$R_1 = \frac{L_1}{R_2 \times C_1} = \frac{8.43}{10^5 \times 12 \times 10^{-6}} = \frac{843}{12} = 7.25 \text{ ohms}$$

From Equation 27:

$$R_3 > 10 \times 6.28 \times 5 \times 10^6 \times 8.43 \times 10^{-6} = 2650 \text{ ohms or greater}$$

From Equation 28:

$$X_{C_3} = < .1 \times 2650 = 265 \text{ ohms or less}$$

$$C_3 = 20 \text{ ufd. or more}$$

And the stage gain, if T_2 is an 1852, will be:

$$A = .009 \times 7.25 = .06525$$

From this it is apparent that the stage is operating at a loss, but the actual overall voltage output will be greater than if we had used a much lower value for R_2 in an attempt to preserve the high frequency response into T_1; also the signal to noise ratio will be better.

PHASE CHARACTERISTICS

These correction circuits will provide essentially flat frequency response to F_c and a phase shift proportional to frequency; or saying it another way, the time delay is independent of frequency. Up to now little has been said of the phase characteristic of amplifiers. The phase characteristic is relatively unimportant in amplifiers designed for audio work, as the human ear is very insensitive to phase distortion, but becomes very important in video work or wherever complex waves are to be amplified without distortion. Without going too deeply into the subject of complex waves, which is beyond the scope of this article, every complex wave is composed of the fundamental frequency and any number of harmonics, having various phase relationship with each other, and whose amplitude and phase may be expressed by a Fourier Series. To see why it is important that the phase shift be proportional to frequency, that is, the second harmonic should be delayed twice as much as the fundamental, the third harmonic three times, etc., let's take a look at Figure 13.

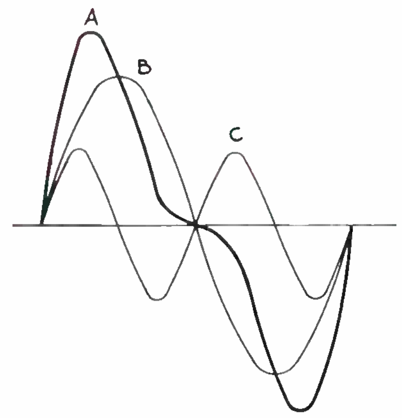


FIG. 13. *Complex wave with components in phase.*

Wave A is a complex wave composed of the fundamental wave B and the second harmonic C in phase. If the wave A is passed through an amplifier that delayed waves B and C the same amount, for instance 30°, the wave shape would be as shown in Figure 14.

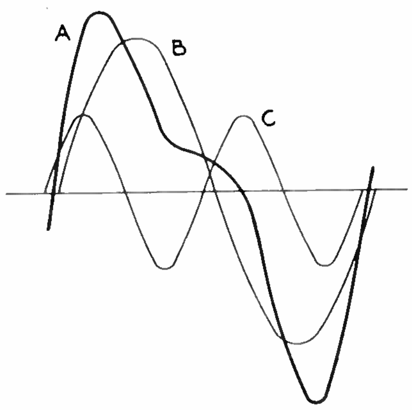


FIG. 14. *Complex wave after both component waves are delayed 30°.*

Wave C goes through two cycles, 720 electrical degrees, while wave B goes through one cycle, 360 electrical degrees; or to put it another way, with respect to time, wave C is traveling twice as fast as wave B. Therefore, if both waves are delayed 30°, wave C will be ready to repeat its cycle 50% sooner than wave B; or with respect to wave B, wave C will be advanced in phase. When these two waves are summed up, with the altered phase relationship, we will get wave A in Figure 14. Compare this with wave A in Figure 13. Both are composed of the same two frequencies, only the phase relationship has been changed. If the phase characteristic of the amplifier is proportional to frequency, the wave coming out of the amplifier would be the same shape as the input wave, provided the frequency response is uniform. As a point of interest, the shorter the pulse, the greater the number of harmonics present and the wider the bandwidth of the amplifier required to pass the pulse without distortion. A single impulse of infinitesimal duration contains all frequencies from zero to infinity of equal amplitude.

CATHODE FOLLOWERS

Cathode follower is the name given to a stage when the load is in the cathode instead of the plate circuit. This type of circuit finds its widest use in video work as an impedance changing device. As the output voltage of an amplifier taken from the plate circuit is at a comparatively high impedance, unless changed by an impedance changing device such as a transformer, securing a proper match into a transmission line of nominal impedance is therefore somewhat of a problem. This is especially true in video work where a wide frequency range is encountered, and the design of a transformer with flat output from 30 cycles to 4 or 5 mc. presents quite a few difficulties. The simplicity and low cost of the cathode follower is primarily responsible for its popularity. Either pentodes or triodes may be used and a conventional circuit for each is shown in Figures 15 and 16 respectively.

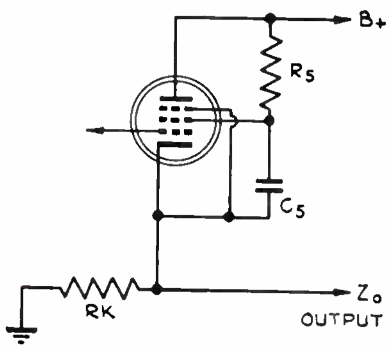


FIG. 15. *Pentode cathode follower.*

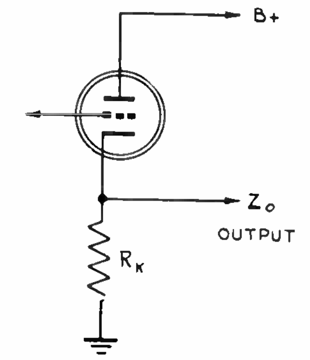


FIG. 16. *Triode cathode follower.*

Both the input conductance and the grid to cathode capacity of the tube in a cathode follower stage are modified by the factor

$$\frac{1}{1 + G_m R_k}.$$

The pentode cathode follower stage is used in preference to the triode in applications where the lower input capacity or a higher output voltage is desired. The effective internal impedance of the tube is the reciprocal of the grid to plate transconductance in mhos and must be added in parallel to the cathode resistor to determine the output impedance, Z_o, Figures 15 and 16.

In a triode cathode follower stage, Figure 16, the dynamic input capacity is given by:

$$C_{eff} = \frac{C_{gk}}{1 + G_m R_k} + C_{gp} \qquad (Eq.\ 31)$$

and if a pentode is used, as in Figure 15, the dynamic input capacity will be:

$$C_{eff} = \frac{C_{in}}{1 + G_m R_k} \qquad (Eq.\ 32)$$

And the stage gain is given by:

$$A = \frac{G_m R_k}{1 + G_m R_k} \qquad (Eq.\ 33)$$

The effective output impedance, Z_o, is given by:

$$Z_o = \frac{\dfrac{1}{G_m \times R_k}}{\dfrac{1}{G_m + R_k}} \qquad (Eq.\ 34)$$

From Equation 33 it can be seen that the stage always operates with a gain of less than 1 and the higher the value of R_k the closer to unity the gain becomes. The circuit in Figure 17 is sometimes used to secure higher output voltages.

In this circuit R_k is divided into two parts, R_1 and R_2, arranged so the dc voltage drop across R_1 is equal to the required grid bias, and as the grid is returned to the junction of R_1 and R_2, the correct bias will be obtained; the G_m will not change, but R_k will be increased and thus the voltage output (Equation 33). Similarly Z_o will be changed (Equation 34).

For example let's determine the effective input capacity, stage gain, and effective output impedance of an 1852 cathode follower stage with a 160 ohm cathode resistor. From the tube manual, C_{in} is 11 uuf. and the G_m is 9,000 umho's (.009 mho).

From Equation 31:

$$C_{In} = \frac{11}{1 + .009 \times 160} = \frac{11}{2.44} = 4.52 \text{ uuf.}$$

From Equation 33:

$$A = \frac{.009 \times 160}{1 + .009 \times 160} = \frac{1.44}{2.44} = .59$$

From Equation 34:

$$\left(\frac{1}{G_m} = \frac{1}{.009} = 111 \right) \quad Z_o = \frac{111 \times 160}{271} = 65.7 \text{ ohms}$$

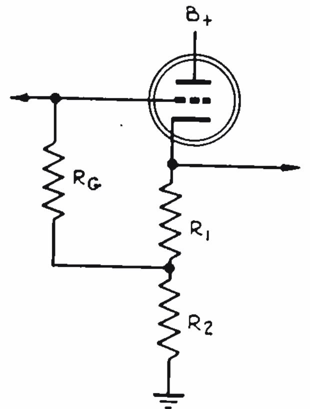


FIG. 17. *Cathode follower with Z_o matched to load.*

By using the arrangement in Figure 17, we could get a perfect match into a 72 ohm line by leaving R_1 equal to 160 ohms and by making R_2 equal to 45 ohms. The gain, A, and Z_o would be then:

$$\text{unloaded— } A = \frac{.009 \times 205}{1 + .009 \times 205} = \frac{1.845}{2.845} = .648$$

$$\text{loaded— } A = \frac{.009 \dfrac{72 \times 205}{72 + 205}}{1 + .009 \dfrac{72 \times 205}{72 + 205}}$$

$$= \frac{.009 \times 54.7}{1 + .009 \times 54.7} = \frac{.492}{1.492} = .33$$

With a normal bias of 3 volts on the grid, the maximum voltage output would be 3 X .33 or .99 peak volts. In terms of peak to peak voltage, and assuming the grid swing was from 0 to 6 volts, the output would be 1.98 volts peak to peak.

The output impedance will be:

$$Z_o = \frac{111 \times 205}{316} = \frac{22755}{316} = 72 \text{ ohms}$$

DESIGN HINTS

It is evident, from the foregoing design data, that the limiting factor, in securing good high frequency response, is the shunt reactance across the plate load resistor and that this shunt reactance has a direct bearing on the gain of the amplifier. Therefore, good practice demands that every effort be made to keep the stray and circuit capacity at a minimum. A well-designed layout and careful planning will pay big dividends.

The practice of placing a small paper or mica condenser across a large electrolytic by-pass condenser to by-pass the high frequencies is sometimes dangerous, as far as flat frequency response is concerned. The inductance of the electrolytic and the paper or mica condenser may form a parallel resonant circuit; and this may cause either an increase or decrease in the gain, depending on the location of the network, at its resonant frequency.

Care should be used in selecting resistors as there is a wide variation in the high frequency characteristics between the products of different manufacturers. Wire wound resistors for plate loads should be used with extreme caution. The inductance and distributed capacity may be quite high and upset the network.

When triodes are used in wide band amplifiers where the required plate load is comparable to the plate resistance of the tube, the plate resistance should be considered in selecting the plate load resistor value. The plate load resistor should be of such a value that when it is in parallel with the plate resistance of the tube, the resistance of the combination will equal the calculated value. For example, if a 6J5 is used and the calculated load resistance is 1000 ohms, a plate load resistor of 1175 ohms would be used.

$$R = \frac{1000 \times 6700}{6700 - 1000} = 1175 \text{ ohms}$$

In critical applications, generally, the peaking coils are made with a moveable hi-permeability iron core for adjusting the inductance to take care of un-predictable minor variations in circuit and stray capacities. The gain-frequency characteristic of the amplifier may be checked with a good grade signal generator supplying the constant voltage input and a wide range vacuum tube voltmeter for monitoring the output. The response of the amplifier may be observed visually using a video sweep generator and a wide range oscilloscope.

A standard oscilloscope may be used in place of the wide range oscilloscope by inserting a linear detector between the amplifier and oscilloscope input and using a sinusoidal voltage equal to the sweep frequency for the time base.

ATTENUATORS

The effects of the circuit and stray capacities, C_1, C_2, and C_3 in Figure 18a are negligible at audio frequencies but become

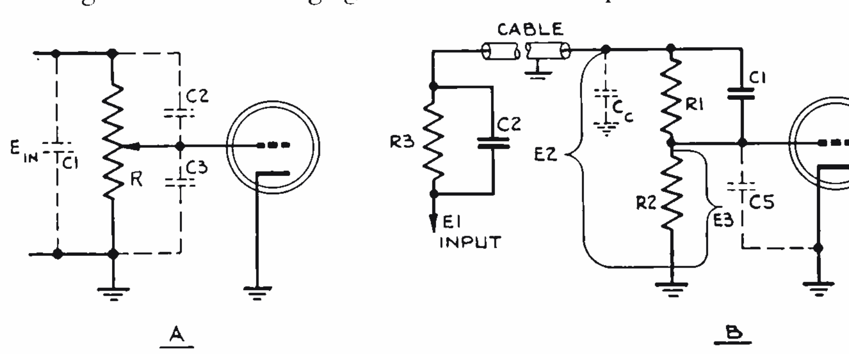


FIG. 18. *Attenuating systems.*
A. *Uncompensated.* B. *Compensated.*

increasingly important as the frequency is increased. At video frequencies they cause reduced input impedance as well as frequency and phase distortion. The frequency and phase distortion, and to a certain extent, the input impedance will vary with the position of the slider on R. This condition can be remedied by use of a compensated step type attenuator. Figure 18b is a schematic of the basic circuit of an input cable and attenuator system generally used on wide range oscilloscopes.

Ignoring the input cable for the moment, the ratio of output voltage, E_3, to the input voltage of the attenuator, E_2, will be independent of frequency if the time constants of R_1-C_1 and R_2-C_s are made equal. As C_s is the sum of circuit and stray capacities, and thus fixed, the design procedure is to set the values of R_1 and R_2 for the voltage ratio desired, and then make C_1 such value that:

$$TC = R_1 C_1 = R_2 C_s \text{ or } C_1 = \frac{R_2 C_s}{R_1} \qquad (Eq. 35)$$

This means that a different value of C_1 will be required for each step of the attenuator; and since, as will be explained below, it is desirable to keep the total resistance of R_1 and R_2 constant, these values will have to be changed for each step also.

It is generally desirable to load the circuit supplying the signal voltage as little as possible. Yet means must, however, be provided for making connection to the signal voltage source, and a low capacity cable with an isolation resistor in the probe is usually satisfactory. Even with so-called low capacity cable, the capacity of a five foot section plus fitting and circuit capacity is considerable at video frequencies.

The voltage division can be made independent of frequency in the same manner as outlined for the attenuator. That is, by considering R_1 and R_2 as one resistor and summing up the cable and fitting capacity together with the effective capacity of C_1 and C_s in series, as one capacity, C_e, and then adding the capacity C_2, across the isolation resistor, R_3, making its value such that the time constants of R_3-C_2 and $(R_1 + R_2)$—C_e are equal. This is the same as Equation 35. This will mean, of course, that

E_2 will become $\dfrac{R_1 + R_2}{R_1 + R_2 + R_3} \times E_1$ but by making the

reduction a factor of 10 and increasing the gain of the amplifier by the same factor, our overall gain remains the same and we have secured a coupling and attenuating system that has a high input impedance and gives minimum distortion of the wave shape of the signal. The effective input impedance will be a resistance equal to $R_1 + R_2 + R_3$ with a parallel capacity equal to C_2 and C_e in series and may be calculated for any frequency by Equation 4. For example, if we wished to have E_3, Figure 18b, one-tenth of E_2, and E_2 one-tenth of E_1, and C_s is 50 uuf. with C_e being 200 uuf., we could proceed with design by making:

$R_2 =$ 10,000 ohms

$R_1 =$ 90,000 ohms

$R_3 =$ 900,000 ohms

$$C_1 = \frac{R_2 C_s}{R_1} = \frac{10^4 \times 50}{9 \times 10^4} = \frac{50}{9} = 5.56 \text{ uuf.}$$

$$C_2 = \frac{(10^4 + 9 \times 10^4) 200}{9 \times 10^5} = \frac{2 \times 10^7}{9 \times 10^5} = \frac{200}{9} = 21.1 \text{ uuf.}$$

And the input impedance will be one megohm with 19 uuf. in shunt (21.1 and 200 uuf. in series). By always keeping the total resistance of R_1 and R_2 equal to 100,000 ohms one setting of C_2 would be correct for any setting of the attenuator.

SUMMARY

As a final summary, the following three design charts have been prepared. There is one chart for compensated stages using Shunt high frequency peaking, one for Series high frequency peaking, and one for Combination high frequency peaking. Low frequency compensation data is included on each to keep each chart complete in itself.

Of the numerous reference sources used in writing this article, the author desires to give special mention to lecture notes of Mr. T. M. Gluyas of RCA, on the subject of "Generation and Application of Non-Sinusoidal Waves."

DESIGN CHART NO. 1

Compensated stage with shunt high frequency peaking.

Gain $= G_m R_L$

$C_T = C_{pk} + C_{gk}$ of T_1 and T_2 respectively + wiring capacity

$F_C =$ highest frequency of correction

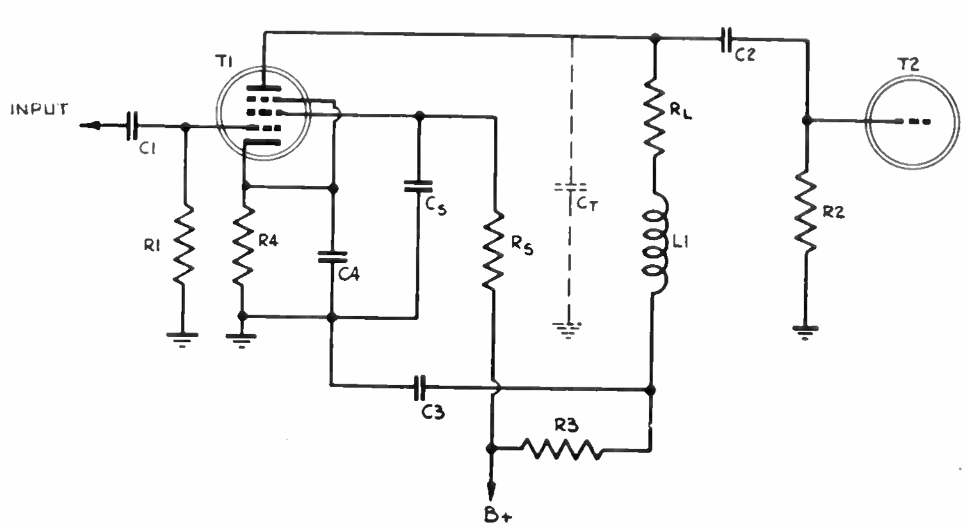
$F_1 =$ lowest frequency of correction

$$\left.\begin{aligned} R_L &= X_{C_T} \text{ at } F_C \\ L_1 &= \frac{R_L}{4\pi F_C} \end{aligned}\right\} \text{General}$$

$$\left.\begin{aligned} R_L &= .85\, X_{C_T} \text{ at } F_C \\ L_1 &= \frac{.3}{(2\pi F_C)^2 C_T} \end{aligned}\right\} \text{Conservative}$$

$$X_{C_S} < \frac{2}{G_m} \text{ at } F_1$$

$$R_S > \frac{3/F}{C_S} \text{ at } F_1$$



To compensate for R_1—C_1 or C_2—R_2

$$C_3 = \frac{C_2 R_2}{R_L}$$

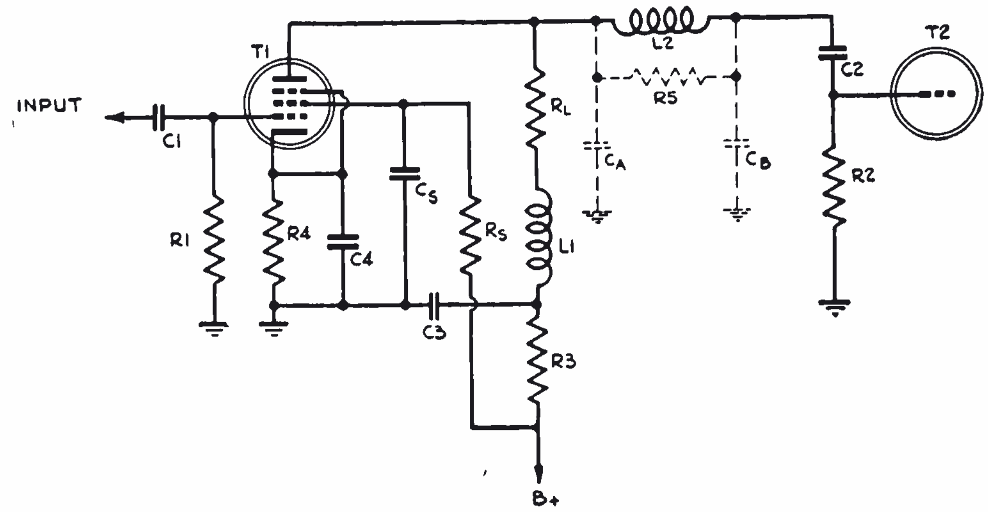
$R_3 > 20\, X_{C_3}$ at F_1

To compensate for R_4—C_4

$$R_4 C_4 = R_3 C_3 \text{ and } \frac{R_3}{R_4} = \frac{C_4}{C_3} = G_m R_L$$

DESIGN CHART NO. 2

Compensated stage with series high frequency peaking.



$$\text{Gain} = G_m R_L$$

$$C_T = C_A + C_B$$

$$C_B = 2\ C_A$$

$$F_C = \text{highest frequency of correction}$$

$$F_1 = \text{lowest frequency of correction}$$

$$R_L = 1.5\ X_{C_T} \text{ at } F_C$$

$$L_1 = .67\ C_T R_L^2$$

$$X_{C_S} < \frac{2}{G_m} \text{ at } F_1$$

$$R_S > \frac{3/F}{C_S} \text{ at } F_1$$

To compensate for R_1—C_1 or R_2—C_2

$$C_3 = \frac{C_2 R_2}{R_L}$$

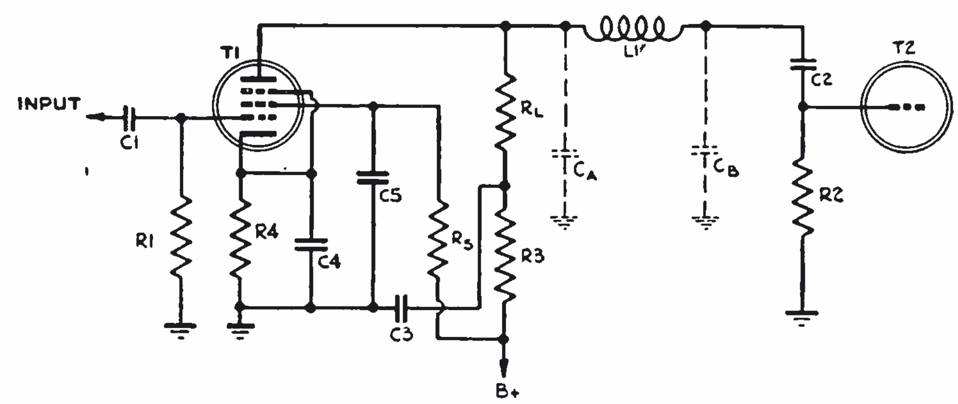
$$R_3 > 20\ X_{C_3} \text{ at } F_1$$

To compensate for R_4—C_4

$$R_4 C_4 = R_3 C_3 \text{ and } \frac{R_3}{R_4} = \frac{C_4}{C_3} = G_m R_L$$

DESIGN CHART NO. 3

Compensated stage with combination high frequency peaking.



$$\text{Gain} = G_m R_L$$

$$C_T = C_A + C_B$$

$$C_B = 2\ C_A$$

$$F_C = \text{highest frequency of correction}$$

$$F_1 = \text{lowest frequency of correction}$$

$$R_L = 1.8\ X_{C_T} \text{ at } F_C$$

$$L_1 = .12\ C_T R_L^2$$

$$L_2 = .52\ C_T R_L^2$$

$$X_{C_3} = \frac{2}{G_m} \text{ at } F_1$$

$$R_S > \frac{3/F}{C_S} \text{ at } F_1$$

$$R_5 \cong 5\ R_L \text{ by experiment}$$

To compensate for R_1—C_1 or R_2—C_2

$$C_3 = \frac{C_2 R_2}{R_L}$$

$$R_3 > 20\ X_{C_3} \text{ at } F_1$$

To compensate for R_4—C_4

$$R_4 C_4 = R_3 C_3 \text{ and } \frac{R_3}{R_4} = \frac{C_4}{C_3} = G_m R_L$$

ELECTRONIC TELEVISION IS AN RCA DEVELOPMENT

This is the third of a series of advertisements showing that RCA engineers developed the basic essentials of the electronic television system—*including tubes and circuits.*

RCA built the first all-electronic television transmitters and receivers — the first commercial television station — established the first television relay system — presented the first electronic theatre television — was the first to televise a baseball game, and a Broadway play; and was first to televise from an airplane.

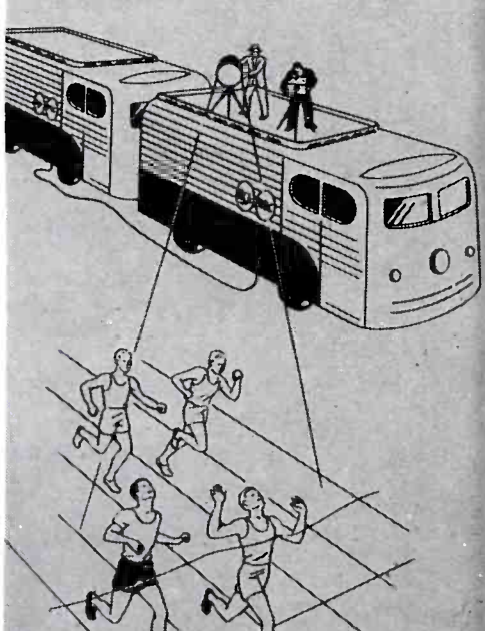
RCA is, and will continue to be, the leader in practical, successful commercial television. You may expect the best of all kinds of television transmitting and receiving equipment from RCA.

BUY WAR BONDS

3. THE ORTHICON

IN a paper presented before the New York Section of the I.R.E., June 7, 1939, Albert Rose and Harley Iams, of the RCA Research Laboratories, announced the Orthicon, a new television pick-up tube. In its issue of the following month this tube was characterized by *"Electronics"* as ". . . one of the most significant advances in television electronics since the advent of the Iconoscope itself . . . A new and greatly improved form of the Iconoscope, using low-velocity electrons for scanning, thereby avoids spurious signals, obtains storage efficiency ten to twenty times that of the Iconoscope, and produces an output current linearly related to the light input."

With this tube, storage efficiency was stepped up to almost 100 per cent, compared to 5 to 10 per cent previously obtained, and overall sensitivity increased 20 times. The practical effect of this tube was to free television from the limitations of the studio and its artificial lighting, and make the whole world of living events a stage for television.



The Fountainhead of Modern Tube Development is RCA

RADIO CORPORATION OF AMERICA

RCA VICTOR DIVISION • CAMDEN, NEW JERSEY

In Canada, RCA VICTOR COMPANY LIMITED, Montreal

You can use the NEW VOLTOHMYST for checking FM Discriminator Alignment

(A ZERO-CENTER-INDICATOR IS INCORPORATED FOR THIS PURPOSE)

—and you can also use the 195-A Voltohmyst

As an ELECTRONIC D-C VOLTMETER

Measures d-c Voltage to 1000 volts in six ranges—has high resistance input of 10 megohms constant on all ranges—plus isolation resistor in probe for dynamic socket voltage readings—polarity turnover switch eliminates confusion in reversing test leads—positive and negative indications are individually calibrated.

As an ELECTRONIC OHMMETER

Measures Resistance up to 1000 megohms with internal source of only 3 volts—six resistance ranges indicating from .1 ohm with shielded cable—zero resetting unnecessary with change of range—all ranges are indicated on "OHMS" scale.

As an ELECTRONIC A-C VOLTMETER

Measures a-c Voltage to 1000 volts r.m.s. in six ranges—with clear linear scale—Binding Jack with locking pin plug prevents accidental ground lead disconnection—meter protected against accidental burn-out.

As an ELECTRONIC A-F VOLTMETER

Measures a-f and Supersonic Voltage up to 100 volts with a range of 20 to 100,000 cycles—internal self-balancing diode—produces linear reading at any frequency.

As an ELECTRONIC OUTPUTMETER

Measures Decibels based on a-f voltage—calibrated in Volume Units for direct reading across 600 ohm audio circuits with standard zero level of 1 milliwatt.

The New Model Of The Famous RCA Junior Voltohmyst Incorporates Several New Features Including:

A diode for a-c measurements (flat 20 cycles to 100 kilocycles); linear a-c scale for all ranges; new plastic meter case with one-piece crystal-clear transparent front (no glass to break or loosen); and a shielded a-c cable and probe.

Buy More War Bonds

TEST AND MEASURING EQUIPMENT SECTION
Radio Corporation of America
Camden, N. J.

Name________________

Street Address________________

City & State________________

137A

RADIO CORPORATION OF AMERICA

RCA VICTOR DIVISION • CAMDEN, N. J.

In Canada, RCA VICTOR COMPANY LIMITED, Montreal

1J9333

Printed in U. S. A.

Better Radio—
Better Television
Begin with RCA

☆ RCA microphones . . . used by *all four* major networks . . . start most of the nation's finest radio programs on their way to you. The leadi television programs, sound motion pictures and phonograph records also get their start through RCA equipment.

Yes, the entertainment you like best *begins* with RCA, and you enjoy it b through the "matched engineering" of an RCA instrument at home. When they are again available, insist on a genuine RCA Victor Radio, Phonograph or Television Receiver. From studio to you—if it's RCA, it *is* the best.

Gladys Swarthout

Famous Victor recording artist, appearing frequently over NBC. Her records reach the peak of fine reproduction on RCA Victor Radio-phonographs—they're quality-matched to each ot

LISTEN TO RCA's radio program, "The Music America Loves Best," every Sunday afternoon, 4:30 P.M., EWT, NBC Network.

RCA Victor

"HIS MASTER'S VOICE"

RADIO CORPORATION OF AMERIC

RCA VICTOR DIVISION • CAMDEN, N. J.

LEADS THE WAY . . *In Radio . . Television . . Tubes . . Phonographs . . Records . . Electron*