PICK-UPS

DECEMBER 1939

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DECEMBER, 1939

BEING A PERIODICAL DEVOTED TO DEVELOPMENT IN SOUND TRANSMISSION. PUBLISHED BY THE

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Assistant Editors

Broadcasting will soon take on special significance for a large number of college students. This issue of *Pick-Ups* describes an architectural competition for the design of a 1,000 watt broadcast transmitter building. The competition is open to architectural students of all schools in the country and is offered by the Beaux Arts Institute of Design under the sponsorship of Western Electric. It is sincerely hoped that broadcasting stations will extend all courtesies to students who may visit them for ideas and help. Full particulars of this stimulating competition are on page 8.

* * *

What is the outstanding characteristic of the broadcast engineer? We'd be tempted to say it's the enthusiasm with which he works. He's ready to try anything that comes along which offers the slightest chance for improvement. He jumps into it with both feet. He is willing to work and study endlessly to master a new technique or method. Right now engineers are hot and bothered over a new development — frequency modulation. Exactly what it offers they do not know, but our hats are off to the engineers for their keen interest in it. No industry will prosper long when its leaders and those in the ranks are willing to let well enough alone, and are loath to try something new.

* * *

Sooner or later, it seems, all photographers, professionals and amateurs alike, go through the stage of photographing door knobs, eggs, peas in a pod. To Nick Lazarnick, our favorite photographer, we gave the job of photographing a hat full of new Western Electric ultra-high-frequency tubes. You'll find the results on page 27. We rather like it, don't you? The tubes, incidentally, are used in the New Western Electric Altimeter which tells an airplane pilot just how far he is above that mountain range.

* * *

Recently, we watched a studio full of high school kids putting on an educational broadcast. They went at the job like professionals and how they enjoyed it. These kids and hundreds of others like them are doing a swell job in connection with New York City's ultra-high-frequency education by radio project. M. M. Beard tells you more about it on page 6.

* * *

Pick-Ups presents two of its star performers this issue. Bill Doherty has written an illuminating article on neutralization of final amplifiers. Whether your rig is a two-tube ham set or a 50 KW. you'll get a lift out of Bill's article, page 3.

Then back comes John Morrison with another antenna story. This time he deals with the subject of transmission lines. He discusses a number of types. Turn to page 9, and then choose your own!

* * *

We held off as long as possible in coming to this point because we've just about run out of new ways of wishing you all a Merry Christmas and a Happy New Year!

THIS ISSUE

NEUTRALIZATION

of Radio-Frequency Power Amplifiers

By W. H. DOHERTY

Radio Development, Bell Telephone Laboratories

Too often neutralization is obtained by blindly following rule-of-thumb instructions. In this article the author digs deep into the fundamentals, tells how to neutralize — and WHY.

When radio-frequency excitation is applied to the grid of a triode, the resulting radio-frequency voltage generated in the plate circuit reacts upon the driving source through the plate-grid capacity of the tube. The effects of this reaction, and the methods employed to overcome it, constitute one of the most interesting and important topics in the study of radio transmitting circuits.

We are dealing here not with a passive network and a single impressed electromotive force, but with a circuit in which there are two distinct sources of power, the second source being more or less under the control of the first but having an important reaction upon it which profoundly influences the behavior of the amplifier.

Let us consider the case of a power amplifier tube operating with a grid excitation of 500 volts r.m.s. carrier and an output voltage of 5000 volts r.m.s. carrier. This condition is represented in Fig. 1. If the output circuit is properly tuned these two potentials are exactly opposite in phase (since that is the *definition* of proper tuning), so that the voltage between plate and grid is, as indicated, the sum of the two, or 5500 volts.

Now suppose that at the frequency of operation the plate-to-grid capacity has a reactance of 5000 ohms, as would be the case, for example, if C_{pg} were 30 mmf and we were working at 1050 kilocycles. With 5500 volts between electrodes the current fed back from plate to grid through C_{pg} is 1.1 amperes. This current will register on a radio-frequency ammeter connected in the grid lead as shown. It seems like a large quantity for a grid current, and still from Ohm's Law we know it must exist. If we were working at 20 megacycles it would be 21 amperes. It is, of course, a displacement current and not an electron current.

We must now determine the phase of this current. We do this with a vector diagram as shown in Fig. 2. The impressed voltage E_g and output voltage E_p are shown as two quantities of opposite phase, one ten times the other. The voltage from plate to grid E_{pg} is the difference between these, and since they are opposite in sign, E_{pg} as shown by the long dotted arrow is larger than either. Now the current I_{pg} from plate to grid due to E_{pg} will lead E_{pg} by 90 degrees, since we are dealing with a capacitive reactance. We are interested, however, in the current as seen looking into the grid input terminals in order that we may determine the effective grid input impedance of the tube. We therefore wish to speak of the current as flowing from grid to plate instead of from plate to grid. Hence we call it I_{gp} and plot it in the opposite direction to I_{pg}. If this point is not clear the reader should stop and think about the matter until he is satisfied as to the correctness of this procedure.

Now observe that this current I_{gp} is 90 degrees ahead of the voltage E_g applied to the grid. When we apply a voltage such as E_g to a pair of terminals and a current flows into those terminals 90 degrees ahead of the voltage, we say that the impedance is capacitive. In this case, therefore, the input impedance of the tube is a capacitive reactance of 500/1.1 or about 450 ohms. This means that the apparent capacity is 330 mmf. Now if someone were to reduce the output voltage of the tube to zero (by short-circuiting the output, for example) the input capacity would obviously be 30 mmf. In other words, the presence in the output circuit of a voltage of 10 times the grid voltage and opposite in phase to the grid voltage, has raised the apparent input capacity of the amplifier to 11 times its static value.

To put the matter in general terms, the dynamic input capacity of an amplifier is related to the static plate-grid capacity by the expression

$$C_{in} = C_{pg} \ (1 + E_p/E_g), \qquad (1)$$

as long as the output circuit is properly tuned so that E_p is just opposite in phase to E_g.

Observe that for simplicity we are neglecting the grid-filament capacity, which is a constant quantity and would simply be added directly to the above.

Expression (1) is very significant. It

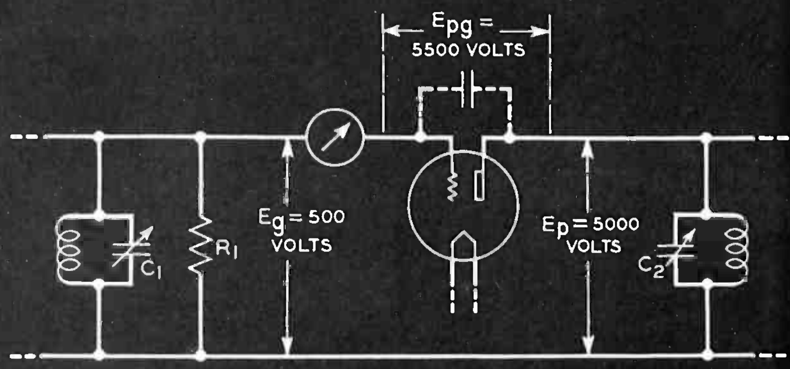


FIG. 1

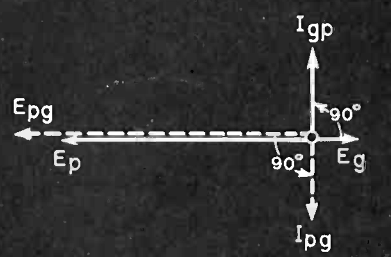


FIG. 2

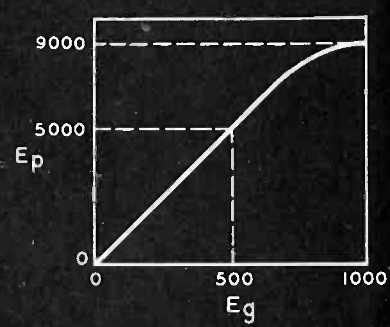


FIG. 3

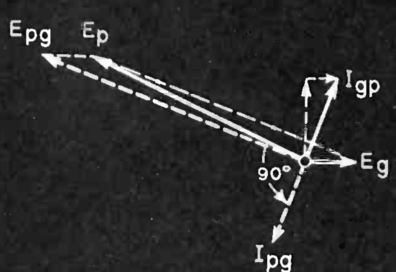


FIG. 4

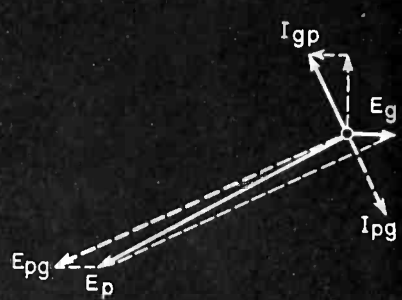


FIG. 5

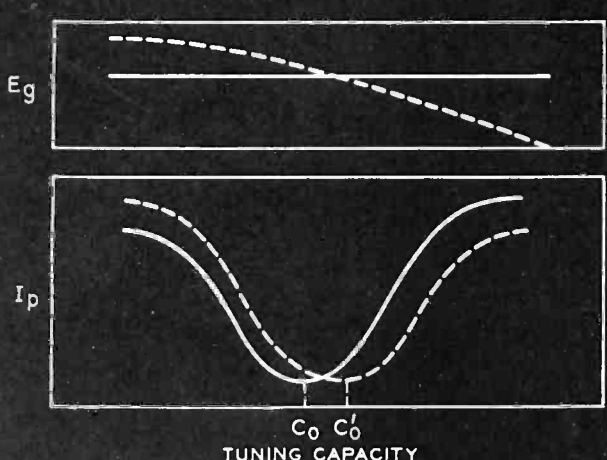


FIG. 6

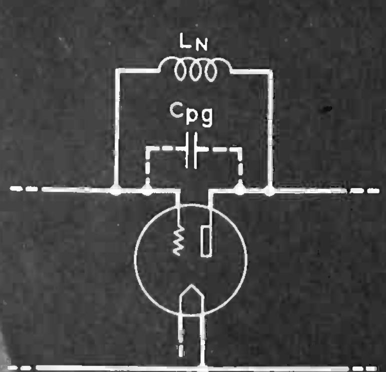


FIG. 7

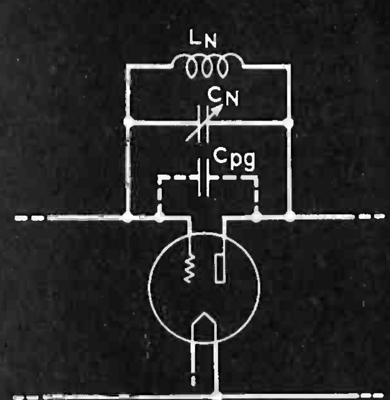


FIG. 8

indicates that if the ratio E_p/E_g were to remain constant the input capacity we encounter, while large, would at least be constant, so that by reducing the grid circuit tuning capacity C_1 we could compensate for it, as long as some singing condition did not occur. But E_p/E_g is often far from a constant quantity. It is, of course, not the mu of the tube, but the voltage gain obtained with the particular value of load impedance employed, and it varies with bias, d.c. plate potential, and plate circuit tuning. The effects of such variations are highly objectionable, and it is in order to eliminate these effects that neutralization is required. It will be instructive to examine these effects before we proceed to devise ways to eliminate them.

In a linear power amplifier E_p/E_g is supposed to be constant; that is, the output voltage of the tube is supposed to follow faithfully the shape of the modulated wave applied to the grid. This is only approximately true. A typical dynamic characteristic of such an amplifier is shown in Fig. 3. At the carrier output the tube impresses 5000 volts across the load in response to an excitation of 500 volts. At the peak of modulation, however, the 1000-volt drive may produce only 9000 volts at the output, so that E_p/E_g at this point has become 9 instead of 10 and the apparent input capacity, according to expression (1), has become 300 mmf instead of 330. If the operator has tuned the grid circuit with the output at carrier level, then at the peak of modulation it is out of tune to the extent of 30 mmf. In other words, the load resistance R_1 into which the previous stage works has suddenly been shunted by an apparent reactance of about 5000 ohms. If R_1 happens to be, say, 1000 ohms, then the *phase* of the grid excitation voltage may change by as much as $\tan^{-1}$ 1000/5000, or about 11 degrees, and the *amplitude* may be reduced by a factor of cos 11°, a 2 per cent reduction. We have, therefore, a phase wabble or phase modulation of the input signal to the tube, as well as a distortion in the modulation envelope, which adds to the distortion in the output.

Now these effects are greatly magnified when the gain of the amplifier is deliberately varied, as in grid bias or plate modulation. In such a case the r.f. drive is constant, and at 100 per cent modulation E_p/E_g is varied between zero and twice its carrier value by the audio-frequency variations in bias or plate potential. The resulting input capacity, in accordance with expression (1), varies from its carrier value of 330 mmf all the way down to 30 mmf and up to 630 mmf. The grid load impedance of 1000 ohms is therefore shunted alternately by apparent positive and negative reactances of 500 ohms, causing intolerably large phase and amplitude variations in the drive.

With phenomena such as these occurring at 1050 kilocycles, and proportionately more serious effects at higher frequencies, the need for methods of cancelling or neutralizing the current fed back through the interelectrode capacity is evident.

When the output circuit of a power amplifier is not tuned to unity power factor, the output voltage is no longer opposite in phase to the grid voltage. If, for example, condenser C_2 of Fig. 1 were made slightly too large, the plate voltage would lag and the vector diagram would appear as in Fig. 4. With the resultant interelectrode voltage E_{pg} retarded in this way, the vector I_{gp} takes a new position, being rotated slightly nearer to the applied voltage E_g. It may be resolved into a capacitive component at right angles to E_g, not much different from the original value of I_{gp} in Fig. 2, and a resistive component in phase with E_g which represents an additional load in shunt with the grid load resistor R_1. The result of this mis-tuning of the plate circuit, therefore, is a reduction in the grid excitation. Now if the plate circuit were mistuned in the opposite direction, causing the plate potential to lead instead of lag (Fig. 5), the resistive component of I_{gp} would be *opposite* in phase to E_g instead of being in phase with it; in other words, the tube would be feeding back power into the input circuit, *raising* the effective value of the grid load resistor R_1 and increasing the drive.

When the operator tries to tune an amplifier in which this phenomenon is occurring, he runs into difficulty. The age-old method of tuning by adjusting the plate condenser or inductance for minimum plate current is reliable only when the drive E_g on the grid is constant. With E_g constant the plate current I_p varies with tuning capacity in the manner shown in Fig. 6, and C_0 represents the correct setting. But if the grid excitation is varying during the process, being high on one side and low on the other, as indicated by the dotted E_g curve, the minimum of plate current will be displaced and a false indication of tuning obtained, as shown by C_0'. The result is that the amplifier is not tuned, the efficiency is reduced, and the distortion is increased. There are probably many transmitters now on the air in which the operation is being impaired by improper plate tuning, as a result of incomplete neutralization of the interelectrode capacity.

The author believes that neutralizing circuits have been somewhat neglected in technical radio literature and that many operators and experimenters would feel on much firmer ground with a simple explanation of the theory of these circuits. We are faced with the fact that a current is bound to be fed back from output to input through the interelectrode capacity and nothing but the interposition of a screen grid will prevent it; so that with a triode our only means of avoiding a reaction on the input is to feed back in some manner an equal and opposite current so that the net current fed back will be zero and the

(*Continued on page 21*)

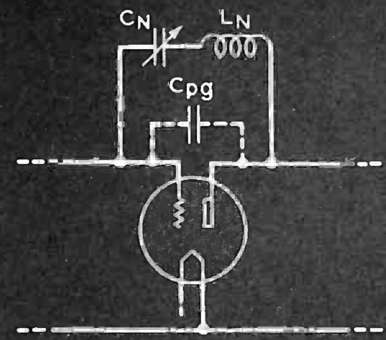


FIG. 9

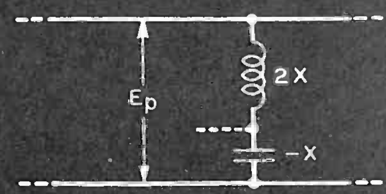


FIG. 10

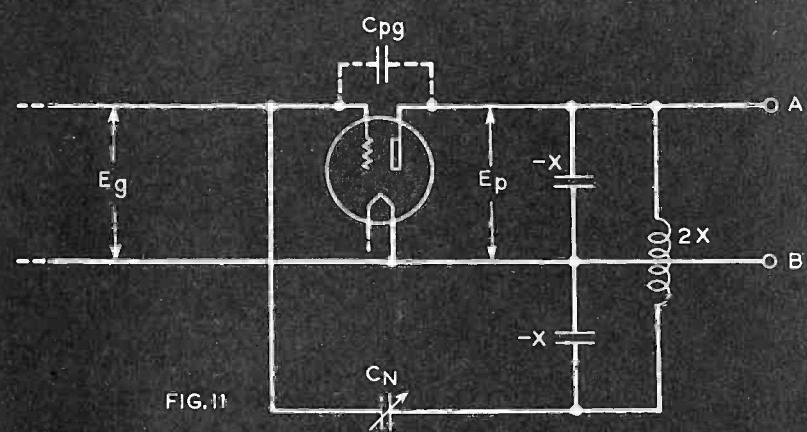


FIG. 11

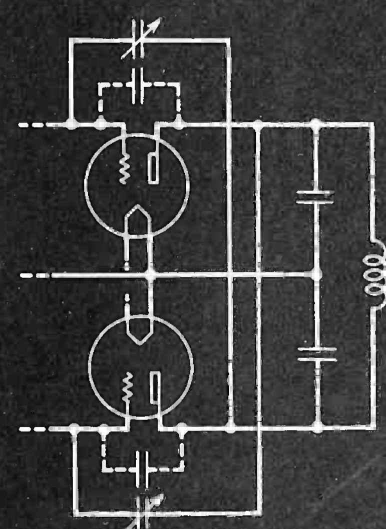


FIG. 12

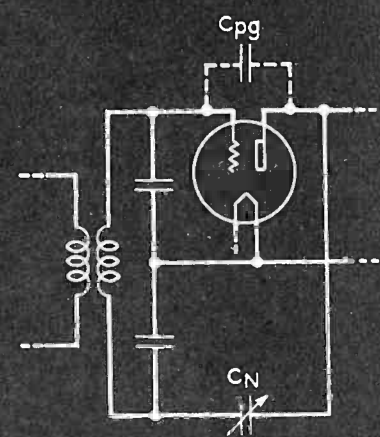


FIG. 13

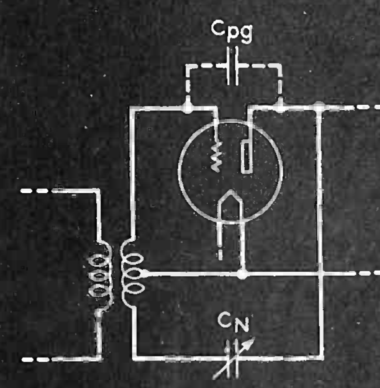


FIG. 14

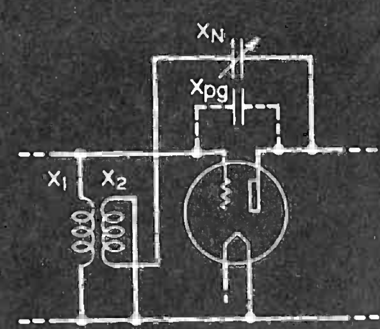


FIG. 15

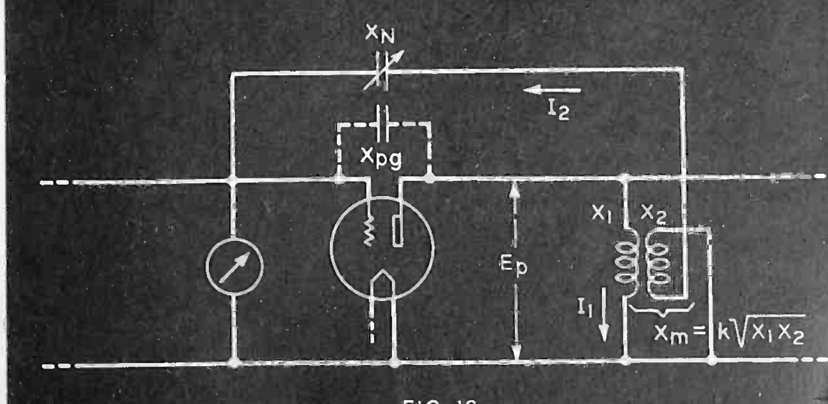
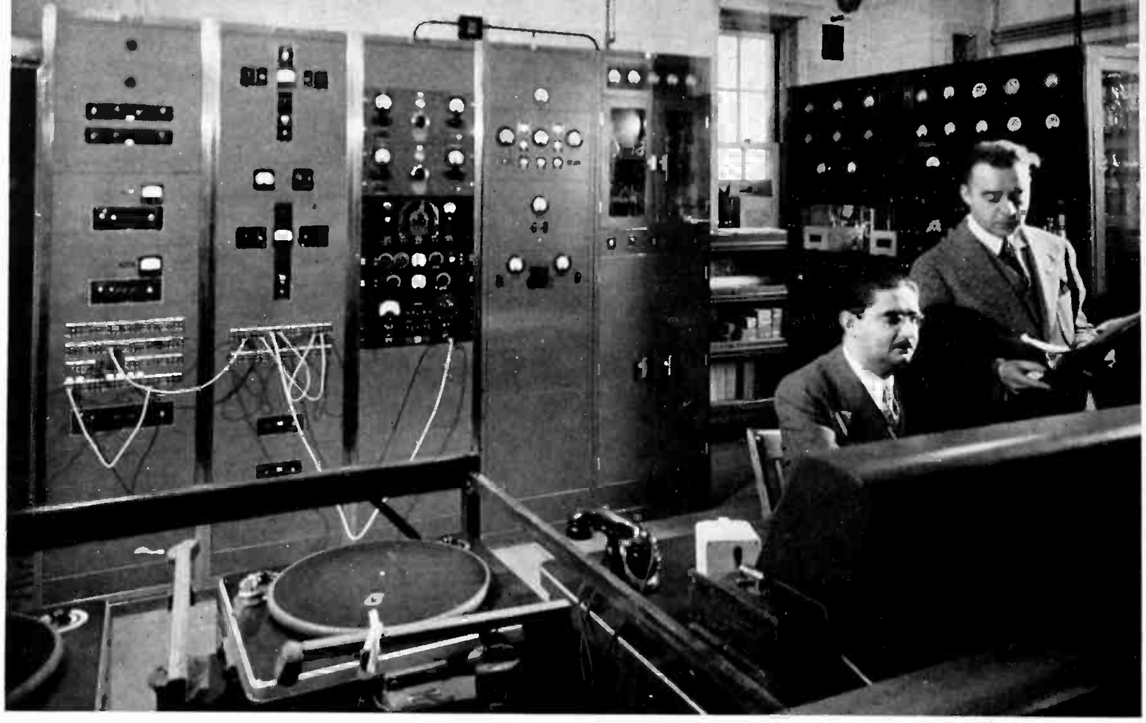


FIG. 16



Dr. Albert L. Colston, director of WNYE and principal of Brooklyn Tech, won the FCC's approval for a short wave channel. WNYE's transmitter room with assistant Engineer Ricardo Muniz at speech input console.

New York's Classroom Teaching by U H F Radio Project Going Strong

Complete Coverage of City's 700 Schools Now Made Possible through Medium of WNYE, New Ultra-High Frequency Station

By M. M. BEARD

Several years ago New York City's Board of Education took radio into the school system on trial. Test programs which went on the air over the municipal station WNYC aroused such widespread enthusiasm among educators and students alike that the Board took steps to establish a station of its own whereby broadcasts could more closely tie in with classroom schedules. Plans for the project were drawn up — hurried down to Washington and laid before the Federal Communications Commission. The FCC finally approved the idea — allocated a special channel on the ultra-high frequency band and WNYE, the Board's own station was born.

It's thriving nicely over at Brooklyn Technical High School. Brooklyn Tech was selected as the site for the new station for several very good reasons. In the first place it is centrally located with respect to the five boroughs. Also the school offers excellent facilities in both equipment and personnel. The building houses 17 laboratories, 40 shops and one of the largest and best equipped auditoriums in the city. More like a theatre than a school auditorium it has a full sized stage, orchestra pit, balcony, motion picture apparatus and sound booth. In addition, the school has installed the latest Western Electric sound distribution system.

It is a colossal undertaking to thoroughly integrate radio into an educational system, serving the largest city in the world. To cover New York City's school area means that 616 elementary schools, 82 junior high, 50 senior high and 26 vocational schools must be equipped with short wave receivers as well as sound systems. Money must be raised to purchase such equipment and, perhaps the hardest job of all, radio broadcasts must be woven into the pattern of the schools' curricula. Many of the schools own sets for intermediate reception, a comparative few have installed short wave receivers. Eventually every school will be equipped with the short wave sets. In the meantime programs are going out over both WNYC and WNYE to assure more complete coverage. When the ultimate goal is reached WNYE can shoulder the job alone.

The project is still so very young that there has been little time to check up on the new medium and learn just how far its arm is reaching over the five far-flung boroughs. However, Dr. Albert L. Colston, director of the station and principal of Brooklyn Tech, and James F. Macandrew, radio coordinator, have been sending out feelers with the most satisfactory results. Returns trickling in show that 65 per cent of the junior high schools and 50 per cent

Van Rensselaer Brokhahne and James F. Macandrew share the job of directing broadcasts. Right: New Utrecht High School students dramatically portray historical events which led to the freeing of the negro people.

of the senior high are tuning in on programs regularly to supplement classroom work. Last year 40,000 elementary school children listened each week to a series of broadcasts on history and English literature. And during the year 1500 students appeared before the microphones in Brooklyn Tech's studio.

A backward glance over the past three years shows how steadily the radio project is progressing. In 1937 twelve experimental broadcasts went out over WNYC. The number shot up to 111 in 1938 while during the spring semester alone of 1939 the station carried 191 broadcasts. This past fall 16 programs a week or approximately 204 broadcasts for the opening semester were scheduled.

Briefly, this is how radio is working hand in hand with New York City's teaching force. Various committees are chosen from the system to draw up schedules covering practically every subject taught in the classrooms. These committees work in close collaboration with WNYE's production and engineering departments. In planning the schedules proper timing is most essential. Broadcasts must coincide with classroom studies. Teachers, supervisors and pupils are selected from the various schools to take part in the programs.

Brooklyn Tech prints the schedules and distributes them to every school in the city. These booklets list subjects, time of broadcasts and brief notations stating the aim of the program along with suggestions to teachers concerning preparatory work and follow-up discussions. In addition, mimeographed material, such as teachers' outlines, is also prepared. All of the printing and mimeographing is done by Tech students — it's a voluntary job and a big one. Eventually copies of the schedules and supplementary pamphlets will be placed in the hands of each of the 35,000 teachers in the system. Just at present the school's printing department is not prepared to carry out such a large order.

Tech boys also built the paraphernalia for producing WNYE's sound effects. No matter what the script may call for the boys can trump up the desired sound in the best showmanship tradition. Soldiers march, rain falls, prison doors clang, bells chime, wind howls, feet shuffle, walls tumble, birds chirp, telephones tinkle as the trick gadgets go into action.

Teachers and children selected to do the broadcasting are assigned certain periods for rehearsing at the studio. Usually two rehearsals are sufficient to put across a finished performance. The children take to it like ducks to water, they say over at Brooklyn Tech. There is practically no such thing as "mike fright" among these young performers. Occasionally a dignified teacher or a shy professor gets a bit jittery but Macandrew and Van Rensselaer Brokhahne, who share the job of directing, soon have the entire cast at its ease. Thoroughly versed in the art radio production these men know just how to inspire children and grown-ups alike to put all they have into the act. They perk up timid little girls — tone down boisterous little boys — do it so kindly that the children are won over in no time. If they were coaching Charlie McCarthy or Baby Snooks they could not put more vim and enthusiasm into the production. Some of the youngest stars can barely reach the microphone—all work their hardest to produce a hit show.

Broadcasts go over the air in the form of lectures, dramatic sketches, informal talks, debates, quizzes, contests. And lessons in history, geography, mathematics, science, foreign languages, literature, art, music, vocational guidance, pronunciation pour out into classroom or auditorium in their most enticing garb.

One of the most successful series broadcast during the fall semester was "The Story of New Amsterdam." Dramatic sketches portrayed the history of little old New York from the time of the Dutch settlers on up to the present era. Prior to the broadcasts classes were familiarized with the meaning of new

(*Continued on page 24*)

ANNOUNCING

Western Electric to Sponsor Beaux Arts Transmitter Building Design Competition

To stimulate interest in the better design of transmitter buildings for broadcast stations the Beaux Arts Institute of Design has announced a new architectural competition to be open to students of all architectural schools and ateliers in the country. Formal announcement of the competition is made in the December issue of the Institute's monthly Bulletin. The subject of the competition is the design of **"A 1000 Watt Broadcast Transmitter Building."**

Sponsor of the competition is the Western Electric Company which offers a first prize of $250; $100, second prize and $50, third prize. The competition opens January 8, 1940 and closes May 1, 1940 at which time all entries must be received by the institute at its headquarters, 304 E. 44th Street, New York City. Final awards and announcement of the prize winners will be made by the judges of the competition on or before May 15th. All prize winning designs and others of merit will be fully published in later issues of this publication.

Four of the country's outstanding architects and one leading broadcast engineer have been selected by the Beaux Arts Institute to judge this competition. They are as follows:

- **J. André Fouilhoux**—of the firm of Harrison and Fouilhoux
- **Eli Jacques Kahn**
- **Ralph T. Walker**—of the firm of Vorhees, Walker, Foley and Smith
- **Alfred Fellheimer**—of the firm Fellheimer and Wagner
- **J. R. Poppele**—chief engineer of Station WOR

"The Beaux Arts Institute of Design has felt for some time that such a competition may do much to stimulate new interest in this important phase of architecture," declared Mr. Otto Teegen, Architectural Director of the Institute. "With Western Electric as sponsor, the Institute is particularly happy to offer the competition to the American student of architecture.

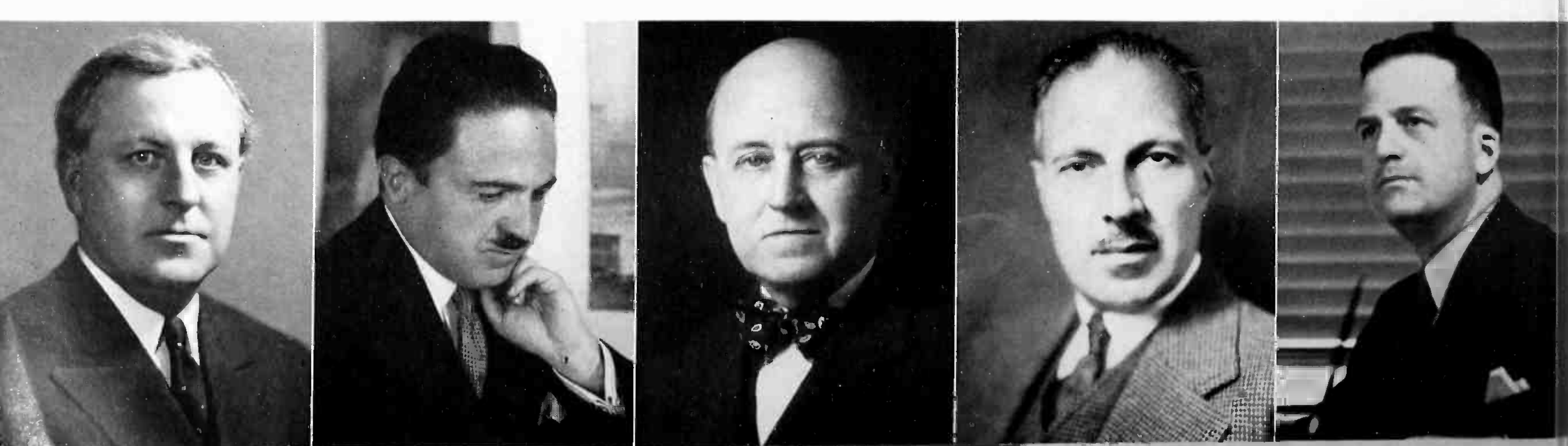
"It is hoped that the competition will be successful in stimulating interest in the architecture of radio stations as a specialized field. Much of present day broadcast station architecture is far from good. Too often a station buys a new transmitter and then hires an architect simply to build a house around it. Not enough thought is given to the functional requirements of the broadcasting job to be done by the building. The result is a building which is not only architecturally bad but also inadequate to supply proper facilities for the specialized requirements of broadcasting.

"Such results are particularly noticeable in the smaller stations where the broadcaster may not have either the funds or the opportunity to obtain the necessary professional architectural services to guarantee the success of his building. For this reason the Institute has purposely selected a small station as the basis for the competition, believing that the greatest good

(*Continued on page 17*)

Famous Architects and Engineer to Judge Competition

Four outstanding architects and a leading Radio Engineer have been appointed to judge all entries in the competition — they are, left to right: Ralph Walker, of Vorhees, Walker, Foley and Smith; Ely Jacques Kahn; Alfred Fellheimer, of Fellheimer and Wagner; J. André Fouilhoux, of Harrison and Fouilhoux; J. R. Poppele, chief engineer of Station WOR.



TRANSMISSION LINES

And Formulas for Certain Characteristics

By JOHN R. MORRISON
Radio Development, Bell Telephone Laboratories

A transmission line is an arrangement of conductors for transmitting electrical energy from one point in a circuit to another. This definition rightfully implies that all conductors, including the shortest connections between adjacent circuit elements, are transmission lines. While these short connections can be treated analytically by transmission line concepts, it is seldom necessary at broadcast frequencies because the energy is altered but a negligible amount in traversing such connections. It is, however, necessary that these concepts be applied when the conductor length becomes a substantial fraction of the wavelength. In such cases careful consideration must be given to the arrangement of the conductors, as well as to the characteristics of the terminal apparatus, in order to avoid unnecessary loss of energy and other undesirable reactions.

In a broadcast installation the system of conductors arranged for transmitting the energy developed by the transmitter to the driving point of the antenna is usually of sufficient length to justify careful consideration of the design features. This system of conductors is, so to speak, a bottle-neck through which all the radio energy must pass en route to the radiating system. The most expensive energy in the broadcast plant is subjected to losses in this system. Unlike the transmitter and coupling apparatus, this circuit is exposed to the weather and failure may cause long and serious delays in operation. Radiation from these lines at the fundamental and harmonic frequencies often causes serious difficulties through interference, aside from the useful energy lost in this manner.

There have been many arrangements of conductors proposed for use as radio frequency transmission lines and at times the broadcast engineer is called upon to select one of the alternatives for his plant. He is usually aware of the problems mentioned above and should make his selection giving due regard to them, as well as to the cost of the circuit in relation to the total plant investment. This paper presents formulas for computing certain important characteristics of several transmission line arrangements in the hope that they will be useful to the engineer when he is called upon to make a selection.

Before discussing these, however, it may be appropriate to review briefly the transmission of energy along a tranmission line. Referring to Fig. 1, the line L is to deliver power from the generator G to the load. In practice the conductors are not perfect and power is therefore consumed in the line by

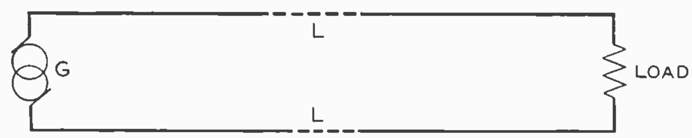


Fig. 1—Schematic diagram of single transmission line.

conversion into heat. This loss is expressed by the relation I^2R, where I is the current and R is the resistance of the conductors. The I^2R loss at broadcast frequencies is usually negligible compared with the power transmitted to the load so that for the majority of problems perfect conductors may be assumed.

Another factor that affects the transmission line loss depends upon the magnetic and electric forces in the space surrounding the line. The conductors are encircled by a magnetic field as illustrated by the solid lines in Fig. 2, and an electric field extends from them as shown by the broken lines of this same figure. These two fields constitute the composite electromagnetic field which carries energy along the line. It is particularly important to bear in mind that the function of the line conductors is simply that of a guide. The energy transmitted is practically all in the medium between and surrounding the conductors rather than within the conductor itself.

Not all the energy guided by the line

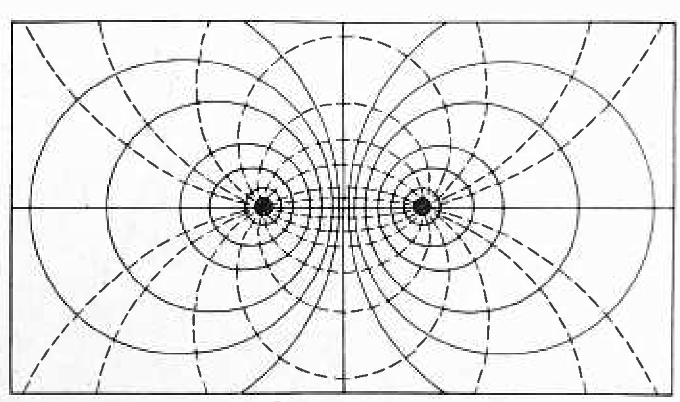


Fig. 2—Electric field about parallel conductors.

conductors reaches the distant end. Some is absorbed in the line itself, some is lost in space in the form of radiation, and some is lost in the imperfect dielectrics surrounding the conductors as well as in any imperfectly conducting objects in the vicinity of the line. If the engineer is to control these losses effectively he must consider ways to perfect the functions of the line as a guide. This will be discussed further, but first let us consider briefly the conditions that affect line termination.

Imperfect termination of the line means that some of the energy is not absorbed by the termination. That not absorbed is reflected, and the reflected energy not lost in transmission is returned to the generator. When reflection occurs, waves of electromagnetic energy are moving in both directions along the line and "standing waves" appear. The currents and voltages of the outgoing and reflected waves add vectorially and the relative phases vary in such a way that the average line currents and voltages are different at different points along the line. This variation represents the standing wave.

If all the energy is absorbed at the termination of the line there can be no energy reflected. This condition defines a perfectly terminated line and if the line were lossless the average current and voltage would be the same at all points over its length.

If the length of the line is infinite, the impedance seen by the generator is the so-called characteristic impedance of the line. This characteristic impedance may be derived from the size and arrangement of the conductors of the line itself and all neighboring conductors, such as the ground. For example, if the line is unbalanced and unshielded, a portion of the current will be conducted along the earth, and this unbalance current must be taken into consideration.

Table No. 1 has been prepared to give in concise form the characteristic impedance and net ground return, or unbalance current, for several transmission line arrangements. In preparing these equations it has been assumed that the lines are erected at a height above a perfectly conducting earth which is large compared to the spacing between the conductors. The conductors are assumed to have negligible resistance and in the case of grounded circuits it has been assumed that they are connected to the earth at frequent intervals.

One of the earliest radio frequency transmission lines was the single wire type, but for general use this line was soon abandoned. All of the current returned to the generator via the earth path, which usually resulted in high transmission and radiation losses. The two-wire balanced line was the next in popular use. This type of line offered low transmission and radiation losses when a reasonably good balance to ground could be maintained. When the balance is perfect the ground return current, is of course, zero. In practice, however, the problem of maintaining a good balance was found difficult, particularly in high power installations where unbalance impedances were practically unavoidable because of the large physical size of the terminal apparatus.

The four-wire balanced line has a characteristic impedance about one-half that of a two-wire balanced circuit and it has proven very successful for application between a balanced generator and load. It is subject, however, to the same objections as the two-wire balanced line, particularly with regard to the cost of terminal apparatus. The final amplifiers of the most recent broadcast transmitters are unbalanced and the radiating systems used are likewise unbalanced, so that an unbalanced transmission line is desirable from the

(*Continued on page 12*)

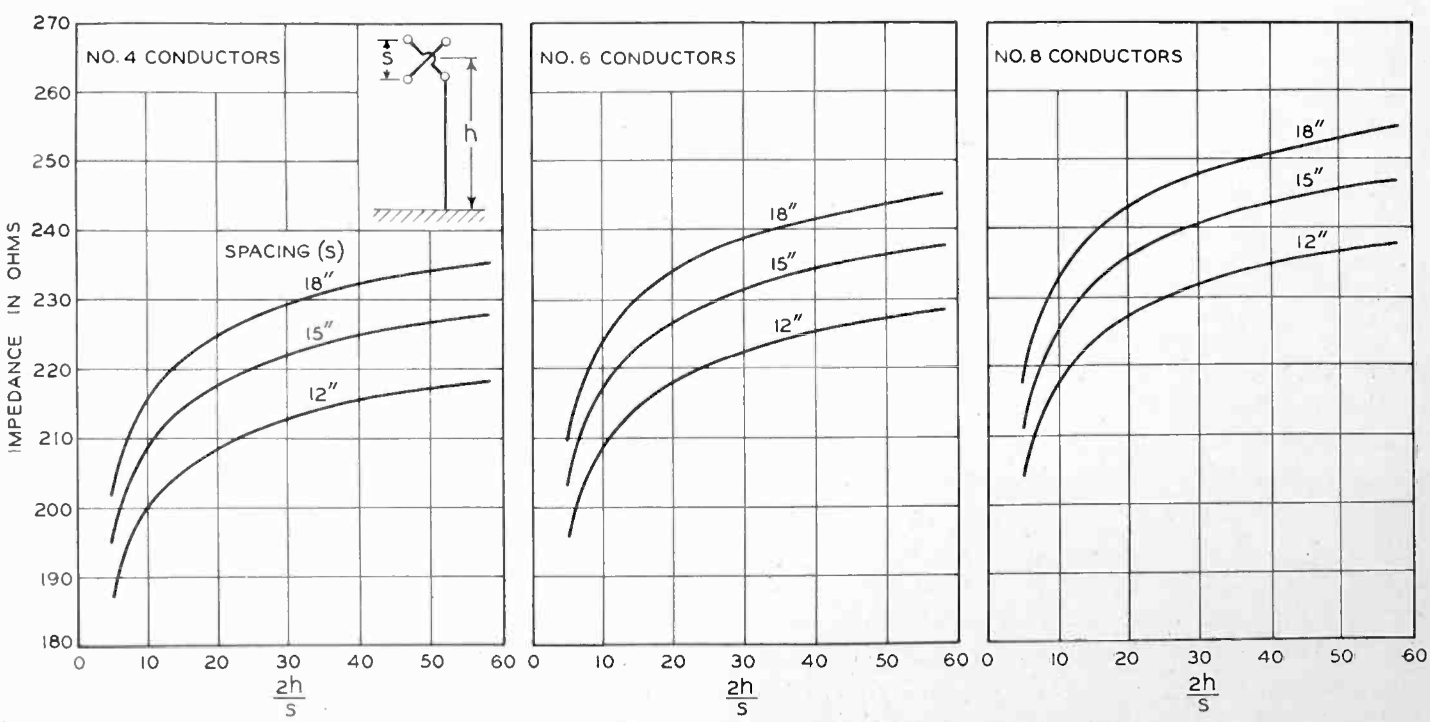
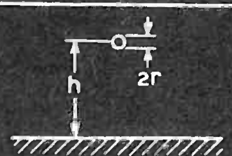
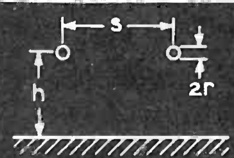
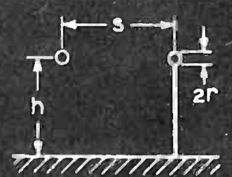
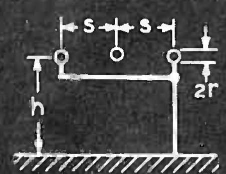
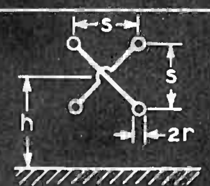
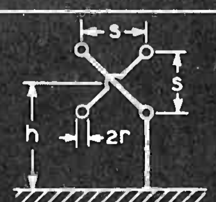
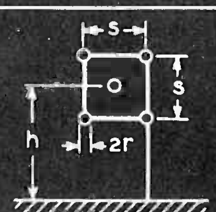
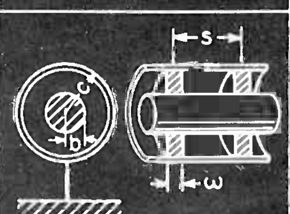
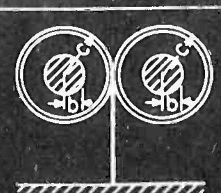
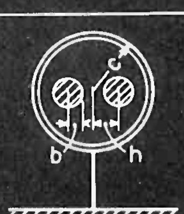


Fig. 3—Characteristic Impedance of Unbalanced 4-Wire Transmission Lines.

TABLE I — CHARACTERISTICS OF RADIO-FREQUENCY TRANSMISSION LINES ERECTED PARALLEL TO A PERFECTLY CONDUCTING EARTH

LOGARITHMS TO THE BASE 10 — I_1 = GENERATOR CURRENT

LINE CONFIGURATION		CHARACTERISTIC IMPEDANCE	NET GROUND-RETURN CURRENT
SINGLE WIRE		$Z_0 = 138 \log \frac{2h}{r}$	$I_{GND} = I_1$
2-WIRE BALANCED		$Z_0 = 276 \log \frac{s}{r}$	$I_{GND} = 0$
2-WIRE 1 WIRE GROUNDED		$Z_0 \approx 276 \frac{\log \frac{s}{r} \log\left[\rho^2 \frac{s}{r}\right]}{\log\left[\rho^2 \left(\frac{s}{r}\right)^2\right]}$ $\rho = \frac{2h}{s}$	$I_{GND} \approx I_1 \frac{\log \frac{s}{r}}{\log \frac{2h}{r}}$
3-WIRE 2 WIRES GROUNDED		$Z_0 \approx 69 \left[\log \frac{s^3}{2r^3} - \frac{\left(\log \frac{s}{2r}\right)^2}{\log \frac{2h^2}{rs}}\right]$	$I_{GND} \approx I_1 \frac{\log \frac{s}{2r}}{\log \frac{s\rho^2}{2r}}$ $\rho = \frac{2h}{s}$
4-WIRE BALANCED		$Z_0 = 138 \left(\log \frac{s}{r}\right) - 21$	$I_{GND} = 0$
4-WIRE 2 WIRES GROUNDED		$Z_0 \approx 138 \left[\frac{\log \frac{s}{r\sqrt{2}} \log\left[\rho^4 \frac{s}{r\sqrt{2}}\right]}{\log\left[\rho^4 \left(\frac{s}{r\sqrt{2}}\right)^2\right]}\right]$ $\rho = \frac{2h}{s}$	$I_{GND} \approx I_1 \frac{\log \frac{s}{r\sqrt{2}}}{\log \frac{\rho^2 s}{r\sqrt{2}}}$
5-WIRE 4 WIRES GROUNDED		$Z_0 \approx 138 \left[\log \frac{2h}{r} - \frac{\left[\log 2\rho^2\right]^2}{\log\left[\rho^3 \frac{h\sqrt{2}}{r}\right]}\right]$ $\rho = \frac{2h}{s}$	$I_{GND} \approx I_1 \frac{\log \frac{s}{r 4\sqrt{2}}}{\log \frac{s\rho^4}{r\sqrt{2}}}$
COAXIAL		$Z_0 = 138 \frac{\log \frac{c}{b}}{\sqrt{1 + \frac{(\epsilon - 1)\omega}{s}}}$ ϵ = DIELECTRIC CONSTANT OF INSULATING MATERIAL	
DOUBLE COAXIAL BALANCED		$Z_0 = 276 \frac{\log \frac{c}{b}}{\sqrt{1 + \frac{(\epsilon - 1)\omega}{s}}}$	
SHIELDED PAIR BALANCED		$Z_0 = \frac{120}{\sqrt{\epsilon}} \left[2.303 \log\left(2v \frac{1-\sigma^2}{1+\sigma^2}\right) - \frac{1+4v^2}{16v^4}\left(1 - 4\sigma^2\right)\right]$ ϵ = DIELECTRIC CONSTANT OF MEDIUM ϵ = UNITY FOR GASEOUS MEDIUM $v = \frac{h}{b}$; $\sigma = \frac{h}{c}$	

Transmission Lines

(*Continued from page 10*)

standpoint of terminal apparatus costs. Mainly for this reason a grounded type of transmission line circuit is used almost exclusively at modern broadcast stations.

The two- and three-wire grounded circuits have not been extensively used. The equations for their characteristic impedance and net ground return currents are given here, however, for the purposes of comparison.

Possibly because of the favorable characteristics of the balanced four-wire line the four-wire unbalanced line has come into fairly extensive use. The four-wire grounded line is, however, a different type of circuit from the balanced one, as may be seen in the formulas for their characteristic impedance and net ground return current. Since in the unbalanced case the earth is connected in parallel with the return conductors the current will naturally divide between the return conductors and the path provided by the earth. The division of current depends upon the height, spacing, and radius of the conductors. The ratio of this current division has been plotted in Fig. 4 for several sizes of conductors, height, and spacing. It will be observed from these curves that for the average size line, 40 to 45 per cent of the current returns through the earth path. For example, with a line of No. 6 conductors spaced one foot and mounted 15 feet high, $2h/s = 30$, the unbalanced current ratio is about 0.41.

This large current unbalance produces a substantial electric field between the conductors and the earth, and results in correspondingly greater transmission and radiation losses than obtained with perfect balance. A large portion of the energy is propagated in the medium between the line conductors and the earth and not, as intended, solely between the conductors. This not only causes higher radiation losses at the fundamental and harmonic frequencies but the performance of the circuit is likely to be more unstable than the balanced circuit with varying weather conditions and the formation of ice and sleet. This type of circuit is not satisfactory for use in connection with antenna arrays because of the interaction between the unbalance line currents and ground return currents of the array elements.

The five-wire unbalanced line is not greatly different in its performance from the four-wire unbalanced line. Its use is not general but the equations are of interest for comparison purposes.

The shielded coaxial line provides a solution to many of the above-mentioned difficulties. It permits the use of an unbalanced transmission circuit which is free from the undesirable features of the open wire unbalanced line.

A coaxial circuit is comprised of a central conductor surrounded by a coaxial shield which is employed as the return conductor. In this circuit the lines of magnetic field intensity are coaxial circles about the center conductor and the lines of electrostatic intensity, are substantially radial from the central conductor. A copper coaxial shield is not an absolutely perfect conductor and the electric field is not completely reflected from its inner surface. A very slight amount of the energy moves radially outward (or inward, as the case may be) into the shield, giving rise to an electromotive intensity parallel to the shield. This outward divergence of energy represents a loss which is rapidly attenuated by the shield. S. A. Schelkunoff (Bell System Technical Journal, Oct., 1934) gives for the propagation constant through a metallic substance where the conductivity is large and the dielectric constant is negligible:

$$P = \sqrt{\pi \mu f g}\ (1 + j) \text{ nepers per centimeter.}$$

The conductivity g is expressed in mhos per centimeter and the permeability μ in henries per centimeter. In copper $\mu = 1.256 \times 10^{-8}$ henries per centimeter and $g = 5.80 \times 10^{5}$ mhos per centimeter, so that at 1000 kilocycles the attenuation constant is

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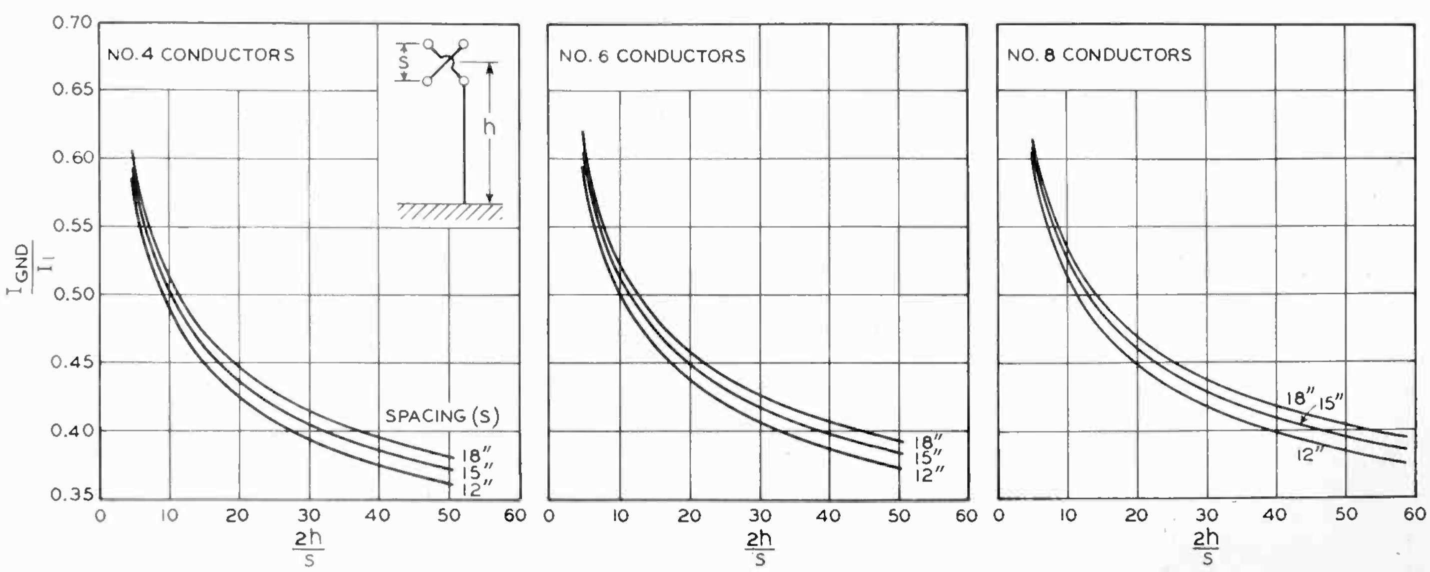
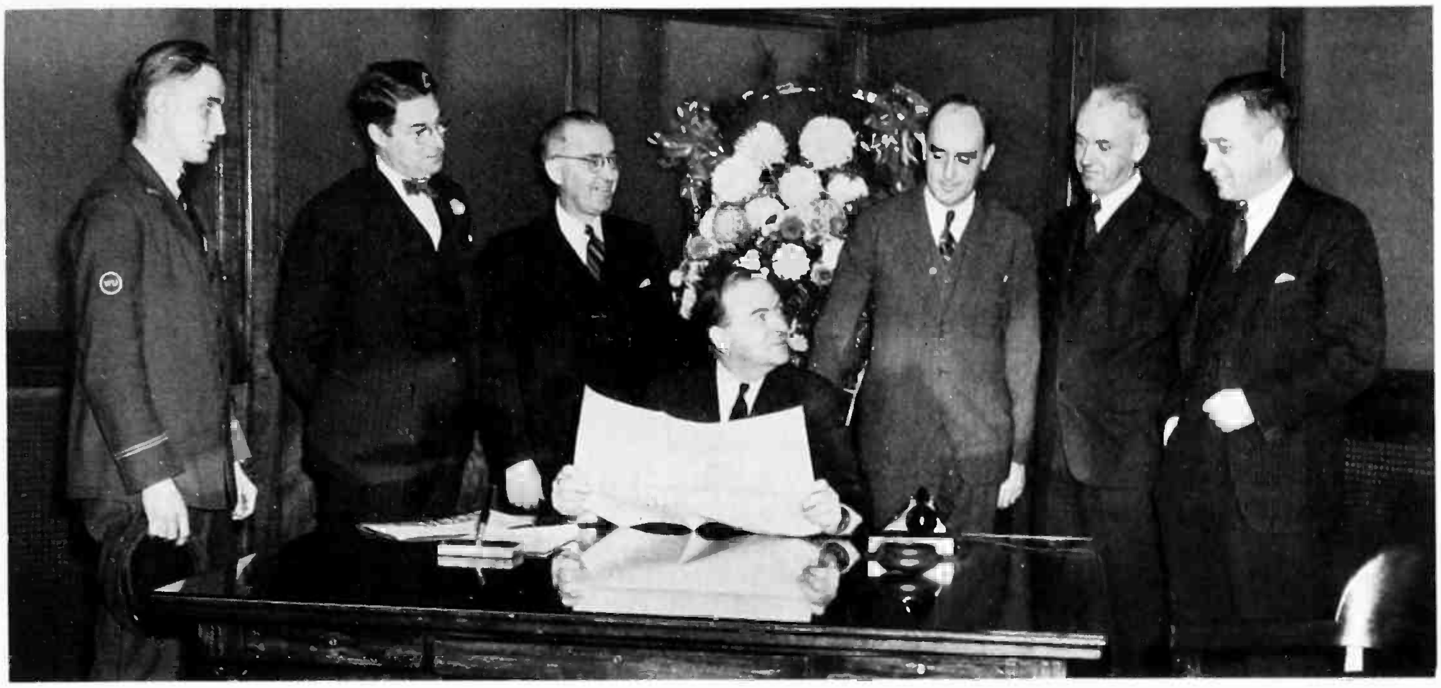


Fig. 4—Ratio of Net Ground-Return to Generator Current with an Unbalanced 4-Wire Transmission Line. I_1 equals the High Side or Generator Current.



Associates H. N. Willets, E. W. Thurston, F. J. Feely, J. W. Sprague, and C. R. Hommowun look on as Mr. Lack (center) receives congratulatory messages on formation of new division.

F. R. Lack Heads New Division for Western Electric Specialty Products

To meet the specialized requirements of broadcasting stations, airlines, the government services and the other users of its communication equipment outside the Bell System the Western Electric Company has announced the formation of a new branch to be known as the Specialty Products Division. This unit is responsible for such by-products of telephone research as: hearing aids, aviation, marine and police radio; broadcasting equipment; sound system, and equipment made to specification for the United States government.

No such formal announcement, however, adequately portrays the services rendered by the new organization nor the influence it wields in the life of the nation. The equipment which it manufactures and supplies to the world colors and affects the lives of practically every citizen of the country.

To visualize the scope of the Division's activities and the services rendered by the equipment manufactured by this organization, just imagine if you can what would happen if this equipment should suddenly refuse to work. Suppose, for instance, some super-scientist should devise some diabolical gadget by which he could cause all such Western Electric equipment now in service in the country to become suddenly inoperative!

Panic would spread across the country like a clammy fog across a sunlit beach. Practically all of the giant airplanes of the country's major airlines would be grounded, afraid to venture forth in the skies without the radio ears of Western Electric Aviation Radio. Millions of citizens would desperately tune in vain for their favorite radio stations made silent because so many of the stations are Western Electric equipped.

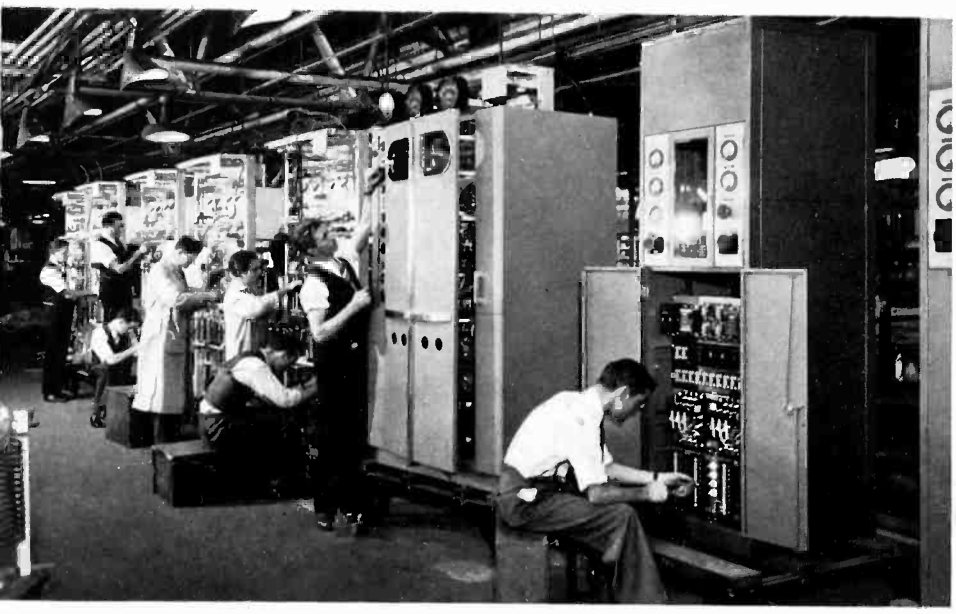
The greatest crime wave the country ever experienced would be launched by the criminals of every state as darkness descended upon more than 45,000,000 people ordinarily dependent upon the added protection of Western Electric Police Radio.

A majority of the world's theatres would be dark and silent with dead Western Electric Talking Picture Sound Systems in their projection rooms. Most of Hollywood's technicians and professional people would be out of work with their studios unable to record the great majority of the year's screen fare without the use of Western Electric sound recording equipment.

In thousands of schools, hospitals, churches, theatres, sports arenas, airports, railroad stations, municipal buildings and other places where people gather, men and women would strain to hear, unaided by the voice amplification of Western Electric public address equipment. Even members of the House of Representatives in Washington would again be forced to shout against the shattering reverberation of marble walls. Deafness would descend again upon thousands of the hard of hearing dependent upon Western Electric Audiphones for their normal human contacts. Yachts, tugs, ferries, fireboats, ocean-going liners and fishing smacks would falter through seas unaided and out of the contact with land ordinarily made possible through Western Electric marine radio.

And as each of scores of other products

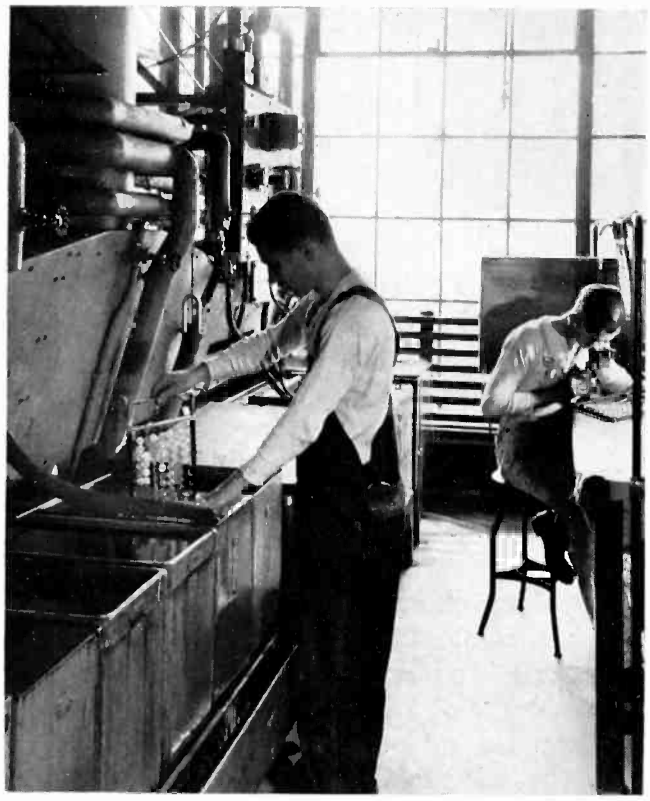
(*Continued on page 26*)



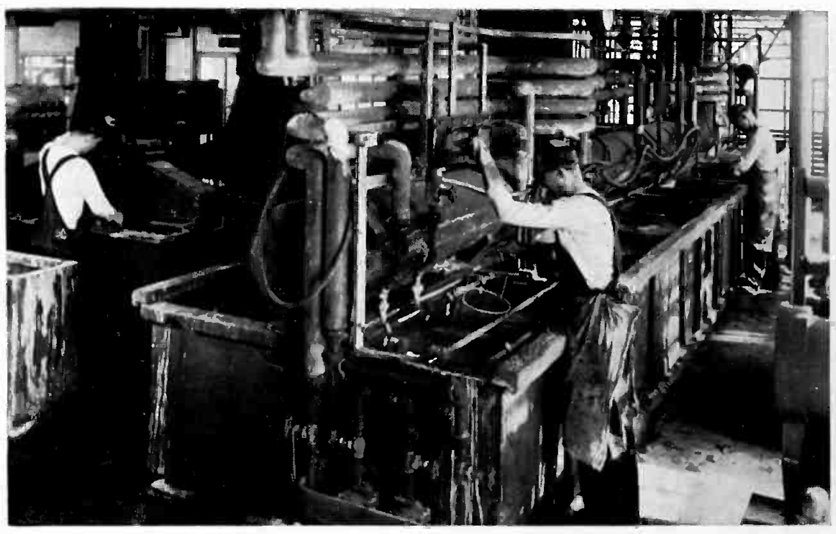
Six of the new 1 KW transmitters and a 9 type rectifier going through final assembly operations in the hands of skilled Kearny craftsmen.

Assembling cardioid microphones in a special double-sealed, air conditi… tween operations instruments being assembled are protected by transp…

WHERE WESTERN ELEC…



Many delicate parts, such as microphone diaphragms, get their protective coating of gold in this gold plating room.

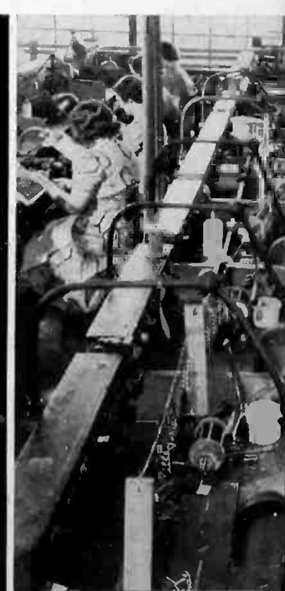


In this general plating room copper, cadmium, nickel, zinc are applied to many other metals which are not naturally resistant to corrosion.

Three layers of lacquer are applied to 639A microphone cases. Transparent lacquer is used for final coating.

With a high powered microscope this inspector makes detailed check of the 639A microphone pressure unit.

Hundreds of thousands … batteries of coil winding…



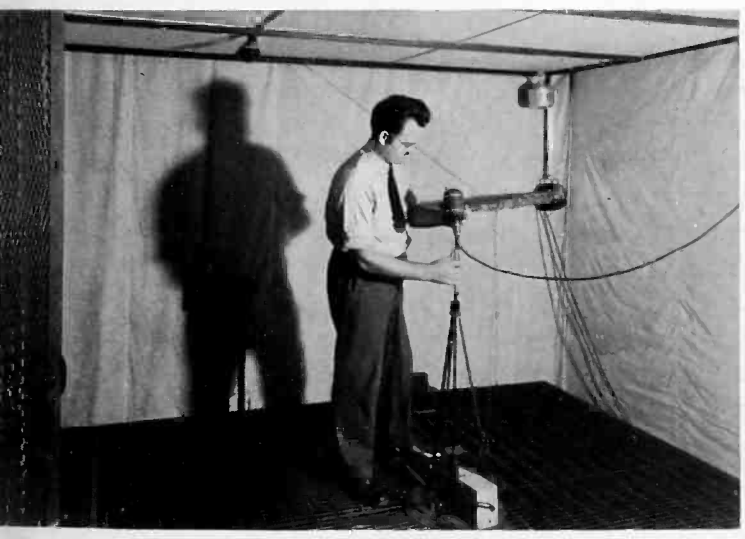
room—be- wrappers.

This view shows only a part of the more than 600 machines used in the manufacture of Specialty Products. Many of these machines are designed and constructed at Kearny.

"Crane Court" gets its name from the huge travelling crane which distributes materials.

TRIC SPECIALTY PRODUCTS ARE MADE

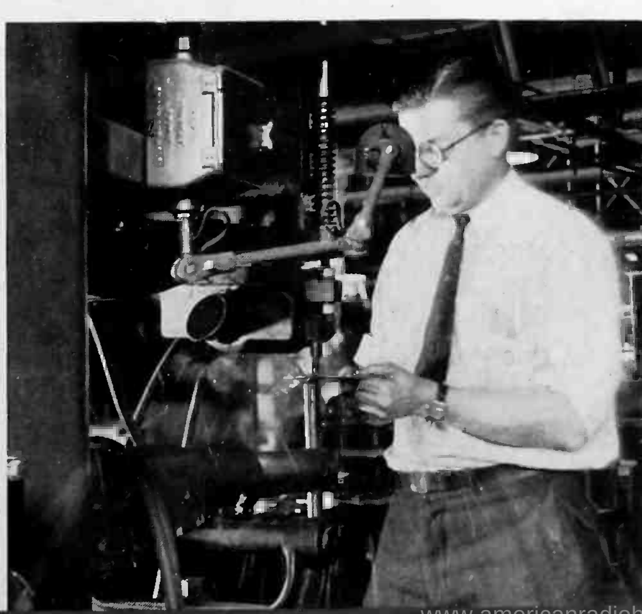
KEARNY (N. J.) WORKS



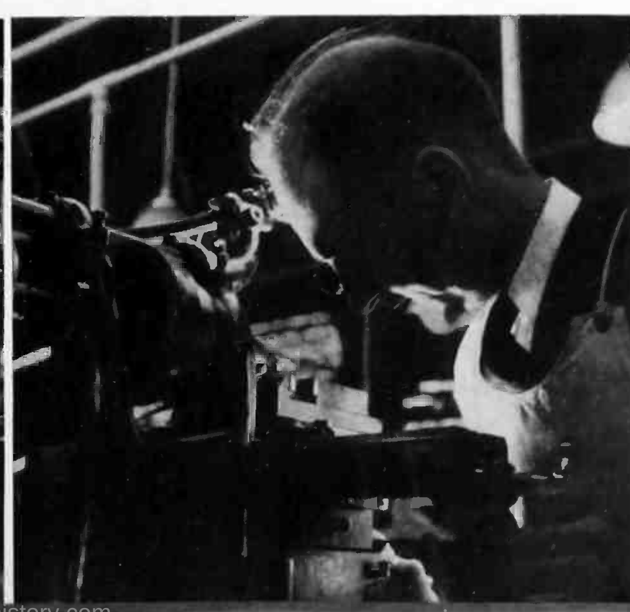
ing up a 639A in sound- and vibration-proof room for final dis- ination test of velocity, dynamic and cardioid characteristics.

Here's a long line of 118 type amplifiers being assembled and wired on a production basis. The finished units are thoroughly tested before shipment.

ls are wound each year on hines such as shown here.



Spot welding, which insures joints of maximum strength and rigidity, is used extensively in the Kearny shop.



This toolmaker, performing a precision milling operation, is one of many specialists trained for this type of work.

Chief Engineer Ben Ackerman operating a mixer on the center control panel. (Left) These racks hold all amplifying and speech input panels associated with the three control units.

WGST Installs New Studio Controls

Station WGST, Atlanta, Georgia, recently installed complete new studio speech input equipment in their new location on the ninth floor of the Forsythe Building. It was in October, 1938, that the decision was made to move studios and offices from their old home in the roof garden of the Ansley Hotel. The necessity for facilitating the move as well as the desire to have the most up to date equipment in their new studios led the owners of WGST to scrap all of the existing control system and install new equipment throughout.

All of the necessary amplifying equipment is of Western Electric make and purchased through Graybar. This material together with a control and switching system designed by Ben Ackerman, chief engineer, was set up in the control room located between the two main studios.

The amplifier setup includes nine 104A amplifiers, two 105A amplifiers, one 106 amplifier and seven 94 amplifiers. The 104A pre-amplifiers are supplied with filament and plate power from a Western Electric 15A rectifier, with provision for switching to the 105A line amplifier for power in case of failure of the 15A.

Three control panels are mounted on a horseshoe shaped desk, so placed that each panel faces the studio which it controls. In the upper left corner of each panel are four interlocking push buttons used for channel switching, providing all three panels with switching buttons for all circuits. Any control panel may be switched to any one of three line amplifiers, or all three may be connected to the same amplifier, making it possible to originate three programs at the same time. When a control panel is switched to a particular channel, the volume indicator on that panel is also switched. These volume indicators, as well as those at the transmitter, are the new type measuring volume levels in "VU."

Each of the two control panels at the ends of the horseshoe, facing the two main studios, has mixers for its own studio only. On the center panel, however, the five mixer controls are for the announcer's booth (which the panel faces) transcription machines, network, remotes and a spare. The eight interlocking push buttons at the top right of this panel control the monitor speaker circuit. The operator may, by pushing the proper button, listen to the program on the air, one of two audition channels, the network, three other local stations or the remote control. Four speakers in the offices also have this setup, each speaker with its own volume control and 94C amplifier. These amplifiers are all in the control room racks and may be patched out if necessary.

The small panel to the left of the center control panel is the order wire panel. A call on any circuit will light the signal lamp over that line and operate a buzzer until answered. To the right is the program circuit panel. When a key on this panel is down the line is connected through coil, equalizer and pad to the remote relay and mixer. When the key is up the program line is connected to a test position where it is possible to connect it to an ohmeter or to the telephone set.

The input and output of every circuit are connected through the patch board, providing maximum flexibility. There are eight microphone outlets in the large studio and six in the smaller one. These are so connected that any setup may be made without running mike cords across the studio. Some of the outlets are in parallel, and all circuits are permanently connected to a pre-amplifier.

The studios are of the most modern design with slanting walls to cut down sound reflection. To reduce the transmission of sound through the observation windows the frames between the panes of glass are lined with sound absorbing material. The studios and control room have no outside windows and are air conditioned summer and winter. The exhaust air from the control room is drawn through the cabinet racks. This keeps the temperature at all points in the racks below 95 degrees Fahrenheit, prolonging the life of all amplifier parts, particularly the electrolytic condensers.

The installation of its new studios gives WGST a high fidelity system throughout, with a frequency response of 30 to 10,000 cycles ± .75 db from mike socket to antenna and a noise level 60 db below 6 milliwatts, including studio transmitter line.

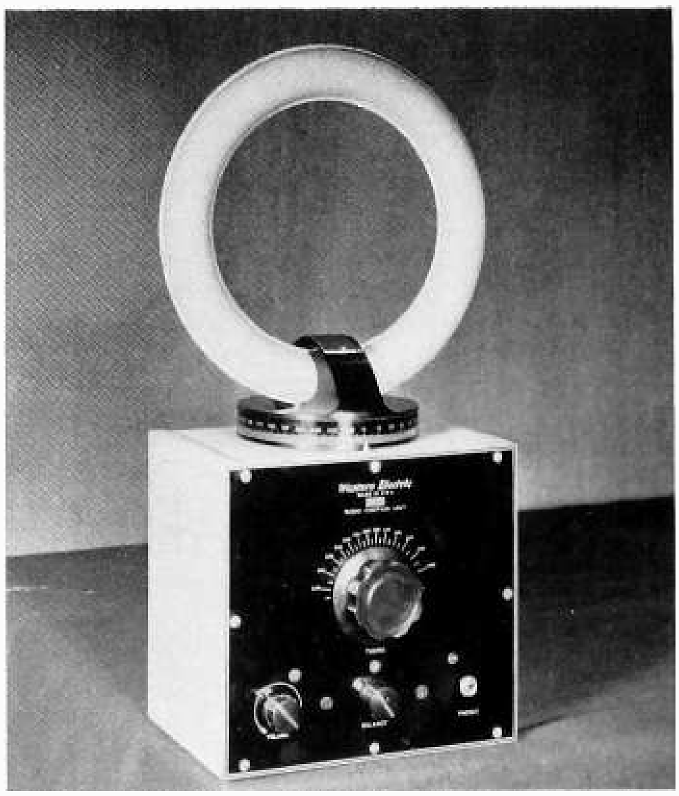
New Marine Radio Compass Is Aid to Ship Navigation

To increase further the usefulness of its marine telephone equipments, the Western Electric Company has introduced the 50A radio compass unit which, in association with the telephone equipment, will permit radio bearings to be taken for determining the ship's position.

The compass unit consists of a small metal box carrying tuning and volume controls on the front and a loop antenna on the top. Power is obtained from the radio telephone system, and the loudspeaker of this unit is also employed. A jack is provided on the compass unit to permit a headset to be used instead of the loudspeaker if desired. A switch on the radio telephone set switches the circuits to the regular antenna or to the compass as desired.

The 50A compass unit covers the frequency band from 230 to 350 kc, which includes all of the marine radio beacons maintained by the U. S. Lighthouse service and located at strategic points on the Atlantic, Pacific, and Gulf coasts, and on the Great Lakes. By taking bearings on two of such stations, the ship's position may be determined regardless of fog or darkness. Also included in the band from 230 to 350 kc are numerous aircraft beacon stations operated by the Civil Aeronautics Authority.

Operation of the compass is simple. On installation, the compass box is permanently fastened in position, and the bearing scale on the base of the loop, which is adjustable in position, is set so that the zero gives a direction in line with the keel of the vessel. After a signal has been tuned in, the loop is turned to the position of minimum signal. The reading of the scale then gives the bearing in degrees with respect to the ship's keel. The true bearing of the station may then be determined by the application of the ship's course obtained from the magnetic compass. The 50A compass was designed particularly for use with the Western Electric 227B Radio Telephone Equipment.



Western Electric 50A Marine Radio Compass

Architectural Competition

(*Continued from page 8*)

may be accomplished for the largest number of stations.

"The competition is wide open to all architectural students in every school and atelier in the country," stated Mr. Teegan. "Furthermore, the rules of the competition have been made as broad as possible in order to stimulate original thinking and to give the greatest scope to the design possibilities. Students may render their designs in any medium, whether it be drawings, complete models in cardboard or clay or any other way best suited to delineate the features of their particular design."

"The Western Electric Company welcomes the opportunity of sponsoring the competition and offering its fullest cooperation to all students in the contest," stated Mr. Frederick R. Lack, manager of the Specialty Products Division of the Company. "The engineers of Bell Telephone Laboratories who design all broadcasting equipment sold by our company have for many years realized that greatest value of the equipment and the best possible broadcasting job can be achieved only when there is a perfect wedding of equipment and the building which houses it. Modern broadcasting is an intricate, specialized undertaking calling for unusual facilities and requirements. If this competition results in new designs offering greater functional harmony it will be justified."

One of New York's new five passenger police planes ready to take off from Floyd Bennett field to patrol the city from the sky

Two sets of Western Electric transmitters and receivers on police planes operate over intermediate ... ultra-high frequency bands

Police Radio Patrols the Sky

The voice of New York's police patrol has penetrated the last outpost—the sky. For police radio has donned wings and that proverbial long, strong arm of the law is reaching up as well as out over the big metropolis. Flying policemen are cruising the airways, keeping a bird's eye watch over the city's 312 square miles of land and 587 miles of water front with two-way radio telephones right at their elbows.

Both the land and the seaplane, composing this new air squad, are five passenger ships each manned by two expert police pilots. On board are two sets of Western Electric transmitters and receivers—one operating on the ultra-high frequency police band—the other on the intermediate police frequency. Thus the flying patrolmen can carry on two-way conversations with police headquarters, with three patrol cars and three patrol boats equipped with similar sets, with Floyd Bennett Airport and with other planes using two-way systems. They also can transmit messages to the entire fleet of radio patrol cars, patrol boats and emergency trucks operating on the intermediate frequency.

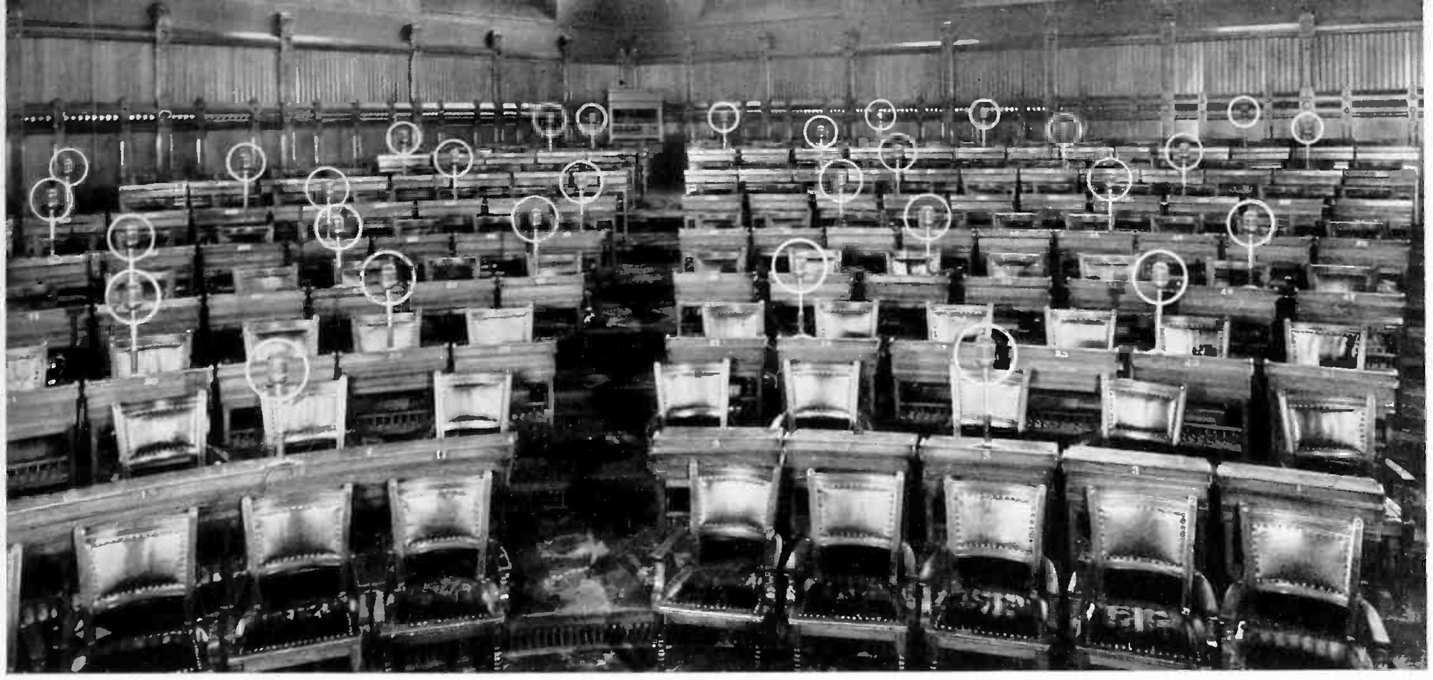
The main job assigned to the winged policemen is to prevent violations of the rules and regulations governing air traffic. Chief violators of aeronautical rules are airmen who fly below the 1000 foot limit, stunt flyers, and unlicensed planes. True, these air officers cannot, like the motorcycle cop, lean out of their planes and tell the offender to "draw up to the side of that cloud." But they can jot down the number of the plane and immediately report it to Headquarters. Headquarters in turn relays the report along to airports in the vicinity and when the flyer lands his ship he may be surprised to find himself answering to the aeronautical authorities for his misdemeanor.

Since distances in the sky cannot be judged by the eye—the police pilot drops to the level of the suspected flyer—checks his own altimeter and if it registers less than the permissible 1000 feet he has his man covered.

Although the radio planes have been operating but a short time it is evident that the services they can render are far reaching. They can, for example, lend considerable assistance in regulating and directing congested traffic on land when big

(*Continued on page 25*)

Line-up of New York's police radio flying squad whose main job is to prevent violations of aeronautical rules governing air traffic



On the floor of the House of Representatives the 639A's are so placed that there is a microphone within reach of every member.

Public Address Helps Legislators

The recent development of directional microphones and loudspeakers has made possible the use of public address systems in many instances where previously the use of voice amplification would not have been feasible. Outstanding among locations which have taken advantage of the sound control offered by modern equipment is the Hall of the House of Representatives of the State of Connecticut in Hartford.

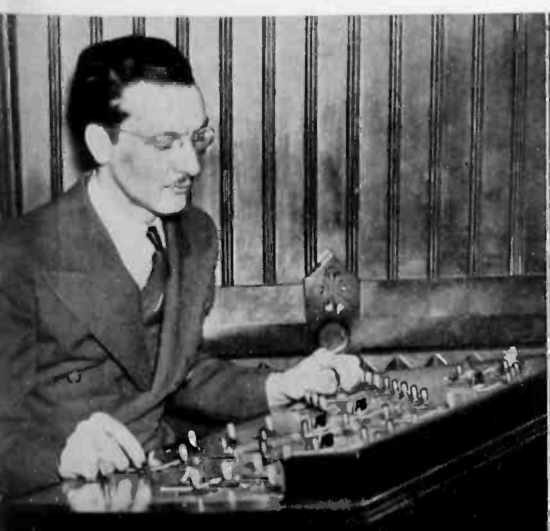
The State Capitol Building in which the Hall is located was constructed before the turn of the century at a time when acoustics was a science about which comparatively little of practical value was known. The room where the 266 members of the House discuss affairs of state occupies a wide floor area and, with its extremely high ceiling, offers a large volume of space in which the voices of members bounced freely about, resulting in attenuation as well as reverberation. Members at one end of the hall had great difficulty hearing those at the other and if a voice was raised in response to the familiar cry of "louder," reverberation made it even harder to understand.

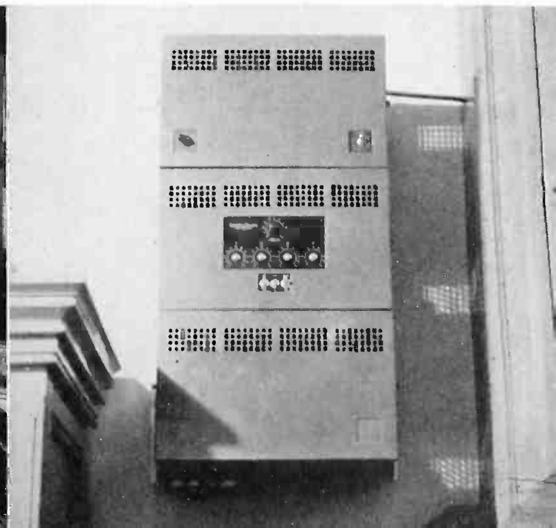
Due to this reverberant condition of the chamber, the ability of the public address system to produce a high volume level of reproduced sound was not the important factor. Instead, the essential requirement was to confine the distribution of reenforced sound to the area occupied by the members. This directing of sound was obtained by using four Western Electric 751A loudspeakers suspended in gondola fashion from the ceiling at the front center of the chamber above the speaker's rostrum.

Forty-six 639A cardioid microphones are used to pick up the voices of the members. These are placed on the desks of various representatives in such a manner that everyone has a microphone within reach. Since all of the reenforced sound is sent directly back toward the microphones, the use of 639A's is an important factor in this installation. The cardioid pattern, with its "dead" area facing the loudspeakers, results in perfect feedback control with little of the reenforced sound reentering the microphones.

A control panel, mounted on a desk in one corner of the room, contains a key for each microphone and a volume control for each group of five keys. This panel is laid out to simulate roughly the floor plan of the House Chamber, with the keys in positions corresponding to those of the microphones on the floor. The control operator, at the direction of the Speaker of the House, easily and quickly connects the proper microphone through its associated key.

The control operator "throws" a microphone key as Representative E. O. Smith talks from the Speaker's position. Members at the desk are M. J. Whelan on the left, and Milo Apley. (Right) In these cabinets are the amplifiers for the system.





WNAX

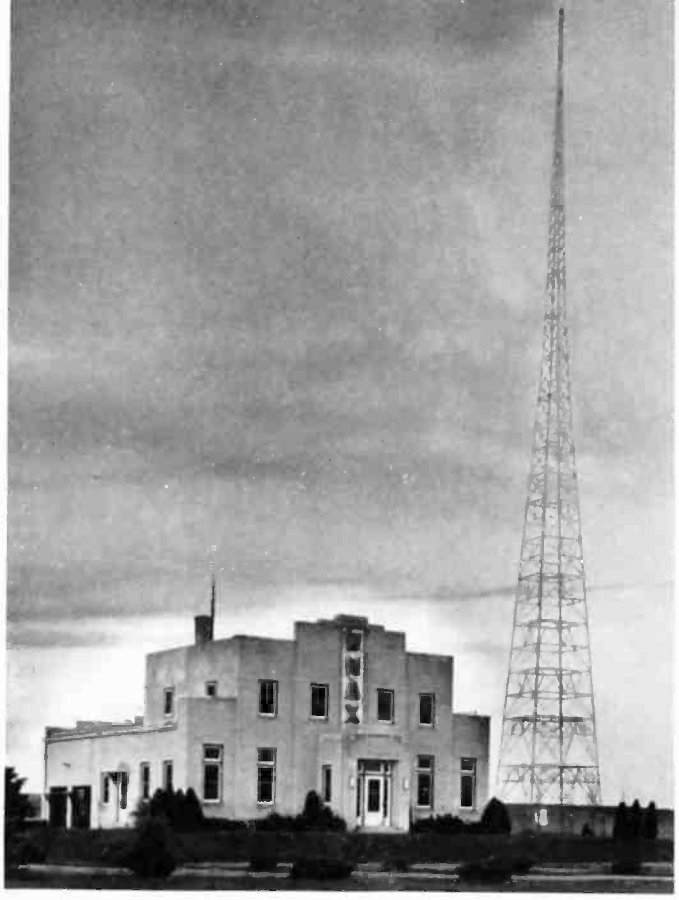
Yankton, S. Dakota

Throughout the states of North and South Dakota, Nebraska, Iowa and Minnesota farm and city folks "just naturally" listen to WNAX.

Ever since the station started operating in 1926 it has been living up to its motto: "serving the midwest farmer." Naturally the past 13 years have seen many changes in personnel, programs and equipment. But the station continues to live up to its original aim — planning programs of special interest to small-town and rural listeners.

Purchased from the House of Gurney, midwest seed firm, November 1938, by Gardner Cowles, Jr., of the Des Moines Register and Tribune, the station has been increasing its personnel and technical equipment for the past twelve months.

The transmitter building, erected in 1935, is located about five miles north-west of Yankton. A 450 foot quarter-wave self-supporting Blaw-Knox vertical radiator gives added push to the 5000 watt day and 1000 watt night-time power of WNAX on the very favorable frequency of 570 kilocycles.



From this attractive building the voice of WNAX travels to North and South Dakota, Nebraska, Iowa and Minnesota. Robert R. Tincher, manager; Clif Todd, chief engineer; Phil Hoffman, commercial manager, get in a huddle over new plans.

The transmitter house contains a work shop, five room apartment for the chief engineer and his family, complete auxiliary studio for use during special broadcasts as well as other equipment. A Hammarlund super-pro communications receiver is part of the standard equipment and is used daily to rebroadcast programs through WNAX.

The Western Electric transmitting equipment includes a D 94-992 transmitter and a 110A program limiting amplifier.

Three factors contribute to the remarkable five state primary coverage area of WNAX: a widening band of soil of A-1 conductivity, fanning out from the transmitter through North and South Dakota, acting as a natural path for WNAX signals; a carrier wave of 570 kilocycles; the fact that separation distances from other stations on the same frequency are greater than in most cases. Due to this splendid coverage the Columbia Broadcasting System has made WNAX its only outlet between Minneapolis and Denver. According to a recent survey it leads all CBS stations regardless of location, in rural daytime listening audience.

A recent development which makes for better service to farmers of the territory is the construction of complete supplementary studios and offices in the Orpheum Theatre building in Sioux City, Iowa. This modern layout uses Western Electric 23A studio console control equipment with Cardioid and Saltshaker microphones. A direct line connects the studios there with Yankton and programs of a special nature emanating from Sioux City add to the already extensive coverage and service.

(*Continued on page 23*)

Announcer Jack Chase gives a remote broadcast from one of the new supplementary studios recently opened at Sioux City.

Neutralization

(*Continued from page 5*)

signal on the grid will be entirely unaffected by what goes on in the plate circuit.

One of the earliest experimenters in the power amplifier field was H. W. Nichols of Bell Telephone Laboratories. His solution to this problem was extremely simple, and although subsequently neglected for many years, has turned out to be the most practical method of neutralizing modern high-power broadcast transmitters, particularly the high-efficiency type developed by Bell Telephone Laboratories. It consists of simply connecting between the r.f. plate and grid leads an inductance, as shown in Fig. 7, whose reactance is equal in magnitude to that of C_{pg} at the operating frequency. The current in this coil lags the voltage across it by 90 degrees, while the current in C_{pg} leads the voltage by 90 degrees, so that the total current fed back to the grid is zero. This method, called "coil neutralization", works so well that in the final stage of the Western Electric 407A 50-kilowatt transmitter the coils are simply wound with a number of turns calculated for the frequency and no taps or adjustments of any kind are necessary. In cases where a variation under power is desired a variable condenser (Fig. 8) of small capacity shunting the coil may be used. This condenser in effect varies the plate-grid capacity to make its reactance equal to that of the coil.

When grid-bias modulation is employed a condenser must be inserted in series with the neutralizing coil, as indicated in Fig. 9. The capacity has to be small to avoid phase shift in the audio voltage across the grid, an important consideration in modern transmitters because of its effect on the feedback. By making this condenser variable the neutralization may be adjusted under power. This circuit is used in the 5-kilowatt stage of the 50-kilowatt transmitter mentioned above, this being a grid bias modulated stage.

The distinguishing feature of the above circuits is that the neutralizing current is fed back from the same point in the plate circuit as the interelectrode current, i.e., from the anode, so that the impedance required is always inductive. The next general type of neutralizing circuit is the type in which the neutralizing current is fed back from a point having a potential *opposite* to that of the anode, so that the impedance required will be a condenser. The problem in this case is to establish such a point of opposite potential. It is also convenient if this second potential is roughly equal in amplitude to the first, so that a neutralizing capacity approximately equal to the interelectrode capacity can be used. Given a source of potential E_p we can always obtain an equal potential of opposite phase by using a combination of two reactances, 2X and —X, as shown in Fig. 10. The current through the circuit is E_p/jX, where j indicates a 90-degree phase shift, and so the drop across the condenser is $-jXE_p/jX$ or $-E_p$. Hence we can use the high side of the condenser as a point from which to feed back, through a small condenser C_N, our neutralizing current. And since the series impedance of the combination is jX, the impedance required to parallel-resonate it is another condenser like the first; so the complete circuit assumes the well-known built-out appearance of Fig. 11.

There are three interesting points to be observed in this built-out circuit, all of them important from the design standpoint. One is that under operating conditions the currents in the neutralizing capacity C_N and tube capacity C_{pg} are not equal, and are not supposed to be. The potential across C_{pg} is the arithmetic sum of E_g and E_p, while the potential across C_N is their difference. The currents that *are* equal and opposite are the *portions* of the two currents that result from E_p. The portions that are due to E_g are actually in phase instead of opposite in phase, so that looking into the input terminals of the amplifier a definite capacity appears; this capacity is, however, independent of E_p, which is what we require for complete neutralization. In the type of circuit shown in Figs. 7, 8, and 9 the currents are actually equal and opposite and no such apparent capacity is presented at the grid terminals.

The second point is that the reactance —X to which we connect the neutralizing condenser C_N is affected by C_N; it can be shown that it is really the parallel combination of the two which constitutes our —X. Hence, if for feedback purposes we were to try broadening the plate circuit by using higher reactances throughout, so that our building-out condenser labelled —X became comparably small in capacity with C_N, we should ultimately reach a point where the former would disappear entirely, whereupon we should find ourselves back to the circuit of Fig. 9. In fact, it was as a result of the careful attention paid to circuit broadening that the method of Fig. 9, in conjunction with grid bias modulation, was evolved as the best possible means of obtaining a wide band in the intermediate stage of the Western Electric 50-kilowatt transmitter.

The third point the author wishes to bring out in regard to Fig. 11 is that if the load is coupled inductively to the coil labelled 2X, as is often done, complete neutralization can never be obtained, because of the phase shift caused by the introduced resistance. For complete neutralization the load would have to be connected or coupled to some circuit at points A and B of Fig. 11, entirely separate from the neutralizing circuit.

When two tubes are used instead of one, the building-out problem assumes a more favorable aspect. In the push-pull circuit of Fig. 12, familiar to everyone, equal and opposite potentials are sure to exist as long as symmetry in tubes, circuits, and excitation is maintained, and the load may be coupled inductively without affecting the neutralization at all. From a neutralizing standpoint, therefore, a push-pull circuit is ideal.

Figs. 13 and 14 illustrate a type of neutralizing circuit which up until a few years ago was quite widely used. It involves a built-out grid circuit with the input inductively coupled. Most radio engineers are not aware of the fact that this scheme does not give true neutralization at all. When the ordinary neutralizing procedure is followed, of applying excitation with the plate voltage removed and adjusting C_N to give a minimum reading on a small r.f. meter in the plate circuit, a very good null is obtained with C_N equal to C_{pg} and the operator usually feels gratified.

But let us look at the matter more closely. The criterion of neutralization is whether a voltage between plate and ground causes any reaction on the grid potential. If we consider Fig. 13 and imagine an r.f. voltage on the anode, this voltage will cause two currents of equal magnitudes and identical phase to flow back through the capacities C_{pg} and C_N. These currents will not appear in the grid inductance because they balance out in it; their only path to ground is through the grid tuning condensers. The currents produce across these two grid condensers, by a potentiometer effect, two voltages which are in phase with the plate potential, while the normal excitation on the grid side of the circuit is opposite in phase to the plate potential; hence the excitation is reduced and we have a negative feedback. On the built-out side of the circuit, where the input voltage is *in* phase with the plate potential, we get an increase in voltage, which has no effect since there is no grid connected at this point.

The author once checked this conclusion by connecting r.f. voltmeters across the two separate sides of the grid input circuit. Before plate voltage was applied, the voltmeters indicated perfect balance. As soon as the plate supply was thrown on, the voltage on the grid side was seen to drop 10 per cent, while the voltage on the built-out side increased by the same amount.

In the circuit of Fig. 14 these two effects would be reversed, giving a positive feedback. This is because the currents fed back in this case do go through the grid inductance, reaching ground through the center tap; and since the coupling between the two sides of the coil is usually poor, an inductive drop is set up which gives us a grid potential *opposite* in phase to the plate potential and therefore additive to the excitation. This conclusion has likewise been checked experimentally.

The excellent null obtained in adjusting one of these circuits is therefore very misleading. The fact is, that the system actually is neutralized as far as any reaction of the plate potential on the total voltage across the "balanced" input circuit is concerned, but since the circuit goes out of balance and we are picking the voltage off of one side only, the assumption that we have a neutralized amplifier is erroneous.

Such a system therefore is certainly not to be recommended, especially in the case of modulating amplifiers, where, as pointed out earlier, incomplete neutralization has very undesirable effects.

We come finally to the ingenious and useful neutralizing circuits of Hazeltine, shown in Figs. 15 and 16. These circuits, like the last ones discussed, employ a condenser as the neutralizing element, but the phase reversal in grid or plate circuit is obtained with a transformer instead of a built-out tuned circuit. Before the interesting equations for these circuits are derived the reader should recognize an important principle which simplifies the study of neutralizing circuits and aids in the devising of new ones to suit particular purposes.

This is, that in a balanced bridge the conditions for balance are entirely independent of the impedance of the detector. In fact, in any circuit in which there is zero current in a given branch, or zero voltage across it, that branch may be opened or short-circuited or changed in any way with no effect on the rest of the circuit. This means that in deriving the conditions for complete neutralization with a given type of circuit, no thought need be given to the external parts of the grid circuit, since the grid-filament terminals really constitute the detector arm of a bridge which we are trying to balance. And to bring out this point graphically we may consider the grid to be actually short-circuited to ground with an ammeter, as shown in Fig. 16, whereupon we simply proceed to design a neutralizing circuit that will keep this meter reading zero when someone impresses an r.f. voltage E_p on the plate of the tube. This makes it unnecessary to include any external grid circuit elements in our equations, and thereby provides a short cut, since these would drop out anyway in the final result.

The ammeter in Fig. 16 will read zero if the current fed back through X_N is equal in magnitude and opposite in phase to the current E_p/X_{pg} fed back through the tube capacity.

The X_N circuit has a negative reactance of $X_N - X_2$ ohms and therefore introduces into the primary coil X_1 a positive reactance of $X_m^2/(X_N - X_2)$ ohms. The current in X_1 due to E_p is therefore

$$I_1 = \frac{E_p}{X_1 + \dfrac{X_m^2}{X_N - X_2}} = \frac{E_p(X_N - X_2)}{X_1X_N - X_1X_2 + X_m^2}. \qquad (2)$$

The voltage induced in X_2 is X_m times this, and to find I_2 we divide this induced voltage by the reactance $X_N - X_2$ of the secondary circuit, obtaining

$$I_2 = \frac{E_p X_m}{X_1 X_N - X_1 X_2 + X_m^2}. \qquad (3)$$

Now since the mutual impedance X_m is $k\sqrt{X_1 X_2}$, where k is the coefficient of coupling between the two coils, this becomes

$$I_2 = \frac{kE_p \sqrt{X_1 X_2}}{X_1 X_N - X_1 X_2 + k^2 X_1 X_2} = \frac{kE_p \sqrt{\frac{X_2}{X_1}}}{X_N - X_2(1-k^2)}. \qquad (4)$$

This is the quantity which is to be equal in magnitude and opposite in phase to the interelectrode current E_p/X_{pg}. The phase will be taken care of by proper polarity of the transformer, so we merely write, cancelling E_p,

$$\frac{k\sqrt{\frac{X_2}{X_1}}}{X_N - X_2(1-k^2)} = \frac{1}{X_{pg}}, \qquad (5)$$

or,

$$\frac{X_N}{X_{pg}} = \frac{k\sqrt{\frac{X_2}{X_1}}}{1 - \frac{X_2}{X_N}(1-k^2)}. \qquad (6)$$

It is interesting to note from expression (6) that if the coefficient of coupling k approaches unity, or if X_N is large compared with X_2, we arrive at the simple result

$$\frac{X_N}{X_{pg}} = k\sqrt{\frac{X_2}{X_1}}; \qquad (7)$$

and that if we intend to use a neutralizing capacity equal to the plate-grid capacity, so that $X_N/X_{pg} = 1$, we simply design the coils so that

$$\frac{X_2}{X_1} = \frac{1}{k^2}. \qquad (8)$$

As with all neutralizing circuits, the actual adjustment is made by applying excitation to the grid with plate voltage removed, and adjusting for minimum r.f. voltage between plate and ground or minimum current in one of the output circuit elements. This procedure simply makes use of the reciprocity principle which tells us that if excitation on the grid produces no voltage at the plate, then a voltage appearing at the plate will produce none at the grid, which is the condition we want to obtain. It just happens to be convenient to apply the voltage to the grid.

In view of this principle, the circuits of Figs. 15 and 16 are just alike, the grid and plate being merely interchanged, so that the expressions derived above will apply to either.

The method of Fig. 16 is well adapted to grid bias modulation, since the small neutralizing condenser and the tube capacity have very little shunting effect on the applied audio signal. This method is used very successfully in the new Western Electric 1-kilowatt broadcast transmitter, which employs grid bias modulation in combination with the high efficiency circuit.

The circuits that have been described, while not the only ones available, represent the basic methods for avoiding reactions between output and input circuits through the interelectrode capacity. The author believes that by keeping in mind the simplified viewpoint given in the foregoing, of imagining the grid short-circuited by an ammeter and determining what is needed to make this ammeter read zero if a voltage were to be impressed on the plate, the experimenter will be able to check the correctness or incorrectness of any proposed method of neutralization and devise new combinations to meet particular requirements.

WNAX, Yankton, S. D.

(Continued from page 20)

Another feature added since the Cowles interests purchased the station is the organization of a Farm Service Department which is under the capable direction of Charles Worcester, well known in midwestern agricultural circles.

Gardner Cowles, Jr., president of WNAX Broadcasting Company, is one of the busiest men in radio. Added to his duties as associate editor of the Des Moines Register and Tribune, editor and publisher of Look magazine and director of the Minneapolis Star-Journal, is the presidency of the Iowa Network.

In a few short years Cowles has set up one of the most complete radio organizations in the country. It consists of stations WNAX, KSO, Des Moines; KRNT, Des Moines; and WMT, Waterloo near Cedar Rapids.

Luther L. Hill, vice-president and treasurer of the WNAX Broadcasting Company and of the Iowa Network, with which WNAX is affiliated, has had a rapid rise in radio. Four years ago, Hill joined the Iowa Network as manager of KSO-KRNT. Previous to that time he had had no broadcasting experience.

Staff members of WNAX include Robert R. Tincher, general manager, who came to the station from the Iowa Net after its purchase by the Cowles; Arthur J. Smith, program director, also from the Iowa Network organization and Phil Hoffman, commercial manager. Clif Todd is chief engineer. Ed La Grave, director of regional sales and merchandising, is in charge of the Sioux City office ably assisted by Jack Chase, announcer.

Beaching by Radio Grows

(*Continued from page 7*)

words used in the script. Suggestions for follow-up activities included excursions to museums or other institutions exhibiting Dutch materials; visits to historical homes and buildings around the city, art work picturing historical events, listing streets with Dutch names, re-enacting simplified versions of the broadcasts. This series was developed through the collaboration of the Brooklyn Children's Museum and the Board of Education's Studio Workshop.

Dr. Colston has fought hard and long to put radio into the schools. It was he who travelled down to Washington again and again to put the matter up to the FCC. His enthusiasm and convincing arguments finally won the Commission's approval for the special short wave channel.

Naturally he was delighted when it was decided to install the new station in his school. His whole life is centered on Brooklyn Tech's progress. He planned the first course of study 18 years ago when the school opened with 1800 students enrolled. Today he has 6300 boys under his jurisdiction. "They're the cream of the city, he says proudly. "We have a live group of radio fans here — you should see the work our amateur radio club is doing over its station W2CXN. It won special recognition during the big hurricane disaster in 1938."

Everything a boy could wish for is right there at Brooklyn Tech — handball courts, two fine gymnasiums, laboratories, shops, swimming pool and even a television room on the roof. Throughout the whole organization there is an unmistakeable atmosphere of good fellowship. As Dr. Colston walks along the corridors or strolls into a shop or laboratory he always finds time to stop for a friendly chat. His manner is so informal, his interest so genuine that he immediately puts the boys at their ease. Often he joins them after school hours in the television room or on the ball courts. His friendliness, understanding and wise guidance has won the profound respect and affection of students and teachers alike.

In accord with other educational leaders

Chief engineer Herman Haverkamp checks the Western Electric transmitter while Technical Director William Pabst looks on.

Dr. Colston agrees that radio will never supplant formal teaching methods. "It will," he says, "most effectively supplement these methods. Through its use teaching and learning can be broadened and accelerated. Experiences in the classroom take on new meaning, heightened interest. Radio vitalizes the whole art of teaching. But, in the final analysis, it is up to the teacher to make this fascinating new medium the truly powerful aid it can become."

When it came time to select a voice for the new station Western Electric equipment was chosen and a 500 watt ultra-high frequency transmitting system consisting of a 16B transmitter and 88A amplifier went into WNYE. The 106B radio telephone broadcasting equipment which serves as an auxiliary transmitter for WNYC has been completely modernized for high fidelity operation and the 7A speech input equipment originally installed with the 106B equipment has been replaced by new equipment engi-

Young musicians from Public School 69 entertain hundreds of their fellow students listening in from classroom or auditorium. Below: Here's how WNYE's sound effects are produced — Tech students built the appartus and pupils from various schools take turns operating it.

neered to fit the particular requirements of the station.

WNYE operates on 41.1 megacycles. The 500 watt output of the amplifier is fed over a 600 foot gas-filled concentric transmission line to a shunt-excited coaxial antenna mounted atop the self-supporting tower at a height of 454 feet above the street level. This 304 foot tower, installed on the roof of the school, is used for a vertical antenna at 810 kilocycles for the modified 106B equipment. A special filter installed at the base of the tower permits simultaneous operation of both transmitters.

The 6B transmitter in use for several years as auxiliary equipment for WNYC was modified to use 700A quartz crystal oscillators, maintaining the operating frequency within one cycle of the assigned frequency. A 5000 volt plate supply rectifier and stabilized feedback were also part of the modification. The output of this transmitter, formerly connected to a "T" type antenna suspended above the roof, is now connected by means of a 300 foot concentric transmission line through a coupling unit to the base of the 304 foot vertical radiator. A special circuit incorporated in the transmitter provides protection to the transmission line against the possibility of an arc set-up across the line by lightning.

The new speech input equipment is designed to feed the 41.1 megacycle transmitter, the modified 106B equipment and a program circuit to station WNYC either simultaneously or separately and employs 104B, 105A, 106A, 110A program amplifiers and 94 type monitoring amplifiers. A custom built speech input console was designed for maximum flexibility and ease of operation.

Plans are being worked out for installing recording apparatus in the studio so that programs may be repeated in the schools when requested. In time the station hopes to build a valuable record library which can be used from year to year or until the present courses of study change. Later, a second studio will be installed. The present one is located on the eighth floor with transmitting equipment and control board in an adjoining room.

WNYE's engineering force is headed by William Pabst, technical director, who also serves as chairman of Brooklyn Tech's Department of Applied Electricity. Herman Haverkamp, chief engineer, tinkered around crystal sets when he was a youngster and received his commercial radio license in 1914. He joined the navy during the world war and when it ended went into commercial broadcasting. He is a lieutenant in the Naval Reserve, a member of the Royal Photographic Society of Great Britain and faculty advisor of Brooklyn Tech's radio club. Ricardo Muniz, assistant engineer, graduated from Brooklyn Polytechnic School in 1930. Following graduation he became actively engaged in radio receiver work and electro-therapeutic design of both high frequency and x-ray equipment. He joined Brooklyn Tech's faculty in 1935 as teacher of applied electricity.

Police Patrol the Sky

(*Continued from page 18*)

parades are in progress or on such occasions as the recent visit of Great Britain's King and Queen. They also can easily spot and ease heavily congested water traffic during boat races or other celebrations which crowd the waterways.

Here's how the voice of authority from the sky will work when a big parade marches up Fifth Avenue or when the next outstanding celebrity graces our shores. The police pilot, cruising over the city, spots a particularly dense crowd of cars and pedestrians struggling to cross Fifth Avenue at the midtown cross streets. He picks up his telephone—talks to the radio cars on duty in the crowded area and directs them to divert traffic up Sixth Avenue to 44th Street—all quite simple and exceptionally speedy.

However, traffic problems are by no means the only jobs police radio planes will handle. They are quite likely to wing through the air at a moment's notice on errands of mercy, to participate in some dramatic rescue or to transport prisoners. Both planes carry stretchers and complete First Aid equipment and the pilots are well versed in First Aid practice. The cargo also includes side arms.

Here's a hypothetical emergency which may well come ringing through the ear-phones of the flying police. "Child lost in deserted section of Canarsie." It's a black night and police radio cars and an emergency truck with its powerful searchlight have been ordered to the scene. Close overhead hovers the radio plane. The truck plays the light across the scrubby downs and with the land thus illuminated the airmen scan the ground for the missing youngster. Cruising slowly, as near the earth as possible, they sight a moving object about a mile east of where the police group is congregated awaiting instructions from the air. And so, through his radio telephone the air officer directs the search.

Operators of the planes belong to the regular police force and are under the jurisdiction of the Emergency Service Division which also has supervision over emergency trucks and boats. Inspector Arthur W. Wallender is in charge of the division. At present the planes are quartered at Floyd Bennett field but it is planned to transfer them to North Beach airport in the near future.

This new service now made available did not come into being overnight. Plans for its inauguration have been in the wind for some years. Back in 1930 police authorities, in collaboration with Bell Telephone Laboratories and Western Electric, conducted experimental flights. Planes equipped with two-way radio carried officials aloft to test the feasibility of such a service.

Today, city authorities are thoroughly convinced that these policemen, whose beat is among the clouds, will prove a valuable investment.

Transmission Lines

(*Continued from page 12*)

151 nepers, 1315 decibels, and the phase change is 151 radians per centimeter.

Because of this rapid attenuation, 1315 db/cm, only an extremely weak voltage drop appears along the opposite surface of the shield. At this surface the field experiences an abrupt change in the properties of the mediums, copper and air, which gives rise to almost complete reflection, practically annihilating the field intensity and doubling the voltage drop. The reflection at the boundaries of the two mediums is analogous to the reflection of energy from the end of an unterminated transmission line.

The total reduction in the electric field due to the shield is therefore a result of two influences which are additive, reflection loss and attenuation loss. The magnitude of the reflection loss depends upon the frequency as well as the properties of the two mediums; or this might be viewed as the differences in the characteristic impedance of the two mediums. For mediums of copper and air and at broadcast frequencies the reflection and attenuation losses each amount to several hundred decibels. The same is true for energy propagated toward the interior of the shield and arising from any spurious currents flowing along its outer surface. Thus we may consider the coaxial line as a completely shielded circuit.

With coaxial lines, moreover, the operators have full control over the medium through which the energy is propagated to the antenna. The line may be kept under pressure of dry gas, such as nitrogen, practically eliminating any moisture as a result of condensation or leakage.

If a balanced shielded circuit is required it may be provided by either one of the two alternatives suggested in Table 1. The double coaxial type might be preferred because the material is more readily obtainable in that form.

There have been two objections to the use of coaxial lines between the transmitter output circuit and the antenna: (a) difficulties during assembly; and (b) the initial cost compared with some open wire circuits. In the earlier installations, a burn-out of the center conductor sometimes occurred during lightning storms. It was soon found that the burn-outs of the center conductor were rarely if ever caused directly by the lightning hits. A continuous radio-frequency arc followed the initial lightning spark and this sustained arc caused the damage. Difficulties from this source have been eliminated by the universal acceptance of protective circuits which momentarily deenergize the radio transmitter the instant an arc occurs in the transmission line. Several circuits for accomplishing this purpose have been devised and one of these should be included as a precautionary measure at all installations, including the open-wire lines.

The initial cost of coaxial lines and difficulties encountered during assembly have been continuously reduced by the manufacturers. This, together with improved installation techniques, has brought the advantages of the coaxial circuit within the practical and economic possibilities of even the very low power stations.

The writer wishes to acknowledge the valuable assistance of Mr. W. H. Wise in preparing several of the formulas given in Table 1.

Specialty Products Division

(*Continued from page 13*)

now manufactured by the Specialty Products Division of Western Electric failed to function chaos would grip the nation. But our super-scientist with his diabolical gadget will trouble nothing more than our imagination, and the newly organized Specialty Products Division will go on to produce more and greater equipment and services for the country.

The Division is made up of men who have brought all these developments to everyday use. Now, with their efforts more perfectly coordinated and centralized under one management for the related jobs of designing, manufacturing, and delivering equipment through which the human voice passes, even greater contributions to the welfare of the nation should come.

The new division, which began formal operation in November, is located at the Kearny, New Jersey, Works of the Western Electric Company and is headed by F. R. Lack as manager. In commenting upon the newly organized unit Mr. Lack said, "By bringing together at one location the personnel involved in development, manufacturing and commercial engineering, we expect to facilitate the fabrication and delivery of those products which normally lie beyond the scope of mass production operations."

The organization reporting to Mr. Lack consists of F. J. Feely, in charge of manufacturing; H. N. Willets, assistant sales manager; E. W. Thurston, sales promotion manager; C. R. Hommowun, service manager; and J. W. Sprague, division comptroller.

Except for a period of active duty with the Signal Corps during the World War, Mr. Lack has been associated with the Bell System since 1911. He devoted several years to Western Electric's interests in China and Japan in connection with radio and allied communication systems. As a member of the research staff of Bell Telephone Laboratories, he figured prominently in the early development of radio communication, particularly that phase concerned with the control of radio frequencies by piezo-electric crystals.

New Ultra-High Frequency Tube

The page illustration opposite shows a number of the new ultra-high-frequency tubes used in the Western Electric Altimeter. This tube, known as the D156548, generates five watts at 750 mc.

"So help me, it's twins! You can play both vertical and lateral records with Western Electric's 9A 2-in-1 pick up!"