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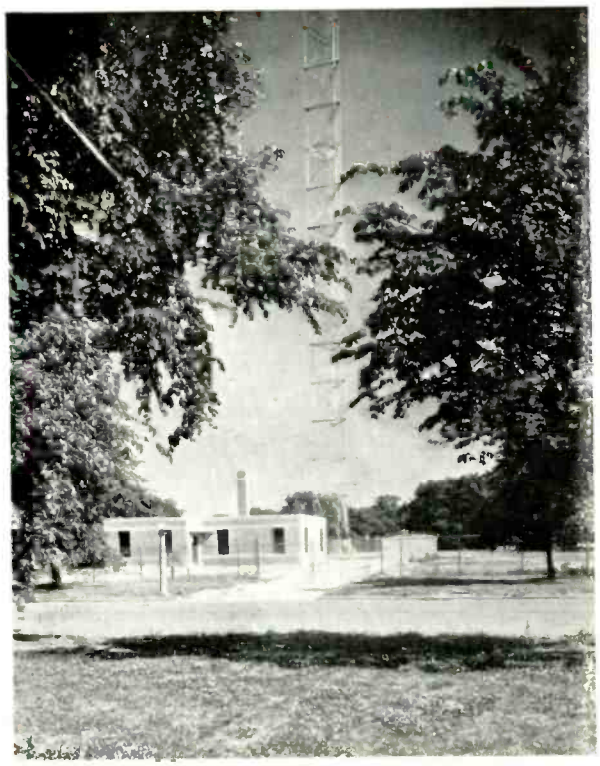

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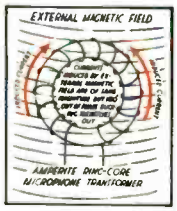

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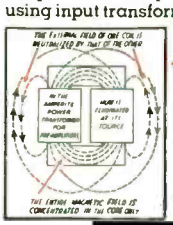

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VOLUME 3 SEPTEMBER, 1936 NUMBER 9

COVER ILLUSTRATION

THE 329-FOOT STEEL TOWER OF UNIFORM CROSS-SECTION THAT IS USED AS THE RADIATOR FOR THE SPRINGFIELD, ILLINOIS, POLICE-RADIO TRANSMITTER. SIX SIMILAR INSTALLATIONS ARE LOCATED IN VARIOUS PARTS OF THE STATE. (SEE ARTICLE, PAGE 8).

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DEPARTMENTS

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EDITORIAL

SINGLE-SIDEBAND TRANSMISSION FOR TELEVISION

THE ADVANTAGES of single-sideband transmission have long been recognized, and with the increasing attention it is receiving, it seems likely that this form of transmission will be more widely used in the next few years.

The single-sideband method was worked out by J. R. Carson some years ago and was first applied to carrier communication on wire lines. Since then it has also been applied with a great deal of success to radio telephony on long wavelengths, in particular to the long-wave commercial radiotelephone circuit between New York and London.

The single-sideband principle has not yet been applied commercially to the short wavelengths. One reason for this has been that until recently the saving of bandwidth has not been a very important consideration at the ultra-high frequencies. Now, however, considering the contemplated and existing services at these frequencies, it is readily apparent that the saving of bandwidth has come to be of considerable importance. This is particularly true in the case of television and its recommended bandwith of six megacycles.

At the present time television pictures can be satisfactorily transmitted with only one sideband. However, no method of producing a single sideband-modulated wave has been devised for use at ultra-short wavelengths. The problems involved are intimately tied up with apparatus limitations and the peculiarities of the modulators that are used. Nevertheless, the reduction in bandwidth and the increase in signal strength which can be had with a given transmitter power are assets which can not be overlooked.

APCO CONVENTION

MUCH GOOD should result from the Convention of the Associated Police Communication Officers which is being held at the Hotel Blackhawk in Davenport, Iowa, from October 5 through 7. This gathering is preceded by a convention of Police Chiefs in Kansas City, Missouri.

At this time it is of interest to point out that the FCC is formulating plans for a radio network linking large cities and state radio systems. Regular voice transmission will probably be used between nearby cities and adjacent states, while code will be used for a great deal of the traffic between distant points. As a matter of fact Indianapolis, St. Louis, Kansas City, Detroit, Davenport, Minneapolis, and New Orleans have already been licensed for experimental work along these lines.

State police-radio systems are also gaining considerable headway. Recent state police-radio installations have been made in Indiana, Michigan, Wisconsin, Iowa and Missouri, and the State of Illinois now has such a system under construction. Some of the former installations have already been described in COMMUNICATION AND BROADCAST ENGINEERING; a complete description of the equipment used for the Illinois system will be found in this issue.

"FACSIMILE"

IN OUR JUNE, 1936, editorial on *Facsimile* a mis-statement occurred. The second sentence in this editorial reads: "A transatlantic facsimile service was begun in 1924 and a telephoto service was started in 1925 by the American Telephone and Telegraph Company, the latter method now being used by the Associated Press for transmitting photographs to certain newspaper members."

While the telephoto service referred to was started in 1925 by the American Telephone and Telegraph Co., the transatlantic facsimile service was begun in 1924 by the Radio Corporation of America over its direct radiotelegraph circuit between New York and London. The facsimile service then inaugurated has been continued by RCA over the same circuit without any interruption from 1924 to date.

"EXPERIMENTAL" TELEVISION

ACCORDING TO FORMAL ORDERS issued by the FCC on August 22, television development must continue indefinitely on an "experimental" basis, without any commercial status or privileges. The new rules were made effective September 15 and follow the informal engineering hearings held last June. The rules also apply to international, facsimile, high frequency and relay broadcasting.

In providing for the future experimental broadcasting of television, facsimile, etc., the Commission adopted substantially the allocation recommendations submitted by the RMA. For television, in addition to limited allocations between 2000-2100 kc, the FCC provided for wide bands from 42-56 mc and from 60-86 mc. Also, allocations of 6 mc bands will be made above 110 mc, except for the 400-401 mc band.

All allocations formally ordered by the Commission emphasize the "experimental" and non-commercial restrictions during development of these new radio services of the future.

COMMUNICATION & BROADCAST ENGINEERING

FOR SEPTEMBER, 1936

MOBILE RECEIVING EQUIPMENT

for the Illinois Police-Radio System

BY CHARLES A. BROKAW
RCA MANUFACTURING CO., INC.

TO THOSE FAMILIAR with the development of state police radio since its inception, the system now being installed by the state of Illinois holds particular interest, embodying, as it does, many of the features associated with the "ideal" system. Ideas as to what constitutes an "ideal" system vary, but the requirement of "absolute reliability at all times" is paramount. In the engineering of the Illinois system, this requirement was given first consideration.

In mobile receiving equipment, this requirement means that, in addition to providing the electrical performance required for reliable communication, the equipment must be able to stand up under all conditions of police service. These conditions can, and usually do, mean 24-hour a day service, over all kinds of roads and in all kinds of weather. In addition, for motorcycle service the equipment must be able to withstand the extreme vibration from the machine. The two types of receivers—automobile and motorcycle—recently installed were designed especially for this type of service and were selected only after exhaustive laboratory and field tests.

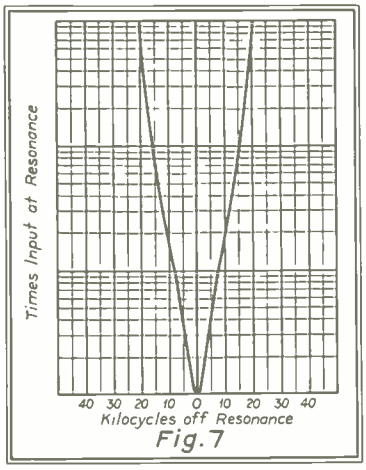


Fig. 7

The automobile equipment (see Fig. 1) consists of three units—the receiver, the power-supply unit and the loudspeaker. In a typical installation the receiver mounts on the passenger side of the fire-wall, the power-supply unit on the engine side and the speaker on the header over the windshield.

Interconnection of units is by means of shielded cables having plug connectors at the receiver ends. The volume and on-off controls are combined in a small control unit which clamps on the steering column and is connected to the receiver through a flexible-shaft cable.

Dimensions and weights are:

Receiver: length 12 inches, height 7½ inches, depth 8 inches, weight 15 lbs.

Power unit: height 7½ inches, width 6½ inches, depth 5 inches, weight 10 lbs.

Speaker: 5½ inches square, depth 2½ inches, weight 3 lbs.

The receiver case, of welded steel construction, is diagonally split and is so

FIG. 1. MODEL AR-5013. POLICE AUTOMOBILE RECEIVER.

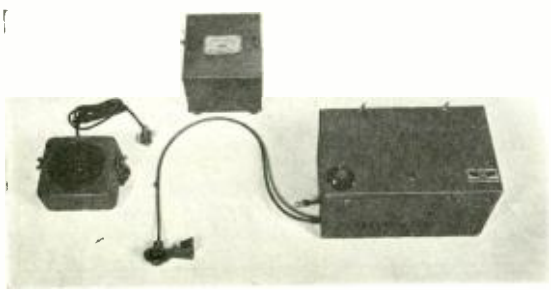
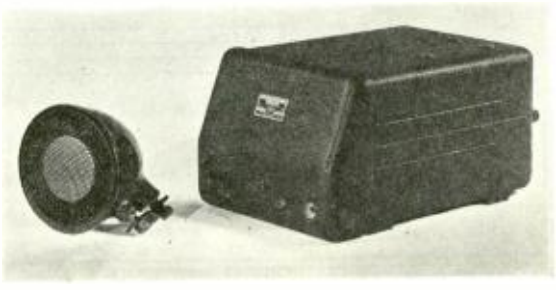


FIG. 3. MODEL AR-5020. POLICE MOTORCYCLE RECEIVER.



hinged that the bottom front section, on which the chassis is mounted, may be tipped down to give access to tubes and tuning adjustments. The complete chassis is readily removable from the case by taking out six screws and removing one knob. Since no connections are disturbed in this operation the unit may be checked or adjusted on the bench by simply plugging in a duplicate power supply. With the chassis removed, every part, including wiring, is accessible.

All parts on the chassis are rigidly mounted and supplementary bracing is used to prevent vibration. Resistors and capacitors are mounted on boards and are connected individually to terminals.

The receiver is of the superheterodyne type (Fig. 2), using a total of seven tubes employed as follows:

RCA-6D6—r-f amplifier.
RCA-6C6—first detector.
RCA-76—oscillator.
RCA-6D6—i-f amplifier.
RCA-85—second detector, avc, noise suppressor.
RCA-6C6—audio amplifier.
RCA-38—power output.

The RCA-85 is employed to perform the functions of detector, avc and noise-suppressor control. The d-c procured from one diode is used to give automatic gain control of the r-f, first-detector and i-f stages. Delayed avc action results from the presence of an initial negative bias on the avc diode plate. The d-c resulting from signal detection on the

FIG. 4. FRONT VIEW OF THE AR-5020 RECEIVER ON ITS CHASSIS.

second diode is applied to the noise-suppressor control circuit. The a-f portion of this voltage is fed to the audio amplifier through the arm of the volume control.

Tuning of the frequency determining circuits is by means of individual air-dielectric condensers, screwdriver adjusted. A separate adjustment on each circuit, accessible with the case open, is provided to take care of the minor changes necessary to convert the receiver to cover the 2300-2500 kc portion of the police band. Individual, can type, shielding is employed throughout.

To provide the degree of frequency stability required for fixed-tuned operation, a thermal frequency-drift compensator is used in the oscillator circuit. This, combined with a circuit having high inherent frequency stability and uniform output, obviates the necessity of frequent readjustment. Provision is also made for crystal control.

To meet the requirement of quiet operation during standby periods, an improved automatic noise-suppressor circuit is used. By means of this circuit the receiver output is, in effect, cut off to all signals, including noise, which are below the level of the station carrier. A control on the front of the set permits adjustment to suit local conditions of signal strength and noise. By means of this same control the suppressor circuit may also be made inoperative.

With the noise-suppressor circuit inoperative and the volume control reduced so that noise output is limited to 12½ milliwatts, the sensitivity is such that not more than two microvolts, modulated 30 percent at 400 cycles applied to a 100-mmfd dummy antenna, is required to produce an output of 50 milliwatts, into an 8000-ohm resistance load.

The power-supply unit consists of a dynamotor and an r-f filter mounted in a substantial metal case. The dynamotor is of the ball-bearing type and is capable of continuous operation over

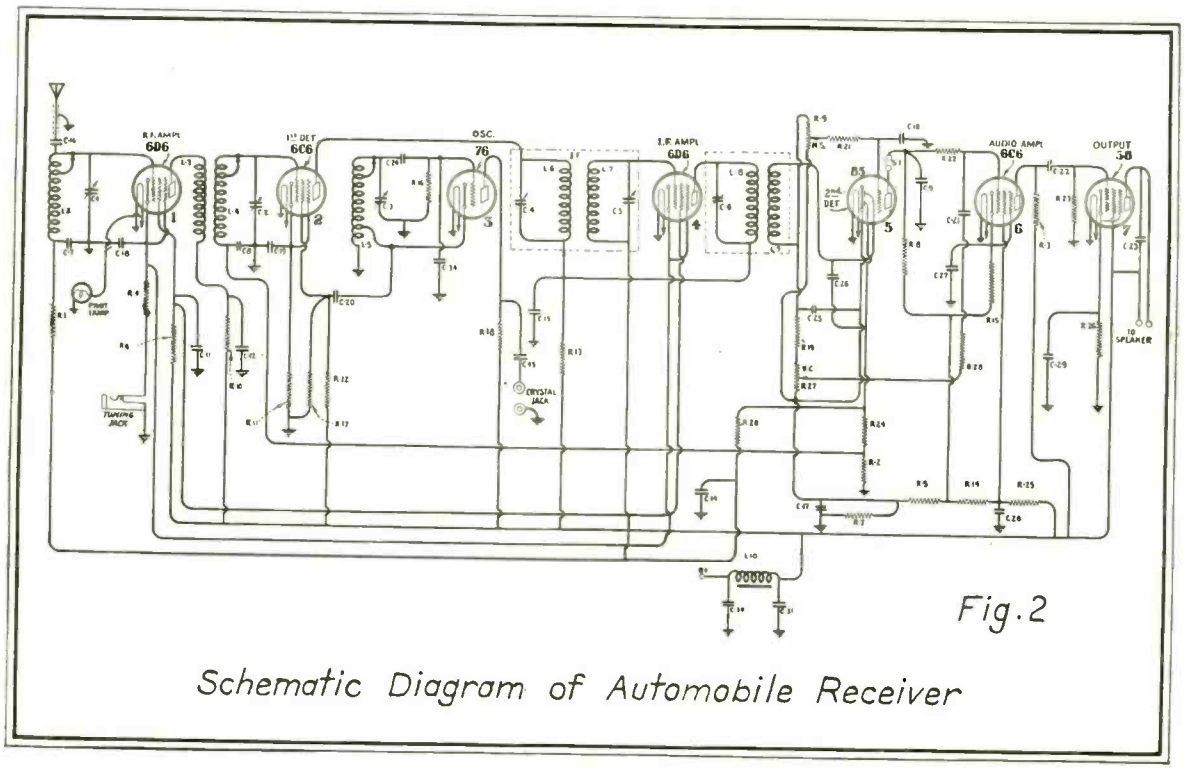


Fig. 2

Schematic Diagram of Automobile Receiver

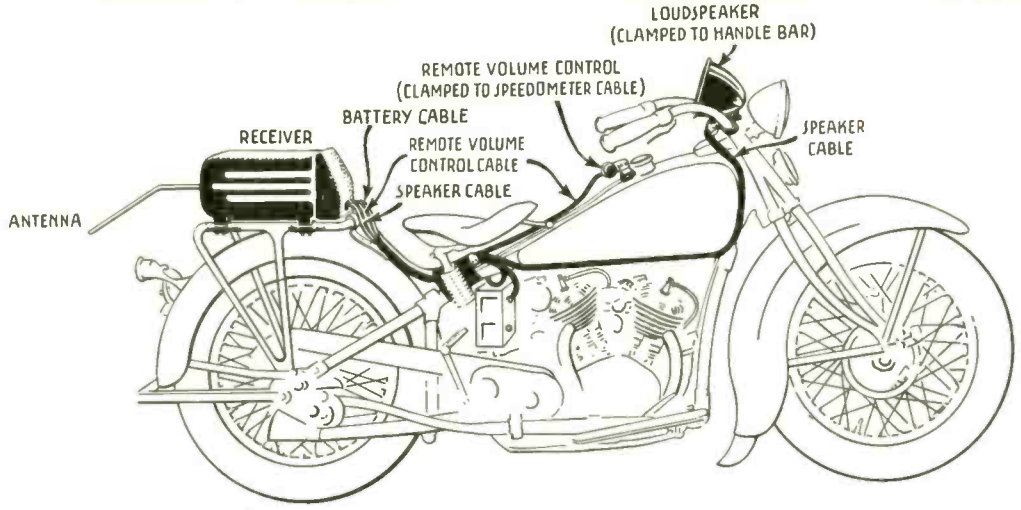


FIG. 5.

long periods of time without attention or service.

The loudspeaker is a small, highly efficient magnetic unit mounted in a small metal case which is provided with an adjustable metal bracket for mounting. Connection to the receiver is made through a shielded cable having a plug-in type connector at the receiver end.

As may be seen in Fig. 3, the motorcycle equipment consists of two units—the receiver and the loudspeaker. The receiver is mounted on the luggage carrier immediately back of the seat, while the speaker is mounted on the handlebars. This is shown in Fig. 5. The volume and on-off controls are combined in a small control head which clamps to the machine near the speedometer where it is readily accessible.

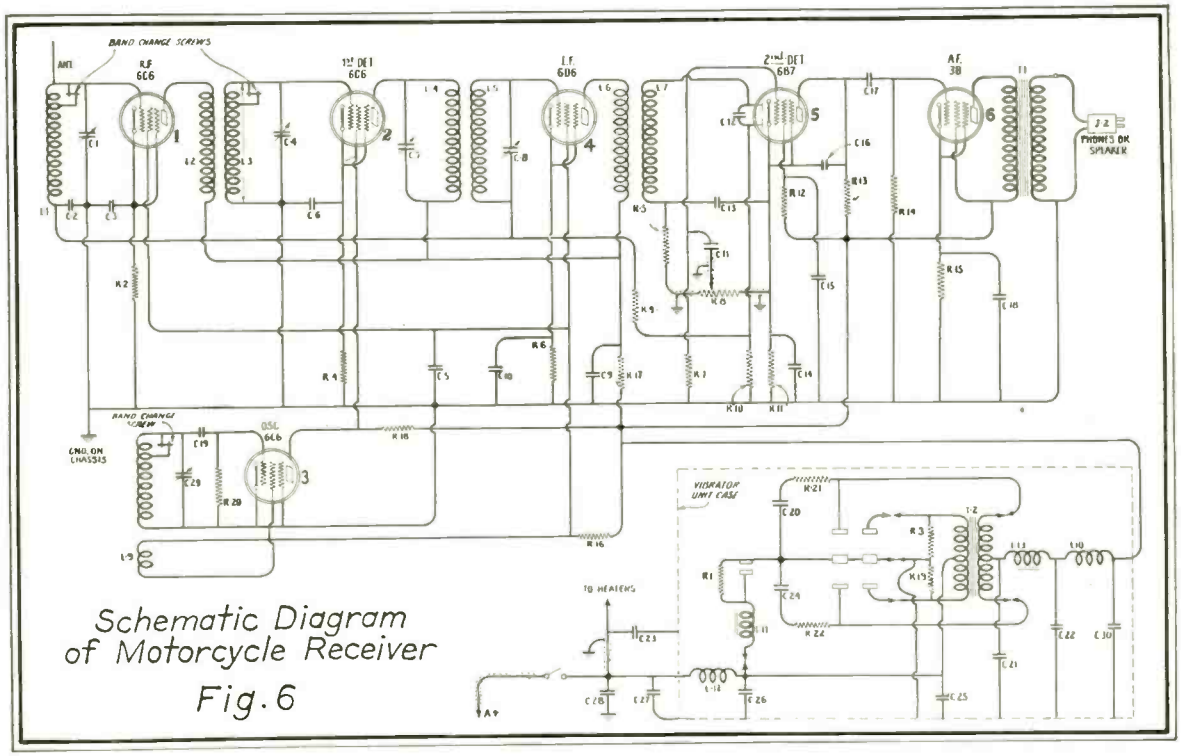
Dimensions and weights are:

Receiver—length 15 inches, width 9¾ inches, height 7 inches, weight 30 lbs.

Speaker—diameter 6 inches, depth 4½ inches, weight 4 lbs.

The receiver (Fig. 4) is housed in a cast aluminum alloy case combining strength and ruggedness with light weight. This case is made in two pieces—the housing proper which attaches to the luggage carrier by means of rubber shock-mount clamps, and the cover. The cover is permanently attached to a frame which supports the

(*Continued on page* 20)



Schematic Diagram of Motorcycle Receiver

Fig. 6

THE ILLINOIS STATE

Western Electric Photos.

THE CONTROL CONSOLE WITH TRANSMITTER IN BACKGROUND.

THE ILLINOIS State police-radio system now under construction will be one of the most complete and most modern state radio networks in America. Carefully planned and thoroughly engineered, this new system will utilize more transmitters, more squad cars, and more police motorcycles than any other state-operated system in this country. Seven high-powered broadcasting stations utilizing modern radio buildings, specially-constructed 329-foot steel towers and high-fidelity broadcasting transmitters will be located strategically throughout the state. Approximately 200 police cars and 325 highway patrol motorcycles will be equipped with modern police-radio receivers. These powerful transmitters will blanket the whole state with strong radio signals 24 hours per day, and 365 days per year. The motorized highway patrol equipped with this modern means of rapid communication will be in a position to carry out its duties and combat crime speedily and effectively.

Plans submitted by commercial organizations and amateur radio technicians showed arrangements varying all the way from three 2,000-watt stations to thirteen 50-watt stations. In order to determine the logical number, location and power of the radio stations required, it was decided to hire a competent radio-engineering firm to make a field survey. The contract for this work was awarded to RCA, who, in the summer of 1934, made a complete field survey of the state. The report submitted showed that the propagation of radio waves was uniformly good all over the state. It was found that a 1,000-watt transmitter, when used with a half-wave vertical antenna, would cover a radius of 65 miles, producing a signal strength of 100 microvolts or greater at all points.

After carefully analyzing the data obtained in the survey, it was recommended that seven 1,000-watt transmitting stations be erected at the following locations: Springfield, Pontiac, Chicago, Sterling, Macomb, Effingham, and DuQuoin.

The accompanying map shows the location of these seven stations, together with circles which indicate the 100-microvolt contours around each station.

The radio-station buildings have been specially designed to meet the needs of a modern police-radio system. They include features which more than fulfill present-day needs; they are being built with an insight into the future. The radio buildings, of which there will be seven in all, are to be one-story, modernistic structures of cream-colored brick. Four of the seven structures will house not only the radio transmitter, but District Police Headquarters as well. The three smaller buildings, where District Headquarters are not to be included, will provide a broadcasting room 20 by 20 feet, a repair room, furnace room and garage. The other four buildings will be provided with an additional suite of rooms for the police officers.

THE 1-KW TRANSMITTER.

A single 329-foot steel tower will be used as the transmitting antenna. This antenna is an entirely new design, and is expected to produce much stronger signals than the conventional types of aerials. The tower is built almost entirely of round iron bars and is uniform in cross section, i.e., does not taper to a point at the top. Each of the three legs are anchored to a separate cement footing which extends 13 feet into the ground and weighs several tons. These legs are fabricated in the factory, and shipped in 20-foot sections. Each leg utilizes three steel rods with an interlacing of welded steel webbing.

The Bureau of Air Commerce requires that all radio towers of this height be painted and lighted as a protection to airplanes. Alternate bands of white and International orange paint are used. Three sets of protective lights are required, one at the 100-foot level, one at the 200-foot level, and one at the top. At the lower levels, a 100-watt lamp in a red glass cover is placed at each of the three corners of the tower. At the top a standard 1,000-watt beacon with red glass lens is required.

POLICE-RADIO SYSTEM

THE CONTROL CONSOLE OF RADIO STATION WQPS.

An electrically operated clock is used to turn these lights on and off at the proper time.

The ground system consists of 72 radials of No. 6 copper wire buried 12 inches under ground and in the shape of the spokes of a wheel with the hub at a point under the tower. This ground system requires a tract of land approximately 11¼ acres in area.

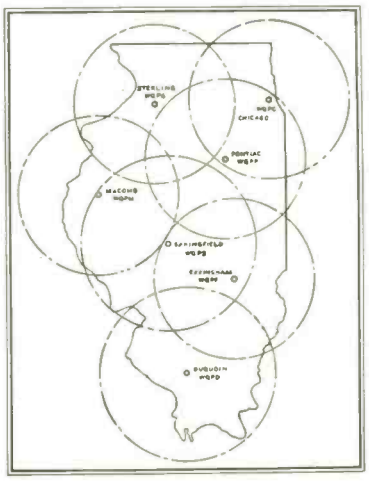
The transmitter is a modern, high-fidelity Western-Electric broadcast transmitter of 1,000 watts output. This transmitter is built to operate 24 hours per day, but will only be on the air at intervals of fifteen minutes or as often as necessary.

The auxiliary equipment associated with this transmitter consists of microphones, amplifiers, frequency monitors, etc. The microphones are the new nondirectional type used in broadcasting studios. The voice amplifiers all have a high-fidelity response. The cathode-ray oscillograph allows the operator to maintain the modulation peaks near the 100 percent point and so be sure of a strong signal without distortion.

The operating room is equipped with a number of station house receivers for use in communicating with neighboring city and state police-radio stations. These receivers are all mounted together at one side of the room on a steel rack which gives a very neat appearance. Each receiver is tuned to a different station and is controlled from the operator's desk. In order to reduce noise in the studio, these receivers are equipped with a so-called "squelch" feature which maintains each receiver in a quiet, low-level operative condition except when the calling station is on the air. By use of an ingenious circuit, only one receiving antenna is used to supply all of these receivers and only one loudspeaker is used to monitor them. This makes it unnecessary to surround the station with a maze of receiving aerials and makes for a neat-looking, business-like station.

The special control desk is localized in the center of the operating room and in front of the transmitter. This desk is finished in dull black color with chrome-plated hardware. Surrounding the operator's position is a raised circular portion with sloping panels which carry the transmitter controls, receiver controls and loudspeaker grille. In the center of the desk and directly in front of the operator is a modern synchronous clock. From his position behind this desk the operator can control the transmitter, turn on and off the receivers, increase the volume of loudspeakers and in fact, perform all of the operations necessary for the routine operation of the station. Telephones, road maps, police data, automobile license-plate numbers and various other aids are all within easy reach.

MAP SHOWING LOCATION OF STATIONS.



Each of the seven police broadcasting stations will be operated as separate units so far as their own radio districts are concerned. Each station will handle the radio traffic within its district, sending messages to the cars and directing the activities of State Police Officers within its district.

All of the seven stations will be under the control of the central station at Springfield. Whenever necessary the activities of all seven stations may be directed from the central station. In case of an emergency requiring the mobilization of all State Police forces, the Superintendent of State Police may direct the activities of the whole State Police force from the control apparatus to be located in his office. Whenever a message of general interest is to be broadcast from all stations, it will not be broadcast simultaneously but will be sent out from each station in succession and according to a previously-arranged sequence.

By the use of the radio it will be possible for the Superintendent of Police from his office in Springfield to control the activities of the whole State Police force. A message may be directed to any squad car or highway patrolman by simply pressing a button and speaking into the microphone.

(*Continued on page* 19)

THE FARNSWORTH

TELEVISION RECEIVER

DURING THE PAST few months considerable interest has been evidenced in the Farnsworth system of television. Although complete information on this system is not yet available, there appears on the following page a schematic diagram of the Farnsworth television and sound receiver. The front and rear views of this receiver are shown below.

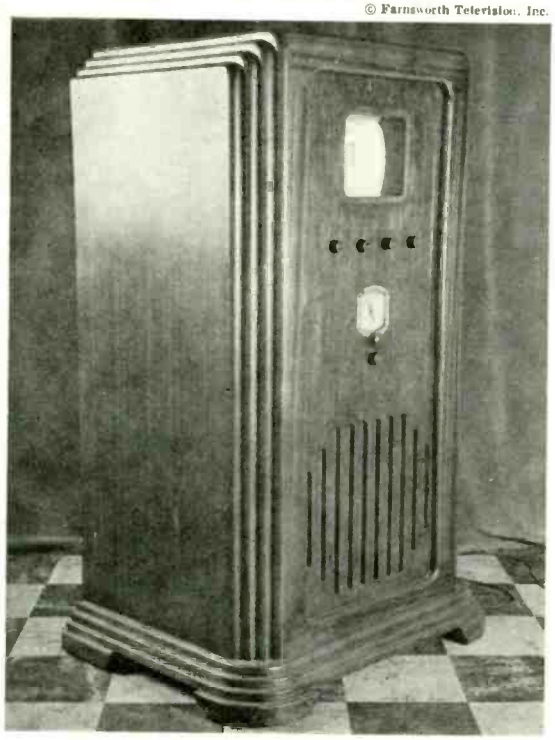
Referring to the accompanying schematic diagram, it will be seen that a dipole antenna feeds the receiver through a balanced transmission line. The transmission line, in turn, is coupled to a tuned circuit which feeds the sound and picture detectors in multiple. One beat oscillator heterodynes both signals.

The sound channel consists of a first detector, two stages of 11.25-megacycle intermediate-frequency amplification, a second detector and one stage of audio amplification. The picture channel consists of a first detector, three stages of 13.25-megacycle intermediate-frequency amplification, a second detector, and two stages of video amplification.

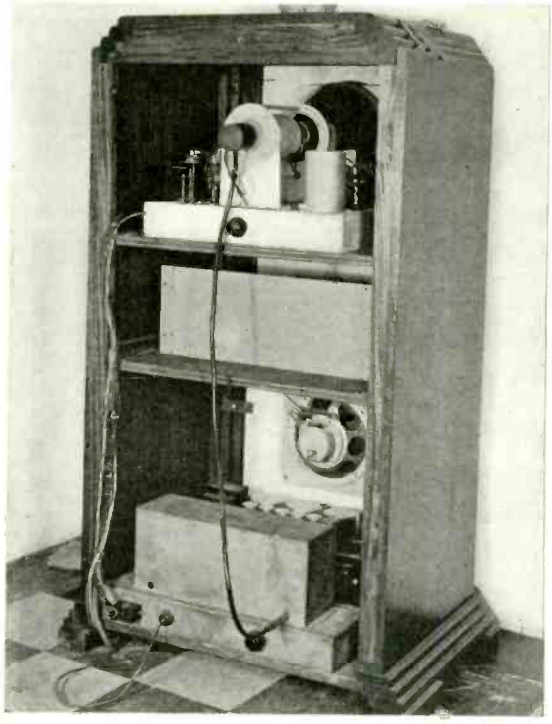
This television receiver differs essentially from other circuits in the isolation of sound and picture channels, accomplished by employing two first detectors. Other proposed circuits have included either two entirely separate receivers, or a single receiver with one first detector feeding two intermediate-frequency amplifiers, one for the sound channel and one for the picture channel.

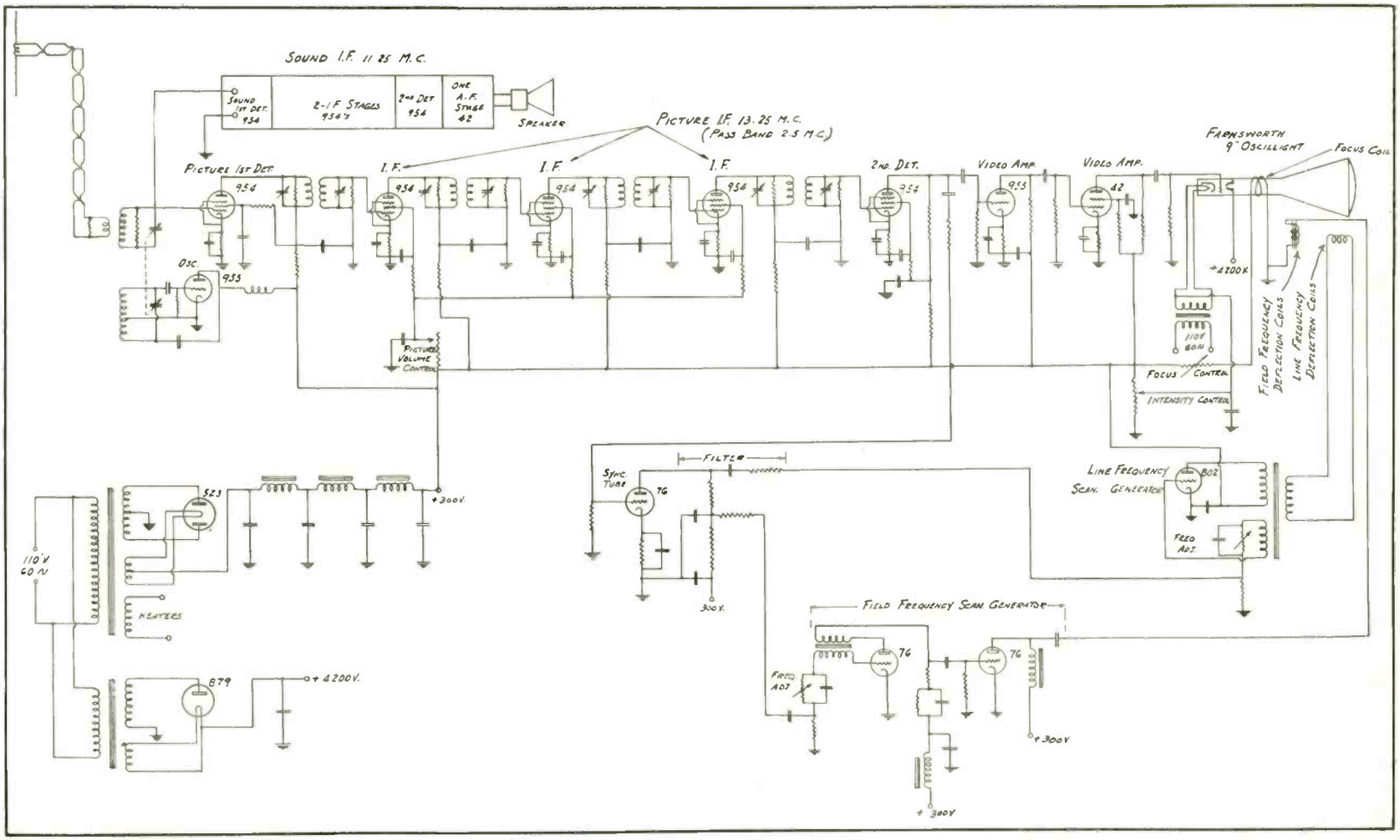
The synchronizing tube, fed from the output of the second detector in the picture channel, controls the line-scanning oscillator and field-scanning oscillator. Both scanning oscillators control the cathode-ray picture tube through the magnetic field generated by the deflection coils. Focusing is likewise accomplished magnetically.

FRONT VIEW OF THE FARNSWORTH TELEVISION RECEIVER. THE RECEIVED IMAGES ARE BLACK AND WHITE.



BACK VIEW OF THE TELEVISION RECEIVER. NOTE THAT THE CATHODE-RAY TUBE IS MOUNTED IN A HORIZONTAL POSITION.





THE FARNSWORTH TELEVISION RECEIVER

Shown above is the schematic diagram of the Farnsworth Television Receiver. In this 19-tube receiver isolation of the sound and picture channels is accomplished by employing two first detectors. A single beating oscillator heterodynes both signals. Focusing is accomplished magnetically.

NOTES ON POLICE-CAR RECEIVERS

By STANLEY E. BENSON
Police Radio Engineer
UNITED AMERICAN BOSCH CORPORATION

RADIO has come to be one of the most important and effective law-enforcement agencies available to police. It can no longer be considered as an expensive experiment of doubtful value. The development of apparatus for police use has been rapid and specialized. At the present time, thoroughly dependable equipment, completely suited to police service, is available. Development of a radio receiver suitable for installation in an automobile and capable of operating continuously and dependably under the severe conditions of police service has been a considerable engineering problem.

Not only are the operating conditions severe, but they are extremely varied. It has been difficult to produce receivers which are entirely suitable for any given set of operating conditions without making undesirable compromises in performance which detract seriously from the effectiveness of the receivers.

The factors which are most important in considering the adaptability of a particular receiver to certain operating conditions are the following: sensitivity, selectivity, freedom from frequency drift, ease of installation, simplicity of operation, and reliability of operation. It is proposed to discuss each of these qualities in relation to its influence on the performance of the receiver, a most vital part of any police-radio system.

Police-radio transmitters are limited in power primarily to avoid interference with other transmitters which are located in a distant area but are operating on the same frequency. Consequently, the receiver is frequently called upon to respond to extremely weak signals while at a comparatively short distance from the transmitter or in a dead spot. With the limited antenna facilities which are available on an automobile, even at best, it is most essential to employ an extremely sensitive receiver especially designed for this type of service.

The great number of police transmitters has forced the assignment of police frequencies with a channel separation of 8 kilocycles. Frequently, transmitters in adjacent territories operate on adjacent channels. In such cases, there are always locations where the strength of an undesired signal is as great as, or many times greater than, the strength of the desired signal. It is then necessary to employ a receiver which discriminates against the undesired signal. Although extreme selectivity results in sideband cutting with a consequent impairment in the fidelity of voice reproduction, the intelligibility of voice transmissions is not greatly affected. However, any frequency drift of the receiver immediately results in decreased sensitivity, since the received signal is transmitted through the i-f amplifier system at some frequency other than the resonant frequency with a consequent reduction in the amount of amplification. Recognizing the fact that it is impossible to construct a receiver which is completely free from frequency drift without resorting to impractical measures, the degree of selectivity is necessarily a compromise between the permissible amount of adjacent-channel interference and the extent to which a reduction in sensitivity can be tolerated.

Many precautions have been taken in the construction of the American Bosch receiver to minimize frequency drift. Among these are: the provision of air-dielectric tuning condensers in both r-f and i-f circuits, the inclusion of a separate oscillator working into a practically constant load despite changes of supply voltages, and the rigid construction of coils suitably treated to render them unsusceptible to changes in humidity and temperature. With all reasonable precautions taken, a control which permits small variations of the tuning is provided when desired, allowing the operator to compensate for the small amount of frequency drift remaining. Where extreme frequency stability is required, it is possible to obtain a crystal for controlling the oscillator frequency. This has been arranged so that it can be added at any time without modifying the receiver. It is merely necessary to plug the crystal into the circuit. Since a temperature-controlled oven to enclose the crystal was felt to be undesirable in an automobile type of receiver, a unique type of crystal mounting is employed. The electrodes of the mounting are arranged so that temperature changes cause capacity changes which compensate for the frequency fluctuation of the crystal. By using a crystal with a low temperature coefficient in this mounting, it is possible to restrict the frequency variation to a very small amount.

No less important than the electrical performance of the receiver is the ease with which it can be installed in any automobile regardless of the number and location of various police accessories such as sirens, car heaters, and fire extinguishers. The greatest latitude seems to be afforded by a receiver consisting of three units: a receiver proper, a speaker, and a power supply.

In order to realize the greatest good from a police-radio system, it is essential that the equipment be capable of simple operation. Usually, the only controls provided are a switch to turn the receiver on or off, a volume control, and a "squelch" switch which inserts or removes a noise-suppression system. The receiver is tuned to the desired signal by the radio expert before being released to the police officer who is to use it. When conditions justify it, a trimmer can be made available which permits the officer to make small adjustments of the tuning. This trimmer does not have a tuning range great enough to make it possible to detune the receiver completely.

When the "squelch" system is in use, any noise or signal less than a certain prearranged amount does not become audible. This "threshold" level is adjusted by the radio expert to a value slightly less than the signal level prevailing in the territory where the receiver is used, so that practically no noise is picked up by the receiver during the periods when the transmitter is not broadcasting. The operator can, by means of the switch, remove the suppression system when operating in areas known by experience to be regions of such weak signal strength that maximum receiver sensitivity is required.

Balanced Amplifiers

PART III

By ALBERT PREISMAN

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IN THE PRECEDING ARTICLES (February and March, 1936), the balanced amplifier was discussed from a physical viewpoint, and graphical methods were used to study its action when loaded with a resistance. The graphical methods are direct and powerful where applicable, but are unfortunately special, and usually do not indicate directly optimum values of circuit parameters, potentials and currents. This may, in part, be due to our ignorance of geometrical methods and our aversion, due to our classic training, of employing other than ruler and compass constructions. However that may be, the aim in science and engineering seems to be to reduce physical behavior to formulas, and, in general, the greatest advances have been made by the use of analytical methods.

When we come to non-linear circuits, such as vacuum tubes, however, we run into a major difficulty in that our mesh equations are not of the first degree (since they do not obey Ohm's Law), and their simultaneous solutions are not possible by the general method of determinants, even for steady-state conditions. Methods of approximations have been evolved[4], but these become exceedingly involved when more than a few terms are used. Accordingly, while the behavior of the balanced amplifier will be studied here analytically, only general conclusions will be drawn in most instances, and particular, practical solutions will be solved by the previous graphical methods.

An ordinary resistance, R, for instance, obeys Ohm's Law, and we may write for the relation between current, I, through it and and voltage, E, across it

$$I = \left(\frac{1}{R}\right) E$$

a first-degree or linear equation. If R is a function, f(I), of the current, however, we must write

$$I = f(I)\, E$$

or, solving (theoretically) for I we have

$$I = G(E)$$

This latter functional relation, when plotted, gives the load line for R (now assumed variable) and is, in general, not a straight line. When we wish to represent this function in specific manner analytically, particularly when it is obtained experimentally, we employ a method known as a power-series development. Specifically

$$I = k_o + k_1 E + k_2 E^2 + k_3 E^3 \ldots\ldots$$

where the k's are constants. Usually when E is zero, I is zero, so that k_o is zero. The above power series represents, in general, any continuous function. If all its derivatives are continuous, then the k's may be represented by factorials times the derivatives at the point of expansion, and the series becomes a McLaurin or Taylor Series, depending upon whether the expansion is about the origin or some other point, respectively. However, the power series method is still valid even when the derivatives are discontinuous, only in this case the k's must be represented by some other functions.

In our work we shall assume that the McLaurin Series is possible, and modify our analysis where this is not true, such as beyond cut-off of the tube. For a triode, a double power series is required in terms of the plate and grid voltages, unless the mu is constant, in which case a single power series will suffice, as will be shown. The application of the methods which follow to four- and five-element tubes should be self-evident to the reader, and are omitted because the triple and quadruple power series required reveal nothing different from the double series. Indeed, for constant screen-grid and suppressor-grid voltages, the multi-element tubes are equivalent to triodes. Also, as shown by Peterson and Evans[5], a single power series in terms of the grid voltage as the independent variable may be written (the ordinary dynamic characteristic), but the more general double power series will be used here because it reveals the circuit parameters more definitely.

VIII. BALANCED-AMPLIFIER EQUATIONS

Hence, as stated, even though the μ is not constant, a double power series can be used to represent the functional relation between the plate current i_p, the plate voltage e_p, and the grid voltage e_g. It will be convenient to expand this series about the origin, and use the portion in the first quadrant, since it is only in this region that the derivatives involved in the coefficients are continuous. The double power series is thus a McLaurin Series. For sufficiently negative grid voltages, i_p is zero, and this special functional relation will be used to supplement the double power series where necessary.

The latter may be represented as

$$\begin{aligned} i_p = {} & A_{10}\, e_p + A_{01}\, e_g + A_{11}\, e_p\, e_g \\ & + A_{20}\, e_p^2 + A_{02}\, e_g^2 \\ & + A_{12}\, e_p\, e_g^2 + A_{21}\, e_p^2\, e_g + \ldots = \sum_0^m \sum_0^n A_{hk}\, e_p^h\, e_g^k \end{aligned} \qquad (14)$$

From the previous article we have seen that if we have two tubes, I and II, in push-pull, and a signal voltage $2e_s$ be applied between the two grids, such that $+e_s$ is applied to tube I and $-e_s$ to tube II, the plate current i_{p1} of tube I increases, and that of tube II,

[4]See, for instance, Carson—*IRE Proceedings*, 1919.

[5]Peterson and Evans—"Modulation in Vacuum Tubes Used as Amplifiers"—*BSTJ*, July, 1927.

namely, i_{p2}, decreases. We have also seen that the plate voltage e_{p1} of tube I decreases from the normal value E_B by an amount

$$(I_1 - I_2)\frac{R_L}{4}$$

(where R_L is the plate-to-plate load resistance), and that of tube II, namely e_{p2}, rises above E_B by the same amount. If there is a mid-branch impedance Z_b (Fig. 15), it causes equal plate-voltage drops in both tubes of an amount $(i_{p1} + i_{p2})\,Z_b$, since the sum of the two plate currents flows through it. If part of Z_b is in the grid circuit, in the form of a bias network Z_c, then the grid voltages of both tubes are reduced by an amount $(i_{p1} + i_{p2})\,Z_c$. If the two halves of the primary of the output transformer have equal winding resistances and leakage reactances, and distributed capacities represented by Z_t for either half, then e_{p1} is reduced by the amount $(i_{p1})\,Z_t$, and e_{p2} by the amount $(i_{p2})\,Z_t$. The impedance of the secondary winding can be combined with the load impedance and open-circuit impedance and designated by Z_L.

From these preliminary remarks we are in a position to formulate the plate voltages, grid voltages, and plate currents of the two tubes. Thus

$$i_{p1} = \sum_{0}^{m}\sum_{0}^{n} A_{hk}\,[E_c + e_s - (i_{p1} + i_{p2})\,Z_c]^h \left[E_B - (i_{p1} + i_{p2})\,Z_b - i_{p1}Z_t - (i_{p1} - i_{p2})\frac{Z_L}{4}\right]^k \qquad (15)$$

$$i_{p2} = \sum_{0}^{m}\sum_{0}^{n} A_{hk}\,[E_c - e_s - (i_{p1} + i_{p2})\,Z_c]^h \left[E_B - (i_{p1} + i_{p2})\,Z_b - i_{p2}Z_t + (i_{p1} - i_{p2})\frac{Z_L}{4}\right]^k$$

$$= \sum_{0}^{m}\sum_{0}^{n} A_{hk}\,[E_c - e_s - (i_{p1} + i_{p2})\,Z_c]^h \left[E_B - (i_{p1} + i_{p2})\,Z_b - i_{p2}Z_t - (i_{p2} - i_{p1})\frac{Z_L}{4}\right]^k \qquad (16)$$

where the various Z's are impedance functions of frequency.

These power series are really identities instead of equations, and are therefore true for any form of e_s. We may therefore, for convenience, assume that e_s is symmetrical about the time axis; for instance, a sine wave. In this case, during the next alternation or half cycle, equations (15) and (16) have $-e_s$ and $+e_s$ present in them respectively, instead of $+e_s$ and $-e_s$. It will be apparent to the reader that for this other half cycle, i_{p1} has the form that i_{p2} has during the first alternation and i_{p2} has the form that i_{p1} has during the first alternation.

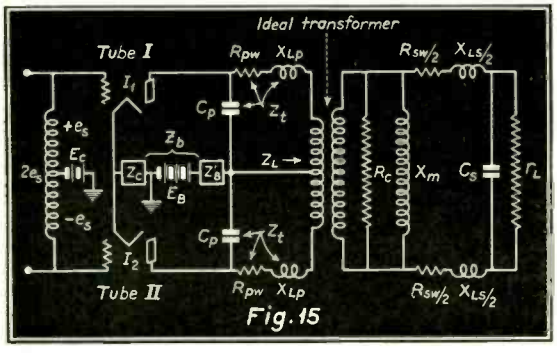

Fig. 15

Such identity in form means that i_{p1} and i_{p2} interchange in value from one half cycle to the next, so that if we formulate

$$\left(\frac{i_{p1} - i_{p2}}{2}\right)$$

the load current through Z_L when $+e_s$ acts on tube I (and $-e_s$ on tube II), it will have the same magnitude, but be opposite in sign to

$$\left(\frac{i_{p1} - i_{p2}}{2}\right)$$

when $-e_s$ acts on tube I (and $+e_s$ on tube II).

In other words, the load current, when plotted against $2e_s$, is symmetrical about the e_s axis, and lies in the first and third quadrants, as shown in Fig. 16. This means that

$$\left(\frac{i_{p1} - i_{p2}}{2}\right) \text{ versus } e_s$$

can be represented by a power series of the form

$$\left(\frac{i_{p1} - i_{p2}}{2}\right) = B_1 e_s + B_3 e_s^3 + B_5 e_s^5 + \ldots \text{ etc.} \qquad (17)$$

Equation (17) indicates that if e_s is a sine wave,

$$\left(\frac{i_{p1} - i_{p2}}{2}\right)$$

can contain terms involving only odd powers of e_s, which

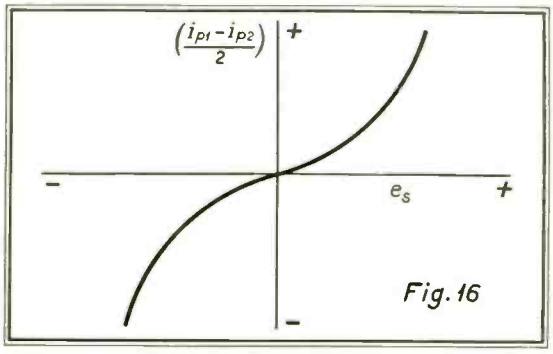

Fig. 16

in this case can be resolved into odd harmonics only. More generally, for any form of e_s,

$$\left(\frac{i_{p1} - i_{p2}}{2}\right)$$

can contain only odd-order modulation products of e_s.

IX. MID-BRANCH CURRENT

We next note that $(i_{p1} + i_{p2})$, the mid-branch current, changes neither in magnitude nor in sign as e_s varies through its cycle. Hence the plot of $(i_{p1} + i_{p2})$ versus e_s lies in the first and second quadrants, and may be represented by the following power series.

$$(i_{p1} + i_{p2}) = C_0 + C_2 e_s^2 + C_4 e_s^4 + C_6 e_s^6 + \ldots \text{ etc.} \qquad (18)$$

It is evident from (18) that if e_s be sinusoidal, $(i_{p1} + i_{p2})$ contains only d-c and even harmonics of e_s, or more generally, only even-order modulation products of e_s. Hence the statement that the odd harmonics flow

in series, and the even harmonics in parallel, through the balanced-amplifier circuit.

X. EFFECT OF MID-BRANCH IMPEDANCE

The preceding analysis has pointed out some interesting things.

(1) Mid-branch impedances, such as Z_b and Z_c, can produce no even-order terms in the output of a perfectly balanced amplifier.

(2) The voltages across them, can, however, cross-modulate with the signal voltage e_s to produce odd-order terms.[6]

(3) If such odd-order terms have the right phase, they may reduce similar odd-order terms produced by the tubes, themselves. This, however, depends upon the

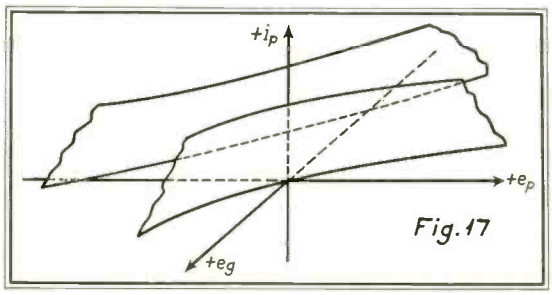

Fig. 17

particular tubes, and in general mid-branch impedances should be avoided, such as by the use of sufficient bypass condenser capacity.

(4) Contrary to statements sometimes made, mid-branch impedances do not produce even-order terms in a perfectly balanced amplifier.

(5) The impedance of each half of the primary, Z_t must be the same, otherwise i_{p1} and i_{p2} will not interchange in value during the two halves of the cycle of e_s. In other words, unbalance here will produce even harmonics.

(6) If the tubes are not identical, the power series for the two will be different, and even harmonics will be produced.

XI. ANALYSIS OF OPERATION BEYOND CUT-OFF

If Z_L be sufficiently small, or e_s sufficiently great, i_{p1} and i_{p2} will alternately cut off. Whichever current cuts off cannot be represented by the McLaurin Series, but instead by the simple equation that it is equal to zero.

Referring to (15) and (16), if e_s is positive for tube I, i_{p1} is increasing away from the cut-off point, and can therefore be expressed by (15). i_{p2}, however, approaches zero and then remains at that value. Where i_{p2} cuts off, i_{p1} proceeds as if tube II were not present, i.e., as a single-tube circuit. The grid voltage at cut-off has reached some value e, the plate voltage some value E. The grid signal voltage proceeds from the value at cut-off as e_s' to its peak value. Equation (15) then becomes

$$i_{p1} = \sum_{0}^{m}\sum_{0}^{n} A_{hk}\,[e + e_s' - i_{p1} Z_c]^h \left[E - i_{p1}Z_b - i_{p1}Z_t - i_{p1}\frac{Z_L}{4}\right]^k \qquad (19)$$

It will be evident that on the negative half cycle of e_s, the equation for i_{p2} is exactly the same as (19), for when i_{p1} reaches cut-off, i_{p2} attains the value i_{p1} attained previously when i_{p2} cut off. Hence, even beyond cut-off,

[6]For an interesting application to vacuum-tube voltmeters see Turner and McNamara, *Proc. IRE*, 18 No. 10, 1743-1747 October, 1930.

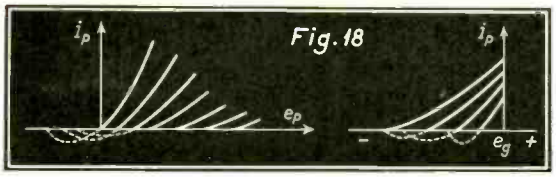

Fig. 18

i_{p1} and i_{p2} exchange values from one half cycle to the next, so that (17) and (18) remain unchanged in form.

XII. EFFECT OF MID-BRANCH VOLTAGES

We have seen that mid-branch impedances produce no even-order terms but the voltages across them may cross-modulate with e_s to produce odd-order terms. Since we have placed no restriction upon the form of Z_b and Z_c they can be such as to have any kind of voltages developed across them by $(i_{p1} + i_{p2})$. Hence what is true for Z_b and Z_c is true for any mid-branch voltages e_1 and e_2 inserted in the grid and plate mid-branches, respectively. e_1 and e_2 may be, for instance, hum voltages.

We now consider the case where the signal voltage $e_s = 0$, and e_1 and e_2 are inserted. Equations (15) and (16) become, respectively,

$$i_{p1} = \sum_{0}^{m}\sum_{0}^{n} A_{hk}\,[E_c - (i_{p1} + i_{p2})\,Z_c + e_1]^h \left[E_B - (i_{p1} + i_{p2})\,Z_b - i_{p1}Z_t - (i_{p1} - i_{p2})\frac{Z_L}{4} + e_2\right]^k \qquad (20)$$

$$i_{p2} = \sum_{0}^{m}\sum_{0}^{n} A_{hk}\,[E_c - (i_{p1} + i_{p2})\,Z_c + e_1]^h \left[E_B - (i_{p1} + i_{p2})\,Z_b - i_{p2}Z_t - (i_{p2} - i_{p1})\frac{Z_L}{4} + e_2\right]^k \qquad (21)$$

The identity of functional form exhibited by (20) and (21) can mean but one thing: that i_{p1} and i_{p2} are equal, or the load current,

$$\left(\frac{i_{p1} - i_{p2}}{2}\right)$$

is zero. In other words, in a perfectly balanced amplifier, with no signal impressed, hum voltages produce no hum output. However, when a signal voltage is impressed, the hum voltages cross-modulate with it to produce odd-order output current components in addition to that which is a copy of the signal voltage. It is therefore advisable to filter adequately the plate and grid bias supplies, although the filtering in practice may be less than for a single-side amplifier because of the fact that the hum is not apparent during silent moments (when $e_s = 0$), and the cross-modulation products are partially masked by the louder signal components in the output when e_s is not zero. For best results and least distortion, however, the filtering should be as complete as possible.

XIII. IDEAL PUSH-PULL TUBES

We now ask ourselves, what form should the power series for either tube have in order that no terms other than the first degree appear in the output, i.e.,

$$\left(\frac{i_{p1} - i_{p2}}{2}\right) = B_1 e_s \qquad (22)$$

at least up to cut-off of either tube.

We have seen that Z_c, Z_b, and Z_t introduce odd-order terms, hence we shall assume them to be zero here. Sub-

tracting (16) from (15), and setting the result equal to (22), we obtain

$$\left(\frac{i_{p1}-i_{p2}}{2}\right)=B_1 e_s=\sum_0^m\sum_0^n A_{hk}[E_c+e_s]^h\left[E_B-(i_{p1}-i_{p2})\frac{Z_L}{4}\right]^k$$

$$-\sum_0^m\sum_0^n A_{hk}[E_c-e_s]^h\left[E_B-(i_{p2}-i_{p1})\frac{Z_L}{4}\right]^k$$

$$=\sum_0^m\sum_0^n A_{hk}[E_c+e_s]^h\left[E_B-(i_{p1}-i_{p2})\frac{Z_L}{4}\right]^k$$

$$-[E_c-e_s]^h\left[E_B+(i_{p1}-i_{p2})\frac{Z_L}{4}\right]^k \qquad (23)$$

The individual factors can be expanded by the Binomial Theorem, so that each term of the function represented by (23) may in itself be written as the difference in the products of two functions. Thus

$$[E_c+e_s]^h=\sum_0^h\frac{h(h-1)\ \ldots\ (h-q+1)}{q!}E_c^{(h-q)}e_s^q$$

$$=\sum_0^h r_{q+1}E_c^{(h-q)}e_s^q$$

$$[E_c-e_s]^h=$$

$$\sum_0^h(-1)^q\frac{h(h-1)\ \ldots\ (h-q+1)}{p!}E_c^{(h-q)}e_s^q$$

$$=\sum_0^h(-1)\,r^q{}_{q+1}\,E_c^{(h-q)}e_s^q$$

$$\left[E_B-(i_{p1}-i_{p2})\frac{Z_L}{4}\right]^k=\sum_0^k(-1)^p$$

$$\left[\frac{k(k-1)\ \ldots\ (k-p+1)}{p!}\right]E_B^{(k-p)}\left[(i_{p2}-i_{p2})\frac{Z_L}{4}\right]^p$$

$$=\sum_0^k(-1)^p S_{p+1}E_B^{(k-p)}\left[(i_{p1}-i_{p2})\frac{Z_L}{4}\right]^p$$

$$\left[E_B+(i_{p1}-i_{p2})\frac{Z_L}{4}\right]^k=$$

$$\sum_0^k\left[\frac{k(k-1)\ \ldots\ (k-p+1)}{p!}\right]E_B^{(k-p)}\left[(i_{p1}-i_{p2})\frac{Z_L}{4}\right]^p$$

$$=\sum_0^k S_{p+1}E_B^{(k-p)}\left[(i_{p1}-i_{p2})\frac{Z_L}{4}\right]^p \qquad (24)$$

Substituting the functions of (24) in the representative term of (23) we obtain

$$A_{hk}[E_c+e_s]^h\left[E_B-(i_{p1}-i_{p2})\frac{Z_L}{4}\right]^k$$

$$-A_{hk}[E_c-e_s]^h\left[E_B+(i_{p1}-i_{p2})\frac{Z_L}{4}\right]^k$$

$$=A_{hk}\left\{\sum_0^h r_{q+1}E_c^{(h-q)}e_s\sum_0^k(-1)^p S_{p+1}E_B^{(k-p)}\left[i_{p1}-i_{p2}\frac{Z_L}{4}\right]^p\right.$$

$$\left.-\sum_0^h(-1)^q r_{q+1}E_c^{(h-q)}e_s^q\sum_0^k S_{p+1}E_B^{(k-p)}\left[(i_{p1}-i_{p2})\frac{Z_L}{4}\right]\right\} \qquad (25)$$

It will be noted that for all even values of $(p-q)$, the terms of (25) cancel, whereas for all odd values of $(p-q)$ the terms add. Since q is the exponent of e_s, and p of

$$(i_{p1}-i_{p2})\frac{Z_L}{4}$$

it will be seen that only odd-order terms are present in the output current of a push-pull amplifier, which is a verification of the results previously obtained for the more general case.

Here we do not desire odd-order terms of degree higher than the first, hence possible combinations for q and p are

$$\left.\begin{array}{l} q=0,\ \ p=0\\ q=1,\ \ p=0\\ q=1,\ \ p=1\\ q=2,\ \ p=0\\ q=0,\ \ p=2\end{array}\right\} \qquad (26)$$

Since q takes on all integral values from 0 to h, and p from 0 to k we see that the pairs of values given in (26) apply to h and k too, hence also to m and n, respectively. The power series for our ideal push-pull tubes must therefore be of the form

$$i_{p1}=A_{00}+A_{10}[E_c+e_s]+A_{01}\left[E_B-(i_{p1}-i_{p2})\frac{Z_L}{4}\right]$$

$$+A_{11}[E_c+e_s]\left[E_B-(i_{p1}-i_{p2})\frac{Z_L}{4}\right]$$

$$+A_{20}[E_c+e_s]^2+A_{02}\left[E_B+(i_{p1}-i_{p2})\frac{Z_L}{4}\right]^2 \qquad (27)$$

$$i_{p2}=A_{00}+A_{10}[E_c-e_s]+A_{01}\left[E_B+(i_{p1}-i_{p2})\frac{Z_L}{4}\right]$$

$$+A_{11}[E_c-e_s]\left[E_B+(i_{p1}-i_{p2})\frac{Z_L}{4}\right]$$

$$+A_{20}[E_c-e_s]^2+A_{02}\left[E_B+(i_{p1}-i_{p2})\frac{Z_L}{4}\right]^2$$

or

$$i_p=A_{00}+A_{10}e_g+A_{01}e_p+A_{11}e_ge_p+A_{20}e_g^2+A_{02}e_p^2$$

Equation (27) is that of a quadric surface or conicoid in space, in general translated from the i_p, e_g, and e_p co-ordinate axes, and rotated in the e_p-e_g co-ordinate plane. From physical reasoning we know that it is valid only for positive values of e_p, and for such combinations of e_p and e_g as give values of i_p equal to zero or positive, i.e., it is not valid below plate-current cut-off.

However, not all forms of this quadric surface are physically realizable in vacuum tubes. Thus, if $(A_{11}^2-4A_{20}A_{02})$ is negative, then, by the principles of solid analytic geometry, (27) represents an elliptic

(*Continued on page 19*)

THE 6L6 AND HIGH-FIDELITY EQUIPMENT

By I. A. MITCHELL
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UNITED TRANSFORMER CORPORATION

THE DEVELOPMENT of the 6L6 tube is an important forward step in vacuum-tube design. Tube companies are already working on the development of large vacuum tubes using beam-power principles. Research is bringing out new theoretical points of view governing some of the factors of these tubes which were originally determined empirically. While the present beam-power tube has extremely high efficiency, large power output, high sensitivity and low harmonic content, its application to high-fidelity equipment has been somewhat deterred due to the high dynamic plate resistance. In the amplifier described here, feedback has been used to reduce this dynamic plate resistance and also to reduce the harmonic distortion to very small magnitude.

OPERATION OF THE 6L6

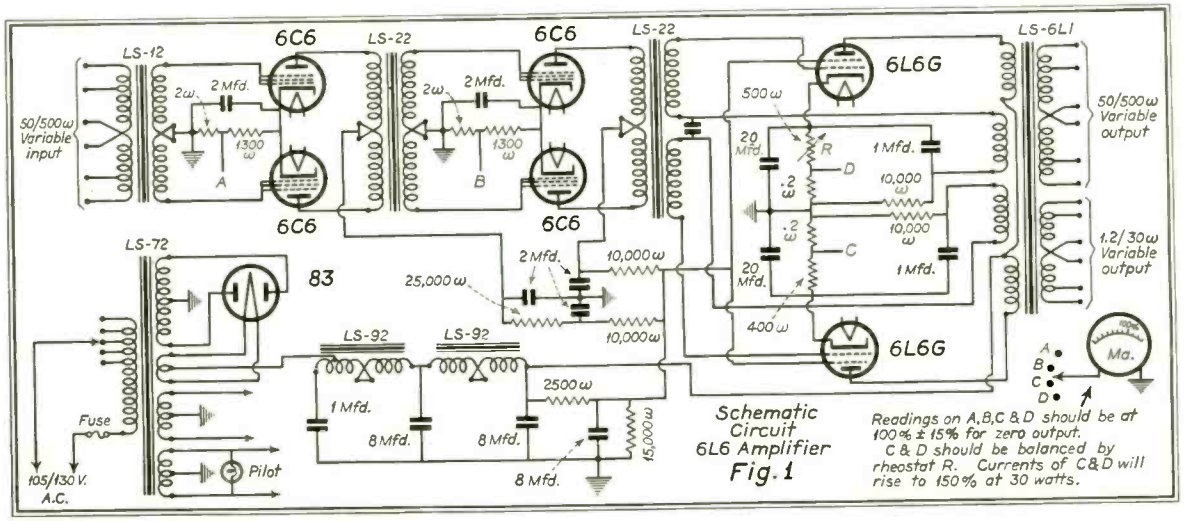
An examination of the operating characteristics of the 6L6 tube shows a number of features bearing upon both engineering and economical angles. A pair of these tubes in self-bias Class AB1 are rated to deliver 32 watts of audio power. The same tubes operating fixed bias or Class AB2 are rated to deliver 60 watts of audio power. However, to obtain the full 60 watts at low harmonic distortion, it is necessary to have a power supply with extremely good regulation, a bias supply of extremely low resistance, and a high power driver having very low internal resistance. *The cost to obtain these refinements would be greater than to use four tubes in push-pull parallel Class AB*1. Preliminary tube tests would also indicate that the tube life operating self-bias is appreciably greater than under the fixed-bias condition. Another point in the favor of the self-bias tube operation is in the reduction of high-power transients which frequently cause breakdown of accessory equipment and loudspeakers.

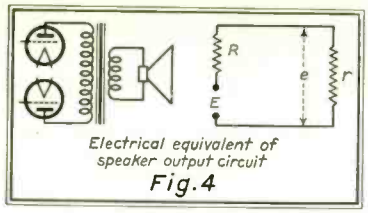
DISTORTION-STABILIZED FEEDBACK

Considerable development work has been done during the past few years on methods of reducing hum, noise and distortion in amplifier circuits by feeding a portion of the energy from the output circuit back into the input circuit. While stabilized feedback of this type is very valuable in many applications, it is critical and should be developed and adjusted under laboratory conditions. A simple and stable form of feedback has been developed, however, and is shown in the schematic circuit of Fig. 1. Two tertiaries are provided on the output transformer so designed that 10 percent of the output-transformer primary voltage is induced in them. These tertiaries are coupled back to the grid circuits of their respective tubes so that a 10 percent degeneration takes place. This 10 percent feedback produces three major effects:

1. Power sensitivity reduced 55 percent.
2. Harmonic distortion reduced approximately 50 percent.
3. Plate resistance reduced 85 percent.

The reduction in power sensitivity is not an important factor with the 6L6 tube as the initial power sensitivity of this tube is extremely high. The reduction in harmonic content is an important factor. Fig. 2 illustrates the normal Class AB, harmonic characteristic of push-pull 6L6 tubes. Fig. 3 illustrates the relative percentage distortion vs. power output of a *single* 6L6 with and without feedback. Feedback reduces the





Electrical equivalent of speaker output circuit

Fig.4

distortion shown in Fig. 2 by 50 percent in the same manner as the reduction shown in Fig. 3.

REDUCED PLATE RESISTANCE

Many of the applications of high-fidelity audio equipment involve output loads which are variable in nature. Among these may be listed recording, loudspeaker service, and driver service. The importance of a low-resistance output tube is not generally recognized when related to these applications. An important example along these lines has been pointed out by RCA. As is commonly known, the impedance of a loudspeaker varies over the audio-frequency range. At the resonance frequency which usually lies below 100 cycles, the impedance of the speaker rises to a high resistive value. At the higher frequencies, the impedance of the speaker rises to a high value due to the self-inductance of the voice coil. Fig. 4 shows in simple form the effective circuit of a speaker coupled to an output tube. Taking the a-c voltage from the tube as E, the internal tube resistance as R, and the reflected speaker impedance at any given frequency as r, we find that e, the voltage developed across the speaker, equals

$$e = E\left(\frac{r}{R+r}\right)$$

based on non-inductive impedances. If the plate-to-plate resistance of each tube is 45,000 ohms and the reflected speaker load at 1000 cycles is 6600 ohms, the actual voltage developed across the speaker based on the above formula would be e equals .13E approximately.

If at the point of resonance of the speaker system the reflected speaker load were to increase to 66,000 ohms, the speaker voltage would increase to e equals .6E.

It is obvious that a considerable increase in power to the speaker is entailed. The combination of this increase in power plus the normal resonance of the speaker itself will naturally result in a very strong boom and will tend to produce relatively rapid failure of the speaker.

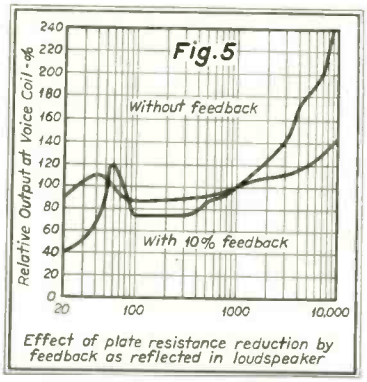
Through the use of stabilized feedback, the normal plate-to-plate resistance of 6L6 tubes (45,000 ohms) is reduced to approximately 7000 ohms. Following the same reasoning as above, it is found that at 1000 cycles, e would equal .49E, and at the resonance frequency, e would equal .9E. Fig. 5 illustrates the effective characteristics of a typical loudspeaker system operated from 6L6's with and without feedback.

FREQUENCY RESPONSE-HUM LEVEL

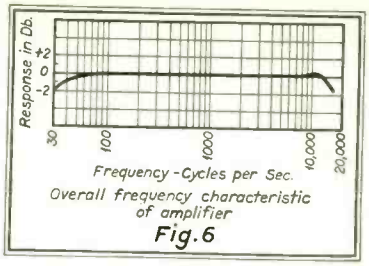
In addition to distortion and output characteristics, two other factors which are of paramount importance in high-fidelity equipment are frequency response and hum level. The frequency response of modern amplifiers is dependent for the most part on the response of the transformers used. In the circuit shown, a high-fidelity broadcast type of transformer is used having good response over the entire audio range. Fig. 6 illustrates the response curve of the complete amplifier shown including all four audio transformers. The overall response is uniform within 2 db from 30 to 16,000 cycles.

The hum level in an amplifier is comprised of hum from the filament supply, plate supply, inductive pickup and electrostatic pickup. The use of push-pull stages throughout in this amplifier tends to balance out both filament and plate-supply hum. In addition, the filter circuit in the plate supply is of the trap resonant type, having high efficiency. This is augmented by considerable resistance-capacity filtering in the early stages.

Inductive pickup at low levels becomes quite important. The transformers used on this amplifier are of the hum-balanced type housed in a high-permeability cast alloy shield having five times the shielding effect of normal cast iron. A metallic shield in the coil structure nullifies stray electrostatic pickup. Pickup of both inductive and electrostatic nature between the power-supply components and circuits and the audio units is reduced very greatly through the use of separate chassis for the power and audio sections.



Effect of plate resistance reduction by feedback as reflected in loudspeaker



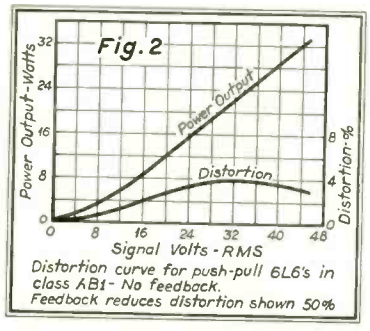
Overall frequency characteristic of amplifier

Fig.6

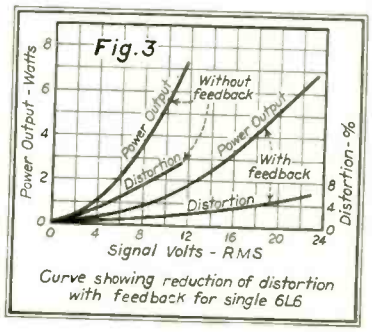
CIRCUIT DETAILS

The general circuit of this amplifier is of a simple conservative nature. All three stages are push-pull transformer coupled using glass tubes throughout. 6C6 triodes are used in the first two stages. The 6C6 tube has very low hum level and very little tendency for microphonics. However, there is considerable variation among tubes of this type. Where it is not convenient to check these tubes accurately, special 6C6 tubes can be obtained from RCA under the designation 1603. Raytheon also turns out a quiet 6C6 tube under the designation "type F construction." 6L6 tubes of the glass type are used, bearing the designation 6L6G. Provision is made to balance the output 6L6G's through the use of separate cathode resistors, one of which is variable. In addition to the feedback used in the output stage, a standard decoupling circuit is incorporated.

In most broadcast and other high-quality equipment where stability is of vital importance, it is advantageous to have a simple quick check on tube plate currents. This not only checks the con-



Distortion curve for push-pull 6L6's in class AB1 - No feedback. Feedback reduces distortion shown 50%



Curve showing reduction of distortion with feedback for single 6L6

dition of the vacuum tubes, but will also show up leaky condensers, open circuits and oscillation. In the past, it has been customary to use a standard milliammeter to check these currents. This would involve a knowledge of the correct current or a calibration chart. This is obviated in the amplifier shown through the use of a percentage system. A single mil-l ammeter is used to check the plate current of the first or second push-pull stages and the two output tubes individually. The meter is shunted over a properly designed portion of the cathode resistor so that with normal plate-current flow, the meter will read at the same scale position for any test position. The scale is calibrated in percentage with 100 percent as normal. Variations up to 15 percent can generally be neglected as they may be due to line-voltage conditions and difference between tubes. The output-tube plate current changes with power output and consequently the meter can be used as an approximate VI or overload indicator when connected in the 6L6G circuit.

BALANCED AMPLIFIERS

(*Continued from page* 16)

paraboloid, which is a closed surface. It would therefore produce families of curves on the co-ordinate planes which are within finite limits of plate and grid voltages. and hence would not correspond to those of any (at present) physically realizable tube.

If $(A_{11}^2 - 4A_{20}A_{02})$ is positive, (27) represents a hyperbolic paraboloid translated from the e_p, e_g and i_p axes, and rotated with respect to first two (Fig. 17).

It would produce realizable curves upon the $e_p - i_p$ and $e_g - i_p$ planes, Fig. 18, and would represent the surface of a variable-mu tube. This is an interesting result in that it indicates that variable-mu tubes having parabolic characteristics have a distortionless output when in push-pull, Class A. Such tubes could be used in a volume-expander without causing any distortion.

(*To be continued*)

ILLINOIS POLICE-RADIO SYSTEM

(*Continued from page* 9)

The speed with which the officers arrive on the scene of a crime is one of the great advantages of the police radio. Recent statistics show that in city areas it requires, on the average, only seventy-five seconds for squad cars to reach the scene. In a state-wide system this time will be considerably longer but speed factor is as important.

The coordination of all law-enforcing agencies, including state officers, county sheriffs and city police will be possible through the proper use of the state radio system. All county sheriffs' offices and city police stations will be equipped with receivers tuned to the state police-radio stations. Police bulletins of general interest will be broadcast at regular intervals. Special messages may be directed to mobile units at any time.

BOOK REVIEWS

RADIO DATA CHARTS, Second Edition, by R. T. Beatty, M.A., B.E., D. Sc. Published by Iliffe & Sons, Ltd., Dorset House, Stamford St., London, S. E. 1, England. 4/6 net, by post 4/10.

This Second Edition is completely up to date, many new Abacs having been added in accordance with modern developments, and obsolete charts correspondingly deleted.

This handbook has been popular with experimenters and engineers for many years, providing as it does, means for instantly arriving at many technical results which would otherwise necessitate much laborious calculation. Accompanying each Abac, as before, are notes to enable the user to derive the maximum service from the book as a whole.

HANDBOOK OF ENGINEERING FUNDAMENTALS, O. W. Eshbach, E.E., M.S., Editor-in-Chief, published by John Wiley and Sons, Inc., New York, 1081 *pages, price* $5.00.

This is the first volume in the proposed new Wiley Engineering Handbook Series. Since mathematics, physics and chemistry form the basis of all engineering, these are the fields dealt with in the new volume. This book has been designed to present a complete summary of the facts pertaining to the fundamental theory underlying engineering practice.

The first section presents a selection of mathematical and physical tables, including new and revised tables of the American Handbook Series, in which particular attention has been given to arrangement, typography and general convenience. In addition to tables on engineering constants, properties of numbers, logarithms, trigonometric and hyperbolic functions, there is included a series of tables of conversion factors for weights and measures arranged in order of dimensional sequence, tables of integrals, standard structural shapes, and physical properties of metallic and non-metallic materials.

Other sections offer such features as: the presentation of dimension systems, systems of units, standards, and introduction to the theory of dimensional analysis; the systematically arranged and illustrated fundamentals of theoretical mechanics and mechanics of materials with applications to beams, columns, shafts, and reinforced concrete; the modern theory of fluid mechanics as applied to the fields of hydraulics and aerodynamics; engineering thermodynamics, embodying the latest physical concepts of the fundamentals of heat engineering; the theory of the electric, magnetic and dielectric circuits and their application to generalized networks and transient theory; the fundamental principles of general chemistry, chemical tables and industrial chemistry; the principles of light, acoustics and meteorological phenomena; a treatment of the properties of metallic and non-metallic materials with reference to features of manufacture and use; and a discussion of the elementary legal aspects of contractual relations with which all engineers should be familiar.

The *Handbook of Engineering Fundamentals* is to be recommended.

CATHODE-RAY OSCILLOGRAPHY, by J. T. MacGregor-Morris, M. I. E. E., and J. A. Henley, M. Sc., published by the Instruments Publishing Company, 1117 *Wolfendale Street, Pittsburgh, Pennsylvania.* 262 *pages, price* $6.00 *postage prepaid.*

This book is Volume II of a Series of Monographs on Electrical Engineering which is being presented under the editorship of H. P. Young, M. I. E. E., M. A. I. E. E. The aim of this electrical monograph series is to enable engineers, advanced students, and the like to obtain authoritative works on special subjects which Mr. Young feels are either ignored or inadequately covered in standard textbooks. The author of each monograph has achieved eminence in his chosen field.

As is customary with books of this type, *Cathode-Ray Oscillography* has its first three chapters devoted, for the most part, to the fundamentals of its subject. These three chapters include Crookes', Thompson's and Braun's apparatus, electron theory, electron beam concentration and electron optics.

Chapters IV and V are concerned with the "Cold-Cathode Oscillograph" and the "Hot-Cathode Oscillograph," respectively. In later sections of the book considerable space is devoted to principal methods of using and applications of the hot-cathode and cold-cathode oscillographs.

Other parts of the book cover the operation, performance and limitations of cathode-ray oscillographs . . . as well as auxilliary apparatus, time sweeping and time bases. The final section is entitled "The Application of the Hot-Cathode Oscillograph to Television Transmission and Reception."

As an added feature over 100 references to the leading articles and books published on cathode-ray oscillographs are given at the end of the book. It appears that the majority of the material published on this subject comes from the United States, England, and Germany.

Cathode-Ray Oscillography is to be recommended.

MOBILE RECEIVING EQUIPMENT

(*Continued from page 7*)

receiver and power unit chassis. This cover-chassis assembly slides into the housing from the front and when assembled the case is completely waterproof.

The receiver chassis is at the rear of the supporting frame and is shock mounted. All components on this unit are rigidly mounted and bracing is extensively employed to prevent vibration. This method of mounting, together with the double shock-mounting feature, effectively protects the components from damage due to shock and vibration.

A superheterodyne circuit, employing the following tubes, is used:

RCA-6C6—r-f amplifier.
RCA-6C6—first detector.
RCA-6C6—oscillator.
RCA-6D6—i-f amplifier.
RCA-6B7—second detector, avc, a-f.
RCA-38—output.

The RCA-6B7 (see Fig. 6) is employed to perform the functions of detector, avc and audio amplifier. The d-c resulting from rectification by the signal diode produces an audio voltage across the volume control. The arm of this control selects the amount of audio voltage which is fed to the grid of the same tube. The d-c from the second diode is used to give automatic gain control of the r-f and i-f stages.

Tuning is by means of air-dielectric condensers, screwdriver adjusted. Waterproof, screw-type plugs are provided in the case to permit tuning without removing the chassis from its housing. A separate adjustment on each cir-

(*Continued on page 25*)

TELECOMMUNICATION

PANORAMA OF PROGRESS IN THE FIELDS OF COMMUNICATION AND BROADCASTING

SOUND-PROJECTING SYSTEM

ONE OF THE LARGEST and most powerful sound-projecting system ever constructed is being installed at Roosevelt Raceway at Mineola, L. I., New York, where Roosevelt Airport No. 1 used to be. The equipment is intended to be used for announcements of automobile racing events and to provide music and entertainment originated by artists in the studio on the premises.

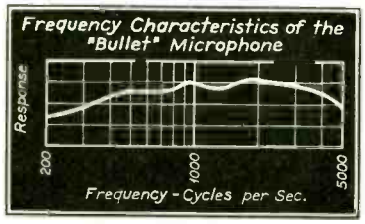
This new Western Electric sound system is designed to cover the entire one-half square mile expanse from a single source. The system is a development of Bell Telephone Laboratories, and the equipment is being furnished and installed by the Guided Radio Corporation, as agent for the Graybar Electric Co.

THE "BULLET" MICROPHONE

THE "BULLET" MICROPHONE is a new addition to the electrodynamic microphone field. It was designed especially to provide a high sensitivity in speech pickup, and an idea of its directional characteristic, frequency response, size and appearance may be gained from the accompanying illustrations.

From the frequency-response curve it is evident that this unit has been purposely designed with a rapid attenuation in response below 200 cycles. Since the lower frequencies are not predominant in speech they have been eliminated in this microphone to prevent "boominess." This means that it is suitable for close talking purposes. The characteristics of this unit also eliminate the necessity for employing wind screens, of obvious advantage in outdoor pickups.

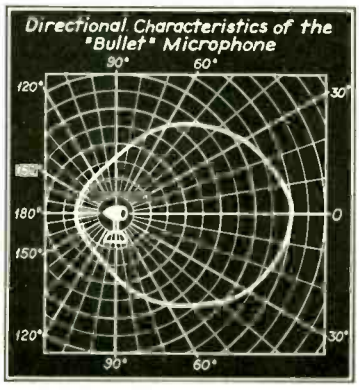
The "Bullet" has a broadly directional characteristic for the region in front of the microphone, which means that there will be no discrimination in this area. An attenuation present in the rear part of the unit reduces the effective reverberation encountered in auditoriums and similar locations. This results in a reduction of feedback and other undesirable interferences that handicap sound reinforcement installations. Directional characteristics, however, are not a limitation, according to the Transducer Corporation, as this microphone, when placed with its



mouth toward the ceiling, has uniform nondirectional characteristics over 360° in the horizontal plane.

This microphone has a sensitivity equal to that of a high-quality carbon unit. No batteries or preamplifiers are

required and it can be used at considerable distances from its associated amplifier. Due to the relative small amplification required, shielded cables are not essential except in locations where strong magnetic fields are encountered.



WROK, WLBC INCREASE SERVICE AREAS

MANY RADIO-BROADCASTING STATIONS which are installing vertical radiators are finding the modernization credit plan of the Federal Housing Administration helpful in the purchase and installation of this new equipment.

Reports from the Middle West tell of several stations which have availed themselves of the opportunity to increase power by the installation of new transmitters and antennas, thus extending their primary markets and making their services more attractive to listeners and to advertisers.

Typical of the experience of such radio stations is station WROK, at Rockford, Illinois. Application to the Federal Communications Commission for full time on the air instead of 7½ hours received favorable action with the installation of a vertical radiator, and with more efficient transmitter, amplifiers and other equipment.

The new single antenna, rising 239 feet in the air, replaces the twin towers measuring 120 feet. The effect of the improvement of equipment and the nondirectional vertical radiator is a signal equal to raising the power of the station from 500 to 1,000 watts. Thus the 1,000,000 WROK listeners in Northern Illinois and Southern Wisconsin, a rich industrial and agricultural area, get better quality receiving as well as full time.

The sale of 1½ hours in the evening, once a week, will pay for the improvements, according to Lloyd C. Thomas, veteran radio official, who is President of the Rockford Broadcasters, Inc., which operates WROK.

Permission to increase its power from 50 to 100 watts was granted radio station WLBC, of Muncie, Indiana, contingent upon the installation of a vertical radiator. A new transmitter, plus the new antenna, will give signal broadcast by WLBC the equivalent of that sent out by a station having 500 watts.

WLBC was desirous of covering more completely the 65-mile area in Eastern Indiana, which comprises the shopping district of Muncie. Rich in industrial activity and a prosperous agricultural section, this territory required better coverage for the users of radio in advertising, and it was with

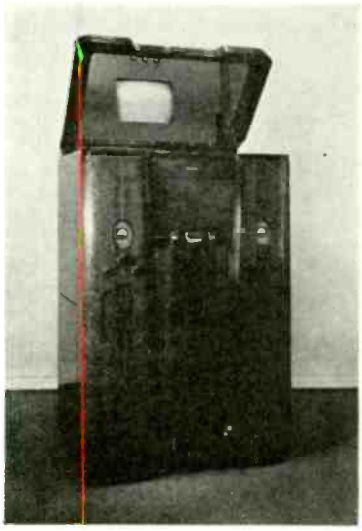
MAKING TELEVISION TUBES.

this in mind that President Don A. Burton, of WLBC, made application for an increase in power.

The new antenna, located on top of the building in downtown Muncie, which houses WLBC, will rise 230 feet above the street level. It replaces twin towers only 50 feet high.

In addition to transmitters, antenna, other equipment which may be financed with government-insured funds includes air conditioning, electric-clock installations, generators, mixing panels, transcription equipment, volume indicators and other items peculiar to broadcasting. Specific rulings may be obtained by writing the Federal Housing Administration, Washington, D. C.

FRONT VIEW OF THE EXPERIMENTAL TELEVISION RECEIVER.

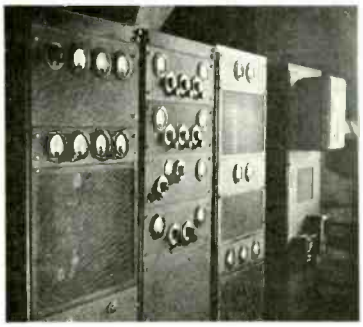


PHILCO'S TELEVISION SYSTEM

ON AUGUST 11, a special television demonstration was given by the Philco Radio and Television Corporation at their plant in Philadelphia. Unknown to most people Philco has been carrying on experimental television work for over eight years.

In 1928 engineers of this organization were experimenting with 60-line scanning discs. During the time of these experiments the license for the visual broadcast station, W3XE, was received and experimental transmissions were begun in 1932. Then, following the development of 240-line pictures, the next progressive step was to 345-line pictures. A satisfactory image was first obtained by wire, after which the station W3XE was rebuilt and the power increased to 1.5 kw.

One of the most difficult problems to be solved, according to Philco engineers, was the modulation of the transmitter by the very high video frequencies necessary for television pictures. It is a relatively easy matter in



THE ULTRA-HIGH-FREQUENCY SOUND TRANSMITTER.

a sound transmitter to modulate from 30 to 10,000 cycles, but when the upper limit of the modulation band is pushed to 2.4 megacycles the problem of constructing amplifiers and modulators becomes a difficult task. The solution was the invention of a new type of modulation which is being used in the system.

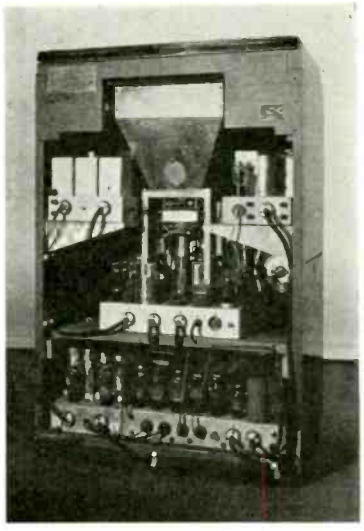
Field tests were started on December 23, 1935, with a one-hour program reproduced at a distance of 7 miles from the transmitter. Beginning on June 18, 1936, regular scheduled programs were broadcast nightly on 51 mc (picture) and 54.25 mc (sound). Experimental console-type receivers have been placed in the homes of the various engineers in Philadelphia, who receive and report on the programs.

Briefly, the electrical specifications for the Philco System are as follows: channel width, 6 mc; spacing between television and sound carriers, approximately 3.25 mc; polarity of transmission, negative; number of lines, 345; number of pictures per second, 60 interlaced; aspect ratio, 4:3; percentage of television signal devoted to synchronizing, 20 percent; synchronizing signal, narrow vertical; carrier frequency of picture transmitter, 51 mc; carrier frequency of sound transmitter, 54.25 mc.

THE TELEVISION CONTROL ROOM.

The latest experimental receiver which was demonstrated comprised a sound and television receiver tuning over the frequency range of 42-86 mc. These receivers are separately tuned, although it is easy to secure single-knob control. The deflecting chassis is the name given the unit which incorporates synchronizing and deflecting equipment. The power-supply units are placed at the bottom of the cabinet.

REAR VIEW OF THE EXPERIMENTAL TELEVISION RECEIVER.



VETERAN WIRELESS OPERATORS ASSOCIATION NEWS

W. J. McGonigle, Secretary, 112 Willoughby Avenue, Brooklyn, N. Y.

TWELFTH ANNUAL

PLANS ARE being formulated in many cities throughout the country preparatory to launching the world-wide Twelfth Annual Cruise of the Veteran Wireless Operators Association and all its Chapters. The simultaneous cruises will be held on the evening of February 11th, 1937, in leading hotels and restaurants in the cities in which Chapters are already organized—or in the process of organization.

Suggestions, offers of assistance and requests for information concerning your local affair should be forwarded to your local Chairman or Secretary.

Charles C. Kolster, Chairman and First District U. S. Radio Supervisor, and Harry Chetham, 34A Prescott Street, Somerville, Mass., will be pleased to hear from members and friends in and around Boston concerning plans for a bigger and better cruise in that city.

George I. Martin, Chairman and Superintendent of the RCA Institutes in Chicago, and B. R. Donges, Secretary and Maintenance Supervisor with the National Broadcasting Company, can both be reached at the Merchandise Mart in Chicago by those desirous of participating in their cruise on the 11th of February.

George Street, Chairman and Superintendent of RCA Communications in Honolulu, and Arthur Enderlin, Secretary with the Mackay Company in that city, from all indications will outdo this year's efforts at their "Surf-Board" Cruise on the 11th of February come next year. We suggest all communications people, and that includes Army, Navy, Coast Guard and all other branches of the government service, get in touch with either George or Arthur and join up with what promises to be one of our largest and most progressive Chapters.

V. H. C. Eberlin, formerly Treasurer of the Association, is now the Chairman of the Miami Chapter and with the capable support of C. J. Corrigan, Chapter Secretary, he promises to really put over a "Big" affair come February 11th. "Ebby" may be reached either at the Tropical Radio station at Hialeah, or at Box 84 Opa Locka, Fla., and C. J. Corrigan awaits your letters and comments at 71 E. 79th St., Miami, Fla.

FIRST CRUISE OF HONOLULU CHAPTER VWOA. LEFT, GEO. STREET, CHAIRMAN, RCAC, AND ARTHUR ENDERLIN, SECRETARY, MACKAY RADIO.

HONOLULU CHAPTER. FIRST CRUISE (FEB. 1936)—KNEELING, LT. COL. LELAND H. STANFORD; STANDING, GEORGE STREET; SARGENT MADDOLONI AT TRANSMITTER.

T. M. Stevens, Chairman and General Superintendent of the Pacific Coast Division of the Radiomarine Corporation of America, and Ray Meyers, Secretary with the Radiomarine Corporation at Marshall, Calif., will be pleased to hear from you concerning proposed fall activities and particularly the "Twelfth Annual" of the San Francisco Chapter. Lt. Col. Leland H. Stanford, U. S. Army Signal Corps, recently appointed to a post at the Presidio in San Francisco, promises to take an active part in the functions of the San Francisco group.

J. A. Pohl, of the Radiomarine Corporation, and E. L. Commagere, of the Tropical Radio Telegraph Company, are anxious to hear from all interested in furthering our New Orleans Chapter. They hope to have a goodly number enrolled and "rarin" to go come February 11th. Why not 'phone, write or visit either Mr. Pohl or Mr. Commagere and find out how you may assist in the work of planning a real get-together?

Emery H. I. Lee, U. S. Radio Supervisor in Detroit, Michigan, will be more than pleased to hear from veteran and present-day wirelessmen regarding the staging of a cruise in that city simultaneous with the many others being held in other cities throughout the world.

L. A. Briggs, with RCA Communica-

tions in London, England, desires to gather together many of the communications people in England for a "jolly good time" which will precede our affair in New York by at least five hours. Mr. Briggs may be reached at the Electra House, Victoria Embankment, London, England.

Chapters are in the process of formation in other cities and we will relate their progress in this page from time to time. We hope to have one going "down under" in New Zealand before long and they may possibly hold a simultaneous cruise almost a day ahead (or is it a day after?) those held in the United States.

If you live in or around New York and plan to take part in the gala festivities being arranged for the 11th of February, 1937, marking an "even dozen" years of VWOA progress. "Ye Secretary" would be pleased to receive your suggestions, comments and criticisms.

MOBILE RECEIVING EQUIPMENT

(*Continued from page 20*)

cuit, accessible with the chassis pulled forward, is provided to convert the receiver to cover the 2300-2500 kc band.

The i-f amplifier is designed so that the overall i-f curve is of the "double hump" type. This feature allows for the slight circuit variations and drift inherent under the conditions of extreme vibration, thereby permitting operation over long time without readjustment.

Since the noise from the motorcycle is normally above the noise level of the receiver, automatic noise suppression or "squelch" is not used. However, if conditions of service warrant its use, it may be added by changing one connection within the set.

With the noise output limited to 12½ milliwatts, the sensitivity is such that not more than 2.50 microvolts, modulated 30 percent at 400 cycles applied to a 15-mmfd dummy antenna, is required to produce an output of 50 milliwatts into a 15,000-ohm resistive load.

The power-unit chassis is rigidly mounted to the chassis support frame. On this chassis are mounted the vibrator, the vibrator transformer, filter chokes and capacitors and the output transformer. The vibrator has an unusually long life; this feature is obtained by keeping the load required from it well below normal capacity.

A magnetic-type loudspeaker is used. The unit mounts in a case which closely resembles the motorcycle headlight in size and shape but which is actually a "folded-up" exponential horn. Mounting is so arranged as to direct the signal toward the operator's head.

The antenna consists of an 18-inch rod projecting from the rear of the receiver housing, directly over the rear mudguard. It passes through a watertight insulating bushing in the receiver housing and screws directly into a fitting mounted on the chassis frame.

OVER THE TAPE...

NEWS OF THE RADIO, TELEGRAPH AND TELEPHONE INDUSTRIES

IRE ROCHESTER FALL MEETING

The annual Rochester Fall Meeting, a joint meeting of the Institute of Radio Engineers and the Engineering Division of the Radio Manufacturers Association, will be held at the Sagamore Hotel, Rochester, New York, on November 16, 17, and 18. The technical sessions will feature such well-known speakers as L. C. F. Horle, A. F. Murray, S. W. Seeley, B. J. Thompson, R. M. Wise, J. J. Lamb, B. Olney, and J. M. Miller. The latest in component parts and test equipment will be displayed.

SHALLCROSS CATALOG

A complete loose-leaf catalog giving characteristics and specifications of precision wire-wound resistors, decade resistance boxes, bridges, test equipment and switches, is now available. Write Dept. S-1, Shallcross Mfg. Co., Collingdale, Penna.

MUTUAL EXPANDS

Two prominent regional networks in the midwest—the Central States Broadcasting System and the Iowa Broadcasting System—will add to their schedules, Mutual programs, as soon as the Don Lee network of California allies with Mutual. This coast-to-coast expansion becomes effective not later than December 29, 1936.

The Iowa Broadcasting System, owned by The Des Moines Register and Tribune, operates two stations in Des Moines and one in the eastern Iowa territory with studios both in Cedar Rapids and Waterloo.

KSO, Des Moines, operates on a frequency of 1430 kilocycles with 1000 watts daytime—500 at night. WMT in Cedar Rapids—Waterloo operates on a frequency of 600 kilocycles with 5000 watts daytime and 1000 watts at night. Gardner Cowles, Jr., is General Manager of this regional network.

The Central States Broadcasting System, an affiliate of the Lincoln Journal and Lincoln Star, owns and operates KOIL, Omaha—Council Bluffs, and KFOR, Lincoln. KOIL operates on a frequency of 1260 kilocycles with 2500 watts daytime—1000 watts at night. KFOR operates on a frequency of 1210 kilocycles with 250 watts daytime and 100 watts night time. John M. Henry is General Manager of this network.

UNITED OSCILLATOR TUBES

"United Oscillator Tubes for Short-Wave and Diathermy Apparatus" is the title of a new 4-page bulletin which has just been made available by the United Electronics Company, 42 Spring Street, Newark, N. J. Characteristics and performance data are given for the 311-T, 311-CT, 311-CH, and 303-U tubes.

DR. EDWARD WESTON

Dr. Edward Weston, famous scientist and founder of the Weston Electrical Instrument Co., died at his home in Montclair, N. J., on August 20. His age was 86.

Dr. Weston was a member of the American Society of Chemical Engineers, American Physical Society, Franklin Institute, Inventors Guild, and many other scientific societies.

GENERAL RADIO CATALOG J

The General Radio Company, 30 State Street, Cambridge, Mass., have just issued Catalog J. This 170-page book contains complete technical information on General Radio industrial devices, resistors, condensers, inductors, frequency- and time-measuring devices, oscillators, amplifiers, bridges and accessories, standard-signal generators, oscillographs, cameras and analyzers, meters, power supplies, parts and accessories. This catalog is available on request.

WESTINGHOUSE STATION MANAGERS

Walter C. Evans, Manager of the Radio Division of the Westinghouse Electric and Manufacturing Company, announced that on August 15, Dwight Myer, Plant Manager of Station KDKA, in Pittsburgh, was transferred to Boston as Plant Manager of WBZ, and that J. E. Baudino, Plant Manager at WBZ was transferred to Pittsburgh as Plant Manager of KDKA.

The move is made in accord with the Westinghouse policy of rotating the personnel of its radio stations at intervals.

ATLAS RESISTOR CATALOG

The Atlas Resistor Company, 423 Broome Street, New York, N. Y., manufacturers of wire-wound tubular resistors, have announced their new 1937 catalog. This catalog is available to anyone requesting it from the above organization.

WARD LEONARD BULLETINS

The following file bulletins are now available from the Ward Leonard Electric Company, Mount Vernon, New York: No. 1500, automatic d-c motor starters and controllers, Nos. 2701, 2702, 2721 and 2722 on motor disconnect switches; Nos. 2751, 2801 and 2852 on motor-starting and protective switches; No. 2951 on thermal overload units; No. 3701, a-c manual speed regulators; Nos. 4001, 4021, 4031, 4036, 4041, 4051, 4061, 4201, 4231, 4236 and 4241 on a-c motor starters; No. 4221, automatic transfer switches; Nos. 5601 and 5601-A, Type EF electronic automatic alternator voltage regulator; and No. 71, vitrohm non-interlocking dimmers.

EXPERIMENTAL FREQUENCIES

The FCC on August 14, 1936, amended Rule 229 by adding the following frequencies for experimental broadcasts: 38,900, 39,100, 39,300, 39,500, 39,700, 39,900, 40,800 and 41,400 kilocycles.

The Broadcast Division will promulgate rules governing the broadcast stations that will be assigned to these frequencies.

RADIO RECEPTOR BULLETIN

The Radio Receptor Company, Inc., 106 Seventh Avenue, New York City, now have available a bulletin featuring the Radio Receptor Series "7" dynamic microphones. These microphones are for public-address, broadcasting, studio and location recording, and sound-reproduction work. Write for Bulletin No. 3013.

ERPI-BRUNO AGREEMENT

By virtue of an agreement with the Electrical Research Products, Inc., the Bruno Laboratories, Inc., is now licensed to manufacture public-address equipment under United States patents owned or controlled by the Western Electric Company, Inc., and the American Telephone and Telegraph Company.

This arrangement widens the sales field of the Bruno Laboratories, Inc., inasmuch as their product can now be used in municipal and government installations or any other institution where patent infringement protection is necessary. This license specifically covers public-address systems including velocity microphones, amplifiers, and loudspeakers.

MAGNAVOX APPOINTMENTS

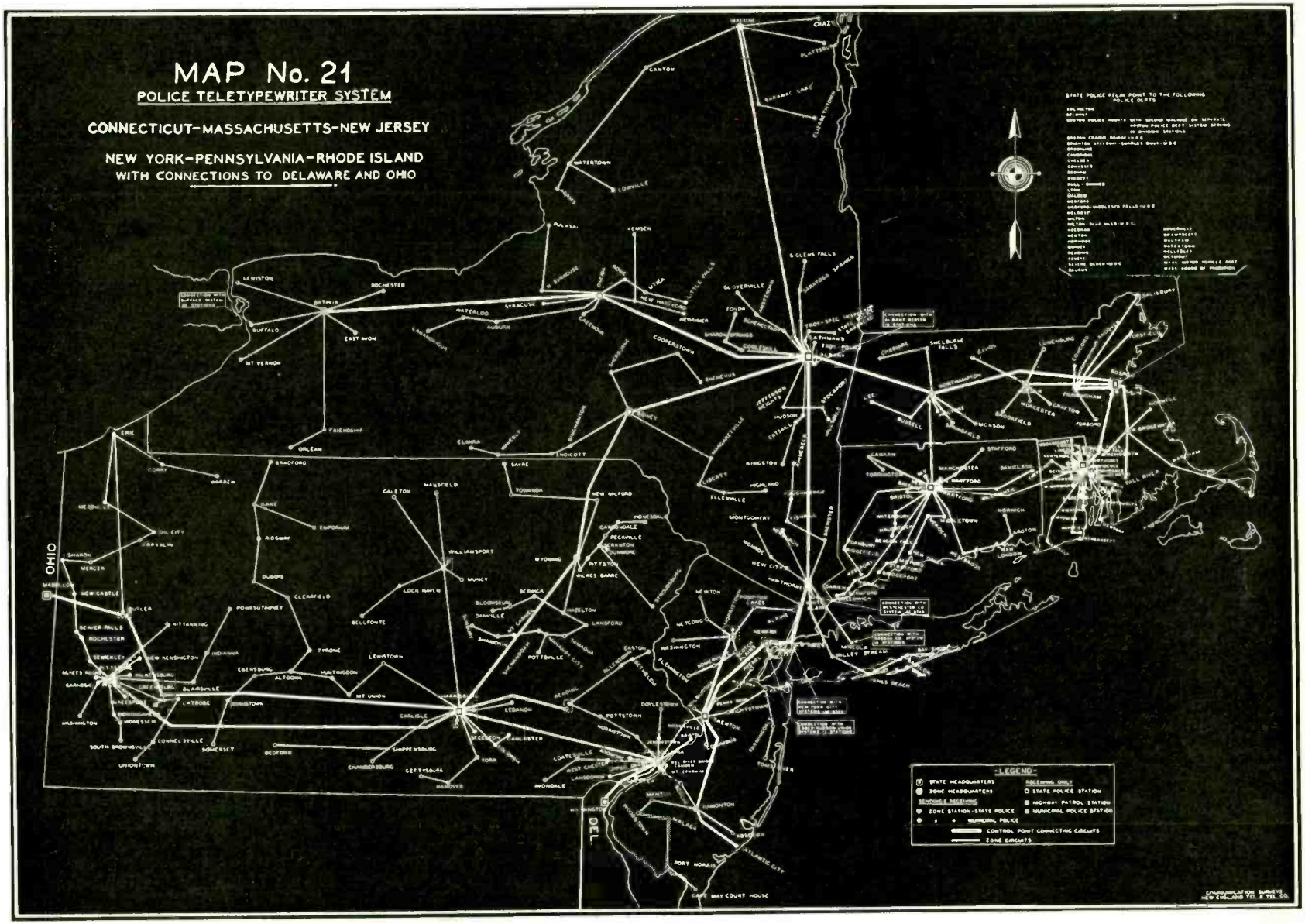
The Magnavox Company, Fort Wayne, Indiana, have announced the appointment of Mr. Burgess Dempster as Manager of the Philadelphia area with office headquarters at 401 North Broad Street, Philadelphia.

Mr. Dempster, who is a University of California graduate electrical engineer, is well known in radio circles having been associated with The Magnavox Company and its affiliates since 1929.

Mr. J. C. Koonz, formerly Manager of the Philadelphia area, was recently promoted as Manager of the Company's new etched and printed glass dial division with headquarters at the factory in Fort Wayne, Indiana.

TRANSCRIPTION PROGRAM BULLETIN

The Radio Producers Sales Co., 606 N. Bronson Ave., Hollywood, California, have announced a 24-page bulletin covering their electrically transcribed programs. This bulletin is available. The Radio Producers Sales Company is a subsidiary of Radio Recorders, Incorporated, also of Hollywood.



THE MARKET PLACE

NEW PRODUCTS FOR THE COMMUNICATION AND BROADCAST FIELDS

POWER RHEOSTAT

The new D-150 power rheostat has just been announced by Hardwick-Hindle, Inc., 40 Hermon Street, Newark, N. J. It is a compact, continuously-variable unit that measures 4 inches in diameter with a maximum depth behind the panel of 1½ inches.

All live parts other than the terminals are enclosed. The contact surface of the wire is protected from dirt and mechanical damage. All moving parts are back of the panel and are smooth and flush with the surface of the rheostat.

Resistance wire is wound on a toroidal ceramic core and coated with vitreous enamel. A minimum of ¼ inch air space or adequate ceramic insulation separates all live parts from the shaft, base, etc., which may be grounded.

The contact shoe is of metal-graphite composition and travels on the inside circumference of the ring where the turns of the winding are necessarily most closely spaced. The shoe has a narrow face that

is said to insure a smooth variation of resistance and freedom from unsteadiness due to shift of contact from one side of the shoe to the other. A coiled pigtail, one end of which is molded within the shoe, has its other end riveted to the central stationary terminal so that the only sliding electrical contact is that between the shoe and the winding itself. A heat-treated coil spring holds the shoe in contact with the winding, while shoe, spring and pigtail are enclosed in a ceramic cavity.

The new D-150 rheostat has a free air rating of 150 watts. It conforms to Underwriter's Laboratories and NEMA specifications based on a maximum temperature rise of 250° C for continuous operation in free air.

AMPERITE MICROPHONE

The new velocity microphone model RBH by Amperite is said to give studio-type reproduction at unusually high outputs. It is acoustically designed to eliminate cavity resonance. Triple shielding is used to prevent the pickup of stray fields. Shock absorption at two different points eliminates mechanical vibration. A switch

is provided for turning the microphone on and off—and a new cable plug having a positive locking device permits disconnecting the cable at the microphone. The new nickel-aluminum magnets are included in this microphone. Obtainable with either low- or high-impedance outputs in either gunmetal or chrome finishes.

Complete information is available from Amperite Corporation, 561 Broadway, New York City.

AMPEREX HF 100

Amperex Electronic Products, Inc., have announced a new low-voltage high-frequency power-amplifier and oscillator tube, the HF 100. The tentative characteristics of this tube are as follows: filament voltage, 10 volts; filament current, 2 amperes; amplification factor, 21; grid-to-plate transconductance at 100 ma, —4000. The direct interelectrode capacitances are as follows: grid-to-plate, 5 mmfd; grid-to-filament, 3.5 mmfd; plate-to-filament, 1.4 mmfd.

The maximum attainable plate power output of the HF 100 is 170 watts at 30

mc, 100 watts at 60 mc, and 50-60 watts at 120 mc.

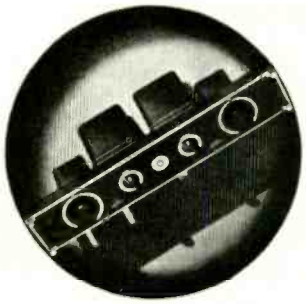
"ACOUSTI-REFLEX" SPEAKER CABINET

The Operadio Manufacturing Company, St. Charles, Illinois, have announced a new development, the "Acousti-Reflex" speaker cabinet. This cabinet is said to minimize "feedback" difficulties as well as to increase the efficiency of the speakers. Better coverage with less amplifier output, and a substantially increased tonal quality are other features of this unit, it is stated.

Catalog 10-E, which is available from the manufacturer, gives full particulars.

UTC EQUALIZER

After two years of research and development, United Transformer Corp., 72 Spring St., New York City, has released a universal equalizer for broadcasting and recording service. This unit is of a depressed-chassis rack-panel construction. It incorporates separate controls for high- and low-frequency equalization. A switch is provided on the low-end control to ob-



tain maximum equalization at 25, 50 or 100 cycles. Another switch is used for the high-frequency end at 4,000, 6,000, 8,000 and 10,000 cycles. Calibrated T-type attenuators are used for low-frequency equalization and high-frequency equalization, permitting control from 0 to 25 db. This unit is said to be suitable for use in equalizing broadcast lines, microphones, pickups, amplifiers, and other radio equipment.

THE VELOTRON MICROPHONE

The Bruno Laboratories, Inc., 20 West 22nd St., New York City, announce the arrival of a new product, the Velotron Microphone.

This is a new velocity microphone which is said to incorporate entirely new principles of construction, employing a static rather than a magnetic field. The output is higher than that of the conventional magnetic velocity microphone being on the order of —50 db. It is a high-impedance microphone but may be employed with cable lengths up to 500 feet, without detriment to the quality of the output, it is stated.

ASTATIC MODEL 218 MICROPHONE

This is a single-diaphragm type instrument having wide-angle uni-directional

pickup. It is 2⅛ inches in diameter by ⅞ inch maximum thickness. The case is ⅝ inch thick; net weight 3½ oz.

The back of this unit is flat and the screen front is domed. Cable attaches through a collett-type ferrule. The output level is approximately —56 db using a 5.0 meg load.

A high-capacity grafoil crystal element is employed which permits of using long cables without serious loss of output. This high internal capacity is also said to be advantageous when transformers are employed to match to low-impedance circuits. Standard finish is telephone black. Standard cable is single-wire rubber-covered 8 feet long.

Further information may be obtained from the Astatic Microphone Laboratory, Inc., Youngstown, Ohio.

PHASE-ROTATION INDICATOR

Ferranti Electric Inc., 30 Rockefeller Plaza, New York City, announce a new addition to their line in the form of a small 2½ inch phase-rotation indicator weighing less than 13 ounces.

This instrument consists of a small three-phase induction motor mounted in a bakelite case and fitted with an aluminum disc, which instantly indicates the direction of phase rotation on a three-phase supply. The portable model which can readily be carried in a pocket, is fitted with three 30-inch leads having crocodile clips of different colors.

These instruments can be used on voltages of from 110 to 650 volts, 25 to 125 cycles, and are extremely useful wherever it is necessary to know the phase rotation of a three-phase circuit.

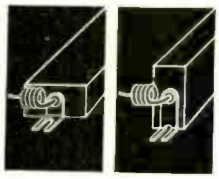
Instruments for switchboard mounting can also be supplied in either of the 2½-inch flush or projecting patterns.

Complete descriptive information will be sent upon request.

"FLEX-MOUNT"

Permitting mounting in any position, "little giant" dry electrolytics are now available with an adjustable mounting lug at each end of the container. This "Flex-Mount" is a movable, universal tab which makes the condenser actually reversible. It may be mounted either flat or on edge, and the position is changeable at will.

Although the connecting wires are generally sufficient support for these units, the Solar Manufacturing Corporation, 599 Broadway, New York City, has designed



"Flex-Mount" to take care of tight corners and difficult installations where it is advisable to mount the condenser rigidly.

ARCTURUS 6L6-G TUBE

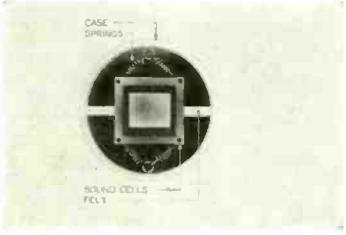
The Arcturus Radio Tube Company, Newark, N. J., has recently marketed type 6L6-G beam amplifier tube. Similar in characteristics and pin connections to its metal counterpart, the 6L6-G is in a ST-16 bulb.

MICROPHONE MOUNTING

A late development in microphone construction tending toward quietness in use is the newly developed spring mounting in the BR2S microphone manufactured by The Brush Development Company, E. 40th Street and Perkins Ave., Cleveland, Ohio. This mounting makes unnecessary any external mounting ring or rubber stand shock absorber.

This device enables anyone using the microphone to pick it up and move it when in use. It is formed by fastening springs to two opposite sides of the unit of sound cells and pieces of felt on the other two sides.

Because of this feature the BR2S is suited for public-address work in which the microphone is likely to receive hard treatment.



METER ENCLOSURES

Circular enclosures, for covering single indicating instruments on all types of trans-

mitters, are now being added to the standard line of Remco meter enclosures.

The types now available are for use with small Weston 301, flush and surface-type meters, and Weston switchboard meters of types 260, 252, etc.

A revised bulletin is available, and lists over 15 standard enclosures for innumerable applications, which may be obtained in any special finish desired to match properly the existing equipment.

For further information write to Radio Engineering and Mfg. Co., Jersey City, New Jersey.

PRESTO RECORDER

The Presto Recording Corporation, 139 W. 19 Street, New York City, N. Y., have announced their "Compac Model D" instantaneous recorder. This portable recording apparatus, shown in an accompanying illustration, has been designed for use in schools, conservatories of music, studios, clubs and homes.

The basic pattern of the recorder is one of simplicity, flexibility in use, ruggedness and high fidelity. It is in keeping with good modern industrial design.

The Model D includes the following features: overhead feed mechanism which is driven from the center of the turntable, microphone receptacle polarized for easy insertion, cutting head assembly to cut either acetate or aluminum, volume-indicator meter, volume control, electro-dynamic speaker, selector switch, crystal pickup, etc.

Complete information on this instrument may be secured by writing to the above organization.

THE Group Subscription Plan for COMMUNICATION AND BROADCAST ENGINEERING enables a group of engineers or department heads to subscribe at two-thirds the usual yearly rate.

The regular individual rate is $3.00 a year. In groups of 4 or more, the subscription rate is $2.00 a year. (In foreign countries, $3.00.)

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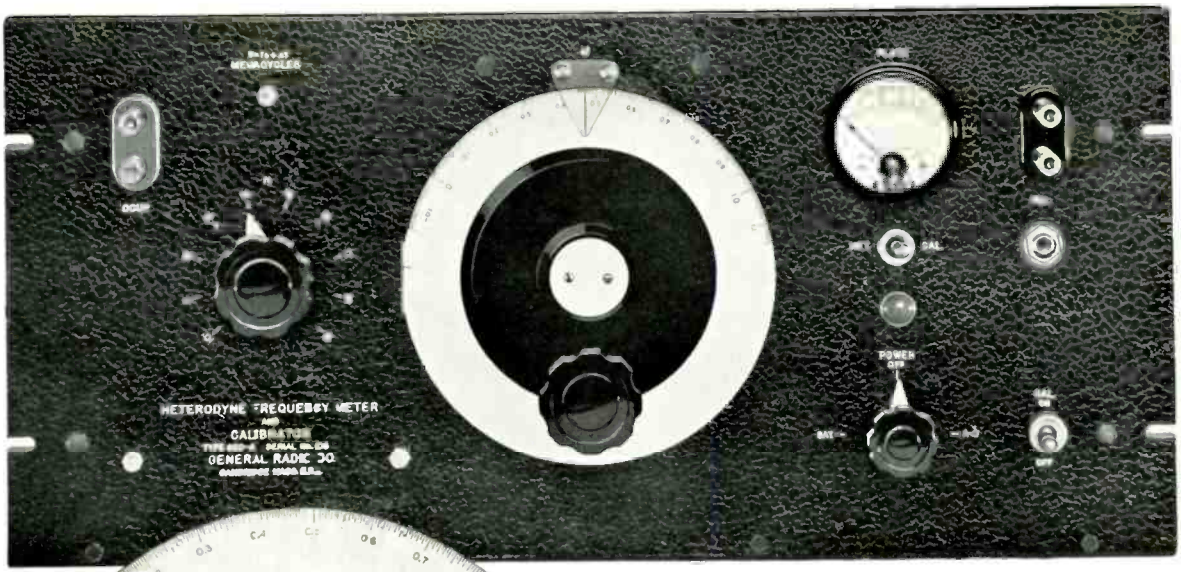


DIRECT READING 300 kc to 300 Mc!

HERE'S a combined heterodyne frequency meter and crystal calibrator which covers the exceptionally wide range of 300 kilocycles to 300 megacycles with an accuracy suitable for all commercial requirements. One instrument for all classes of service including the ultra-high frequency!

Check These Features

1 DIRECT READING — No calibration charts, curves or plug-in coils.

2 WIDE RANGE — Continuous from 300 kc to 300 Mc.

3 EXCEPTIONAL ACCURACY — Suitable as a monitor throughout its entire range except in the standard broadcast band.

4 SELF-CALIBRATING—Calibration can be checked anytime against the built-in, low-temperature-coefficient quartz plate; the over-all accuracy of measurement is 0.01% or better.

5 PORTABLE — The portable model weighs only 45 pounds and can be operated from batteries.

ABRIDGED SPECIFICATIONS

CIRCUIT: Heterodyne frequency meter, with detector and audio-frequency amplifier for obtaining beats; a piezo-electric oscillator for calibration.

FREQUENCY RANGE: Fundamental from 10 to 20 megacycles, in 10 ranges of 1 Mc each. By harmonic methods frequencies between 300 kc and 300 Mc are measured easily.

CALIBRATION: The condenser dial is graduated to read fractions of megacycles directly, the smallest division corresponding to 5,000 cycles. Settings for 1,000 cycles can be estimated readily.

CALIBRATOR: A low-temperature-coefficient quartz plate is used in the one megacycle piezo oscillator for checking the calibration of the meter. Checking frequencies fall at the same dial readings on every coil range, making the checking very simple, rapid and accurate.

POWER SUPPLY: Either 105-125 volts 50-60 cycles, or 6 and 180 volts dc selected at will by means of a switch on the panel.

MOUNTING: Standard 19-inch relay-rack model weighing 40 pounds or Portable Model in metal case equipped with cover and handle, weighing 45 pounds.

TYPE 620-A Heterodyne Frequency Meter & Calibrator: Relay Rack Model . . $490.00 . . . Portable Model . . $555.00

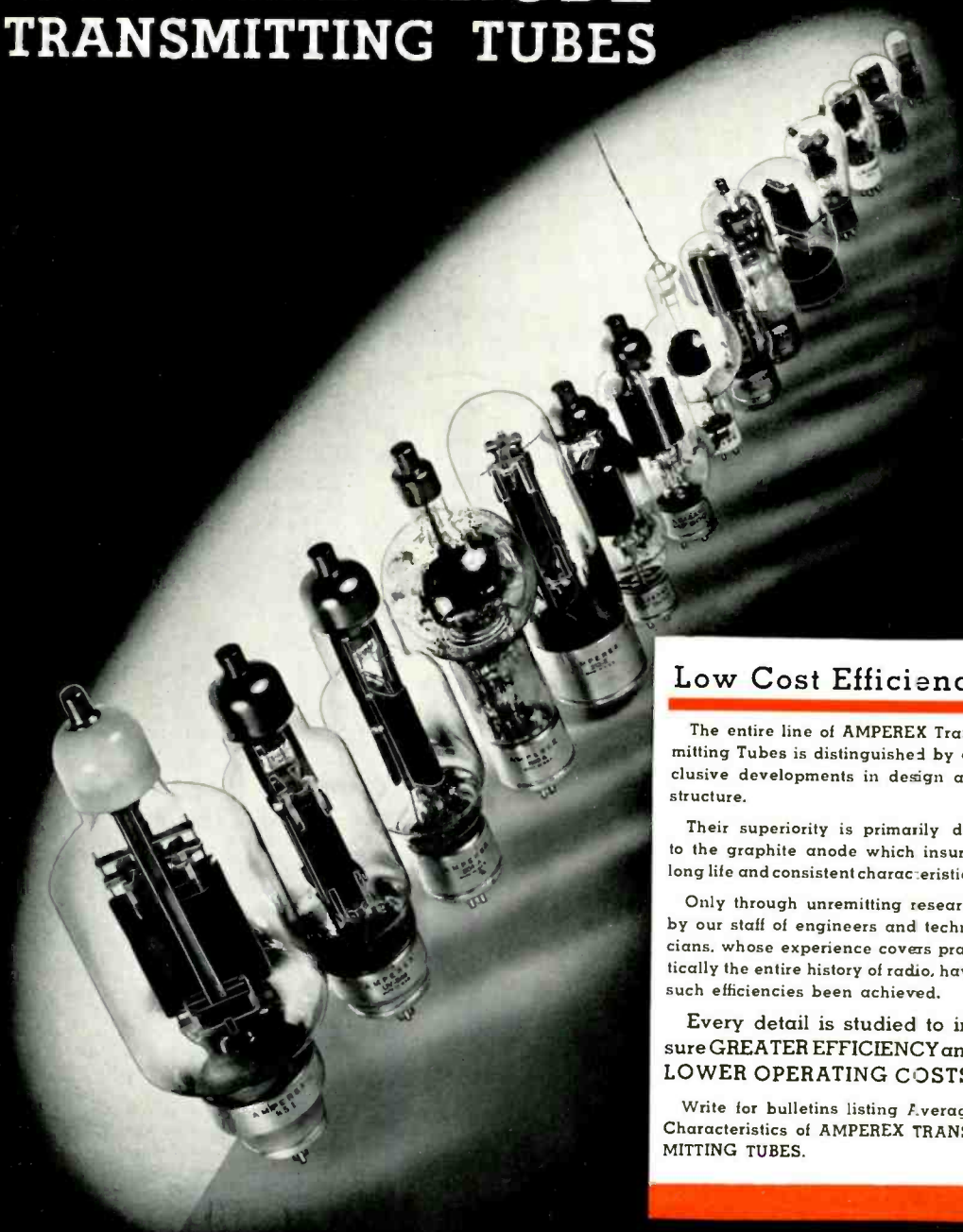
Write For Bulletin 54-K For Complete Details

GENERAL RADIO COMPANY

30 State Street, Cambridge, Massachusetts

AMPEREX

GRAPHITE ANODE TRANSMITTING TUBES



Low Cost Efficiency

The entire line of AMPEREX Transmitting Tubes is distinguished by exclusive developments in design and structure.

Their superiority is primarily due to the graphite anode which insures long life and consistent characteristics.

Only through unremitting research by our staff of engineers and technicians, whose experience covers practically the entire history of radio, have such efficiencies been achieved.

Every detail is studied to insure GREATER EFFICIENCY and LOWER OPERATING COSTS.

Write for bulletins listing Average Characteristics of AMPEREX TRANSMITTING TUBES.

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