RADIO-CRAFT LIBRARY No. 23

PRACTICAL PUBLIC ADDRESS

NEWEST PROCEDURE IN INSTALLING AND SERVICING MODERN P. A. EQUIPMENT

By B. Baker Bryant

PUBLISHED BY
RADCRAFT PUBLICATIONS, Inc.
99 HUDSON ST.-NEW YORK

PRACTICAL PUBLIC ADDRESS

Modern Methods of Servicing and Installing Public Address Equipment

BY

B. BAKER BRYANT

PUBLISHERS

RADCRAFT PUBLICATIONS, INC.

99 HUDSON STREET NEW YORK, N. Y.

 Printed in U. S. A.

Contents of

PRACTICAL PUBLIC ADDRESS

♦

♦

★

Foreword

★

THE need for a book of this type has been apparent to those actively engaged in the public-address field, or who have had an opportunity to do occasional work of this nature in related fields. The experience of one man is never complete. It is only by the exchanging of ideas and information that science has been able to progress. And, since practically every amplifier installation presents a new wrinkle which must be mastered, it is the obvious intention of this book to present these and other data in as complete a form as possible; so that others in the field, or those who contemplate entering it, may profit thereby.

A considerable amount of this information has been obtained by the author through practical experience in installing, designing and servicing sound and public-address equipment.

Credit is here given to manufacturers of public-address equipment who have cooperated by supplying engineering information which is of utmost importance to the P.A. engineer.

While it is impossible to include in a book of this scope specific information pertaining to theatre reproducing and recording devices, it is hoped that the material on amplifiers and other associated equipment will prove informative and helpful.

PRACTICAL PUBLIC ADDRESS

CHAPTER I

Introduction

THE function of a vacuum tube as an electrical amplifying device is so well understood by the radio man of today that repetition seems unnecessary. But the fact, that a public-address outfit is something more than a microphone which is attached to an amplifier consisting of a number of amplifying tubes feeding into a loud speaker, does not seem to be as well understood. The importance of matching microphone to amplifier, and amplifier to speaker or speakers, must not be underestimated. And of primary importance is the design of the amplifier itself.

Such salient factors must be considered as: the tubes employed; voltage and power amplification; whether the final or power stage has a sufficient output to meet requirements; whether previous stages have sufficient gain to drive the power tubes; method of interstage coupling; overall gain; class of audio amplification employed; fidelity or range of audio-frequency response of amplifier; power supply design; and, finally, the electrical and mechanical design of the amplifier—that is, volume-control regulation, control of tone or frequency output, tapped input and output impedances, shielding, appearance, margin of safety provision for transformer and condenser units, etc., etc.

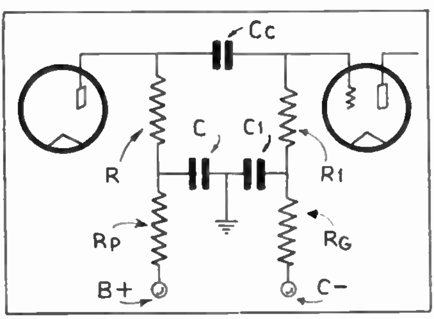


Fig. 1
Resistance coupling of improved type, eliminating possibility of "motor-boating" or regeneration.

AUDIO COUPLING METHODS

The use of a vacuum tube necessitates devices of some form to work into and out of it, in order to obtain the highest possible efficiency. Such a device is generally termed a "coupling" unit, and may be of any of the following types:

(1) Resistance Coupling;
(2) Transformer Coupling;
(3) Impedance Coupling;
(4) Combination of Resistance and Impedance units;
(5) Direct Coupling (Loftin-White method).
(6) Electronic Coupling.
(7) Push-Pull Coupling

RESISTANCE COUPLING

Fig. 1 illustrates a resistance-coupled stage. Condenser "Cc" which couples the output (plate) of the previous tube to the input (grid) of the next, also serves to keep the plate voltage isolated from the grid. A value of from .006- to 25-mf. is generally used, and the unit should be preferably of "mica" dielectric construction.

The values of the resistors "R" and "R1" must be carefully chosen. These resistances should be as large as possible, to obtain maximum transfer of energy from one tube to the following tube. For standard use it has been determined that the happy medium is attained when "R" is between 50,000 and 100,000 ohms for a three-element tube; and up to 500,000 ohms for a screen-grid tube.

The purpose of the grid resistor "R1" is to apply a negative biasing potential to the grid, and this value is generally 250,000 ohms; although it may vary, in some cases, to as high as 500,000 ohms.

"Rp" and "Rg" are generally 500,000-ohm resistors. The condensers "C" and "C1" are of the bypass type and should be approximately 1 mf. This combination is intended to prevent "motor-boating" or audio oscillation common in many amplifiers, and this result is accomplished by keeping the signal current (through "C" and "C1" in the plate circuit), out of the common impedance created by the power supply.

The feature of this type of coupling in audio amplification is that it is theoretically and almost practically possible to get "straight-line" frequency amplification. Resistors "R" and "R1" which are employed in the circuit are generally pure resistances; no varying impedance to the flow of either extremely high or low audio frequencies; nor peaked resonance effects, which prevent obtaining uniform frequency response. The reactance of the coupling condenser "Cc" (when 0.25-mf.) is negligible at 10,000 cycles and is still comparatively low at at 60 cycles; thus permitting uniform transfer of all frequencies from the plate of one tube to the grid of the next.

IMPEDANCE COUPLING

The major drawback to the resistance-coupled type of amplifier is the relatively high voltage required to overcome the coupling resistance "R", so that the applied voltage to the plate of the tube will be proper. Hence, the use of impedance coupling; which is similar in design to resistance coupling, except that impedances are substituted for "R" and "R1". The D.C. resistance of these impedances is considerably lower than that of "R" and "R1". (See Fig. 2.)

However, while the D.C. resistance should be low, the inductance of the coupling impedances must be as high as possible, to obtain best results. Since the reactance (A.C. resistance) of an inductance is equal to 6.3 x f x L, (where f is the frequency in cycles per second and L is the inductance in henries) we can readily see that, the greater the inductance, the higher is its resistance to alternating signal currents. If the inductance value were low, at 60 cycles the reactance of this unit would be low too; which would mean a considerable loss in low frequencies since they would more readily shunt or pass through this unit instead of through the coupling condenser. The voltage ratio, too, of this type of coupling is not as high as in the resistance type; since it can be readily seen that the effect of the varying impedance at different frequencies prevents an even, uniform transfer of energy to the next tube.

We may have a combination of resistance and impedance coupling, in an attempt to obtain the advantages of both methods. The fault of "P" in presenting a varying impedance at different frequencies and preventing an even transfer of energy to the next tube, is somewhat offset by the low D.C. resistance of the unit which does not require that the tube be operated with a "B" potential as high as otherwise would be needed. "R" in the grid circuit does not present any such problems and, consequently, even if it is of high value (250,000 ohms), it maintains the grid at a sufficiently negative potential to obtain satisfactory operation.

Where the plate impedance winding

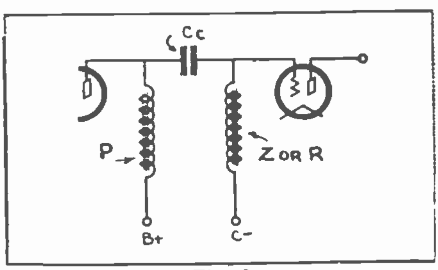


Fig. 2
Method of impedance coupling.

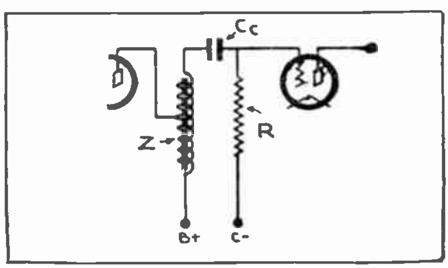


Fig. 2A
Autoformer coupling—a compromise between impedance and transformer coupling.

is tapped as in Fig. 2A, the device is generally termed an "autoformer." The coupling condenser is generally wired within the unit. Also, because of mutual coupling existing between the two windings the device acts as a transformer, and the voltage ratio is dependent upon the turns-ratio. Thus, if the full winding has three times the number of turns in the primary section alone, the voltage in the secondary will be almost three times that in the primary.

TRANSFORMER COUPLING

In a transformer, the primary and secondary windings are inductively coupled only; energy being transferred from primary to secondary by magnetic induction. See Fig. 3. Here we have the

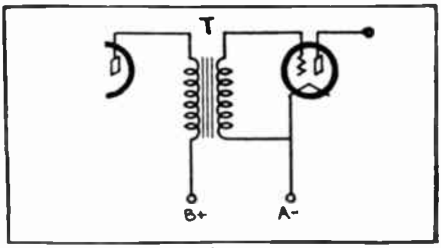


Fig. 8
Transformer coupling between stages.

defects and merits outlined for impedance coupling, in addition to others. Since no coupling condenser is employed, there is a still further loss in energy transfer at different frequencies. For that reason it is difficult to obtain a transformer with an ideal characteristic curve; that is, one whose amplification is absolutely linear from 30 to 15,000 cycles. In addition to all this a certain amount of distortion is introduced, so that the "wave-form" of the voltage generated in the secondary is unlike that in the primary. This is divided into frequency and harmonic distortion. The first is caused by the distributed capacity of the windings, creating resonant circuits. The latter is sometimes caused by saturation of the iron core.

The greatest advantage of the transformer method of coupling lies in the step-up ratio between primary and secondary voltages, which is dependent upon the turns ratio. This results in increased amplification; since, when calculating the over-all gain of an amplifier this step-up ratio multiplies the "mu" (amplification factor) of the tubes.

DIRECT COUPLING

This is more commonly referred to as the Loftin-White method, named after the inventors. No coupling conden-

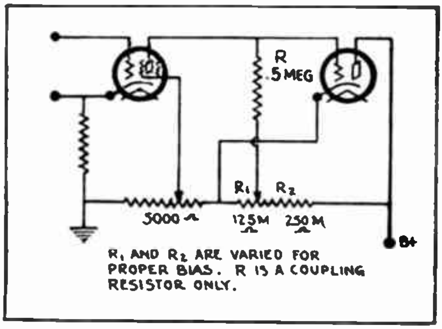


Fig. 4
Improved and practical circuit for "Direct Coupling"

ser is used; the plate of the first tube feeds directly into the grid of the next tube.

In this method the two tubes are in a series arrangement, eliminating the coupling condenser, which is poor for uniform transfer of energy from one stage to the next at all frequencies. While admittedly, the reactance of a coupling condenser varies with the frequency, the direct-coupled circuit introduces other objectionable features which are as detrimental as the use of the coupling condenser method. Fig. 4 illustrates the circuit. "R" is only a coupling resistor, bias being obtained by varying "R1" and "R2".

ELECTRONIC COUPLING

The Electronic Coupled system is another example of direct coupling. The cathode of the first tube is connected directly to the control grid of the second tube. While separate tubes may be coupled in this manner, special tubes (the 6B5 and 6N6G) prove more satisfactory.

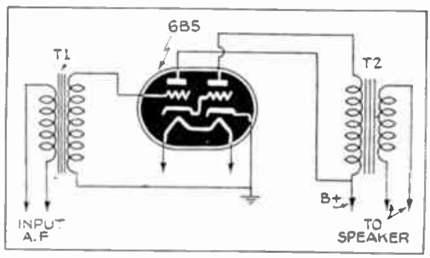


Fig. 5
Electronic coupling using a 6B5 tube. Coupling takes place internally.

Fig. 5 illustrates the method of electronic coupling. The first tube or section is the driver, the cathode of which is directly connected to the control grid of the output tube or section.

The connection is made internally, as is the output control grid resistance, the return of which is connected to the output cathode. The output cathode is externally connected to the minus of the power supply, no bias resistor being required. The Input control grid does not draw grid current since grid bias is automatically developed within the tube. Input coupling may be any of the above mentioned systems. The electronic coupled system is especially adapted to push-pull arrangements, delivering large output power with low distortion.

PUSH-PULL COUPLING

Fig. 6 illustrates push-pull transformer coupling from a single tube into two tubes in such manner that their control grids are electrically 180 degrees out of phase. Note that, when an A. C. signal flows, the impulse impressed on one tube grid is positive, while that on the grid of the other tube is negative.

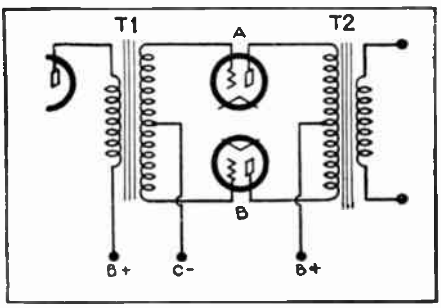


Fig. 6
Schematic diagram of "class A" push-pull stage.

Since the current that flows through the transformer winding is of an alternating nature, the current reverses itself on the next half-cycle; and the previous positive lead (A) becomes negative, whereas the lead to the other grid (B) now becomes positive. As a result, when the plate current of one tube is at maximum, the plate current of the other tube is at minimum: then vice-versa, as the current in the input winding alternates. Hence the term "push-pull." Operating tubes in this manner reduces the distortion, by the cancellation of "even" harmonics in the output of each stage, produces greater power output, and allows use of a greater power input to the amplifier.

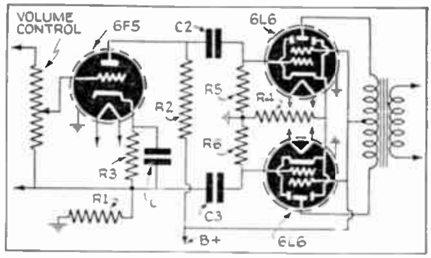


Fig. 7
Illustrating the cathode method of phase inversion for Push-Pull operation.

PHASE-INVERTER

Phase inversion, such as the method illustrated in Fig. 7, may be used to advantage to obtain resistance push-pull coupling from a single tube into the grids of two power tubes.

When the control-grid of the input tube swings in the positive direction, plate current through the tube increases and the voltage drop across R1 and R2 increases. The plate swings negative while the cathode swings positive, thus voltages, 180 degrees out of phase, are supplied to the power tube grids. These voltages will be equal as the resistors R1 and R2 are equal (.1 Megohm). R3 and R4 are normal bias resistors. R5 .5 Megohm for most power tubes. C1 should be 4-10 mf., while C2 and C3 are .01 MF. It should be noted that any capacity across R2 should not be greater than any capacity across R1 to obtain balanced inversion.

NEW TERMS AND THEORY

The public-address engineer of today must be familiar with present nomenclature, unheard of a few years ago in amplifier work. Not only the expressions but the theory, requirements, and mechanical construction of devices that he may have to install or service must be familiar to him. The many instruments to be described can be used in various combinations and, for that reason, some details must be given in regards to requirements, efficiency, best practice, and when to use them.

CLASS "A"

All amplifiers in previous years were built along "Class A" amplification

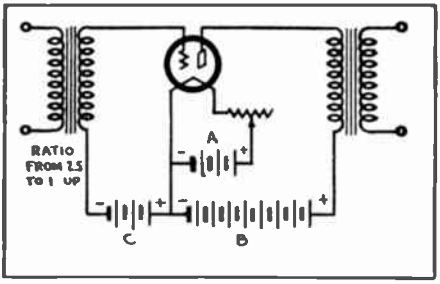


Fig. 8
A "Class A" stage. Note the use of a "C" battery, the value of which depends on the tube employed. The input transformer has a step-up ratio.

lines. That is, the amplifier tube was operated with a suitable grid bias, so that the applied signal to the grid produced plate-current variations proportional to the signal variations. A typical amplifier operating in "Class A" is shown in Fig. 8. Note the use of "C" bias (battery) which is sufficiently high to overcome all positive swings in the signals applied to the grid; thereby preventing grid current and grid distortion. It is still the best method of obtaining distortionless amplification.

CLASS "AB"

Those push-pull arrangements wherein the negative bias applied to the control grids is higher than that used in a Class "A" stage are known as Class "AB" amplifiers. They are subdivided into Class "AB_1 and AB_2." In the former there is no flow of grid current as the peak signal voltage never exceeds the negative grid bias. In the latter there is a flow of grid current when the peak signal voltage exceeds the negative grid bias. Because of the flow of grid current in the Class "AB_2" system there is a loss of power in the grid circuit. The total of this loss plus the loss in the input transformer determines the driving power required by the grid circuit. The driver or preceding stage should deliver more than this power in order that distortion introduced into the grid circuit will be at a minimum. The coupling transformer is usually of the step-down type. The power supply must have good regulation, otherwise the power output will be decreased and distortion will be increased.

CLASS "B"

"Class B" amplifiers are used where larger power output is required; there is required very little or no grid bias—where the tube is specifically designed for class "B" operation only. Thus, when a signal of sufficient magnitude is applied to the grid, no plate current will flow over the greater portion of the negative half-cycle; but, as the signal becomes of a low negative order, plate current begins to flow until it rises to maximum with the maximum positive signal. Since the grids become positive in "Class B" operation, grid current flows in the input circuit, and a considerable amount of second and higher "even" harmonics are thus introduced into the power output of each stage. For that reason, push-pull amplification is recommended for "Class B" operation so that all "even" harmonics may balance out and thereby reduce the distortion.

Tubes that are not specifically designed for "Class B" operation may be used for such purposes by biasing them almost to the "cut-off" point.

The tube preceding a "Class B" stage must be able to supply sufficient power with good regulation, because of the grid current drawn by the grids of "Class B" tubes when positive. It can be considered that from 5 to 7 per cent. (approximately) of the rated output of a "Class B" tube should be used for the input, to obtain that output at which the tube is rated. For example, two 46 tubes in "Class B" push-pull, rated at 16 watts output, require approximately 800 milliwatts input. R.C.A. specifications designate 650 milliwatts as the required input, which indicates how how closely the above method works out.

The transformer employed for coupling into the "Class B" stage is of the step-down type. The reason for this can be readily seen, when it is understood that the resistance of the secondary of a "Class B" transformer must be as low as possible; so that the voltage drop is low when grid current is drawn. The value of the secondary winding impedance of this transformer is relatively unimportant, because of its constantly changing impedance, varying with the voltage polarity when a signal flows through its windings. Of course, the input impedance should be of the lowest order possible, if a high voltage ratio is to be maintained. Output impedance is governed by such factors as lowest harmonic distortion and maximum power output.

According to R. C. A. specifications, the ratio of the primary of the interstage transformer to one-half of its secondary may vary between 1.5 to 1. and 5.5 to 1. This ratio is dependent upon the following factors:

(1) Type of "driver" tube;
(2) Type of power tube;
(3) Load on power tubes;
(4) Permissible distortion;
(5) Transformer efficiency (peak power).

The "driver" tube in the stage ahead of the "Class B" should be worked into a load resistance higher than normal value for optimum power output in a "Class A" amplifier; since the distortion produced by the driver stage, in addition to the power stage, will be present in the output.

The power supply for a "Class B" amplifier must have good regulation, to maintain constant proper operating voltages regardless of current drain. Filter chokes and transformer windings should have low resistance, so that high currents are available to meet the heavy demands in plate current of a "Class B" tube.

CLASS "C"

This type of amplifier operates in a manner such that output varies as the square of the plate voltage within limits. Distortion is high at audio frequencies. This type is employed usually in radio-frequency power amplifiers of broadcast transmitters where distortion may be sacrificed for greater plate efficiency and output with lower ratio of power amplification. This system is not suitable for P. A. work.

VOLTAGE AMPLIFIERS

Tubes functioning essentially as voltage-amplifying devices generally have a high amplification factor and a low plate-current characteristic. They are used for amplifying feeble impulses, such as those from a photo-cell, condenser microphone, or velocity microphone. Sometimes referred to as "pre-amplifiers," they are not generally designed for loud-speaker operation, but are used with power amplifiers which employ larger tubes to supply relatively large amounts of power to the loud speaker or speakers. It can be said that the driver tubes in an amplifier comprise the voltage-amplifier portion; whereas the final power stage using large power tubes, in "Class A" or "B", is the power amplifier stage.

BEAM-POWER TUBES

A recent development, the beam-power tubes (Types 6L6, 6V6, and 25L6), is responsible for considerable improvement and increased efficiency in audio amplifiers. The higher power sensitivity, output, and efficiency is a result of a different method of suppressing secondary emission. Secondary emission has limited these effects here-

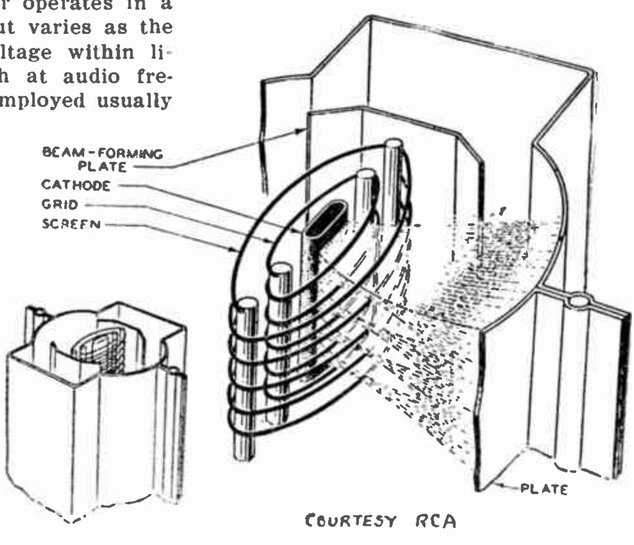


Fig. 9
INTERNAL STRUCTURE OF BEAM POWER TUBE.

tofore in the triode and pentode power amplifier tubes.

The elements of the tube are so spaced that secondary emission from the plate is suppressed without the use of a suppressor grid element. When the plate voltages are low during a part of the input voltage cycle, electrons speeding to the plate slow down to almost zero velocity in a region between the screen and plate. Here a space-charge or cloud of electrons form, that repel the secondary electrons emitted from the plate, forcing them to return to the plate.

The tube also has low screen-grid current drain as the screen and grid spiral wires are wound in a manner that each grid spiral shades each screen spiral from the cathode, this causes the electrons to travel in sheets between the turns of the screen so that very few of them flow to the screen. See Fig. 9.

The second harmonic distortion is high in order to reduce the third and higher harmonics to a minimum. In push-pull stages the second harmonic is reduced to a minimum. In a single stage, inverse feedback may be used to reduce the second harmonic. Where this is not possible a corrective filter, consisting of a resistor and condenser in series may be connected across the primary of the output transformer. The resistance should be 1.3 times the recommended plate load of the single tube, and the condenser usually has a value of .05 mfd.

INVERSE FEEDBACK or AUDIO DEGENERATION

Inverse feedback or degeneration is used in audio amplifiers to reduce distortion to a minimum in the output stage where the load impedance on the tube is a loudspeaker. The impedance of loudspeakers is not constant for all audio frequencies, therefore the load impedance on the tube will vary with the frequency. When the tube is a pentode or beam-power tube having very high plate resistance, considerable distortion may result from the variation of the plate load impedance. This may be corrected by feeding back an out of phase voltage from the plate to the grid of the tube. This voltage is equal to the output voltage times the fraction of the resistances R3 over R2 plus R3. The condenser C isolates the D.C. from the grid of the tube. Fig. 10 illustrates the method which may be applied to push-pull stages. In such case the secondary of the input transformer must have a split secondary. Other methods of feedback may be employed but are not explained here for lack of space.

Inverse feedback or audio degeneration may be applied to any Class A or AB_1 amplifier.

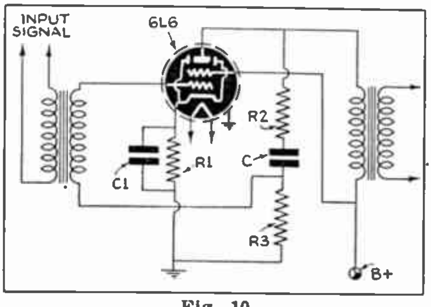


Fig. 10
Application of de-generation or inverse feed-back to a beam power amplifier stage.

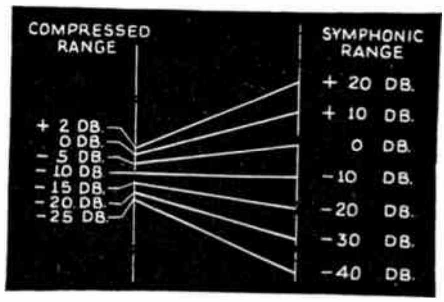


Fig. 11
The compression of the volume range in broadcast transmission.

VOLUME EXPANDER

In the reproduction and recording of symphony orchestration, the music varies from very loud passages to very soft passages. It is impossible, because of recording difficulties, to reproduce the music on a recording exactly as played. The recording process is monitored by the recording engineer so that the loud passages are reduced in volume and the soft passages increased in volume. This compression of the music is illustrated graphically in Fig. 11. Because of the compression it is readily appreciated that the reproduction of the music will not be natural.

In order that the naturalness of the reproduction be accomplished, a volume-expander amplifier is used. This amplifier is arranged to have a variable gain which is less for a low intensity signal than for high amplitude signals. Therefore the loud passages are amplified more than the soft passages thereby restoring the reproduction of the music to a volume range more nearly like the original, the fidelity becomes more natural.

Two systems for volume expansion are generally used; the injector grid bias control, and the bridge type. The injector grid system, Fig. 12, operates on the principle that the gain of a 6L7 as an amplifier can be varied by the variation of the bias voltage applied to Grid No. 3. When the bias is less negative the gain rises. The signal applied to No. 1 or control grid is also amplified by the 6C5 and rectified by the 6H6. The rectified voltage developed across the load resistor in the cathode circuit of the 6H6, is applied as a positive voltage through the resistor R4 to the No. 3 grid of the 6L7. As the amplitude of the input signal increases, the voltage across the 6H6 load resistor increases, and the bias applied to the No. 3 grid of the 6L7 becomes less negative. This increases the gain of the 6L7, the gain of the amplifier increases with the increase in signal amplitude therefore expanding the volume of the signal.

Fig. 29 (Chapter III) shows the bridge type volume expander (heavy lines) incorporated in a 30 watt beam-

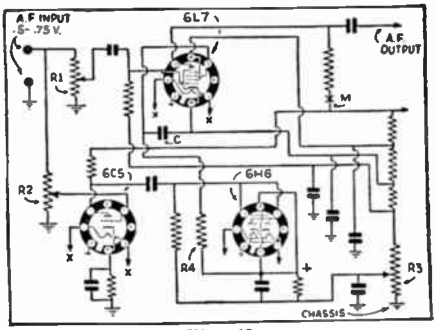


Fig. 12
A practical expander using metal tubes.

power amplifier, as developed by L. A. de Rosa. When the voltage across "A" and "C" is increased, the current in both sides of the bridge is increased, more heat is evolved in the lamp filament causing a rise in temperature. Because of the high temperature co-efficient of the filament wire, an unbalance occurs causing a current to flow between the "B" and "D" terminals of the bridge. The amount of expansion is determined by the settings of "R2a" and "R2b". If these are balanced for a just audible signal, any slight increase in signal amplitude will result in a huge change in contrast. If the resistance of "R2a" and "R2b" is made less than the resistance of the lamp filaments at low volumes the expansion will be less. If the resistance is made greater an increase in signal amplitude will result in a decreased output and compression will result. Component values for the expander and amplifier are given in detail in Chapter III, Fig. 29.

CHAPTER II

Microphones—Characteristics and Principles of Operation

In public-address work, it is necessary to understand the construction and operating principles of the microphone. Without this information the technician would be lost when required to make a satisfactory average installation—or in servicing too, since a good many troubles in P.A. work originate at the mike end.

There are five types of microphones in general use in present P.A. work—the carbon microphone (single and double button), the condenser microphone, the crystal microphone (the diaphragm and the sound cell type), the dynamic or moving coil type, and the velocity or ribbon microphone.

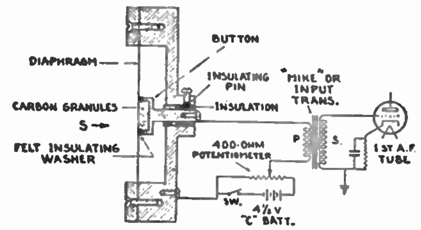


Fig. 13
Mechanical arrangement of the single button carbon microphone.

THE CARBON MICROPHONE

Carbon microphones have a diaphragm against which is placed a brass cup of carbon granules. The constructional details of this are illustrated in Fig. 13 for the single button type, and Fig. 14 for the two button type.

The diaphragm in the better grade instruments is made of very thin duraluminum while in the cheaper grade instruments it is made of thin rolled steel. The duraluminum diaphragm is stretched and air damped to minimize self-resonance effects in order to obtain a more even response at ordinary audio frequencies. The rim of the brass cup is insulated from the diaphragm with a ring of soft felt which also serves to confine the granules in the pocket between the diaphragm and the cup.

As the sound waves impinge against the diaphragm, it vibrates in accordance with the sound vibrations, varying the battery current by compressing and decompressing the granules. The modulated current is made to complete its circuit through the primary of a transformer, the secondary of which is con-

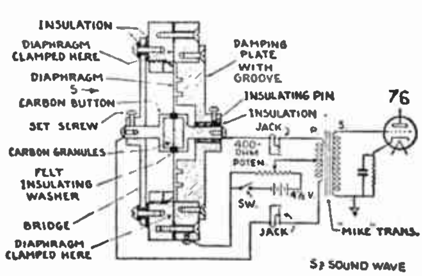


Fig. 14
Illustrating the construction of the two button or push--pull carbon microphone.

nected to the input tube of the amplifier. The primary impedance of the transformer must be adjusted to that of the microphone which may vary from a few ohms to 400 ohms. The microphones used for P.A. work have 200 ohm impedance for a single button and 400 ohms for the double button type.

The common faults of the carbon microphone are the background noise, referred to as "Carbon Hiss" (caused by the current flowing through the carbon granules), its high maintenance factor, and the care with which it must be handled. It has the advantage of high power output levels of -65 to -30 DB. The low impedance characteristic en-

Fig. 14A
(Courtesy Universal Microphone Co.)
Two-button microphone. Three connections are necessary to this unit, one to each button, the third to frame (or casing).

ables the operator to use the instrument at considerable distances from the amplifier.

PROPER HANDLING

All microphones should be mounted and used in an upright position; and it is highly important that they be protected from jars and mechanical vibration. All units should be flexibly suspended, that is, on springs or rubber bands. Rubber bands are preferred by some users, but lack in reliability and long life. We recommend springs of the correct tension for all-around use.

Use batteries, by all means, for successful results (dry cells will last a very long time in microphone use, because of the very low current consumption), unless provision for self-powered microphone current within the amplifiers is made.

Never use over 3 volts across the microphone; or a current of over 10 milliamperes per button. The less current used, the better for the delicate contact surfaces of the microphone.

Too much importance is generally attached to variation in reading between buttons in a 2-button microphone. Within reasonable limits, variation in reading does not noticeably affect volume or quality. The difference in current flow is caused primarily by the fact that one button is sealed behind the diaphragm, while the other is open to the atmosphere where it is subject to changes of temperature and may be affected by moisture. During the first several minutes of its operation the button current may show an unbalanced condition; but, as use is continued, they gradually become equalized.

Moisture is a natural enemy of microphones, and they should be kept and used in a dry place. If buttons become packed, from moisture or long standing in one position, hold unit in one hand (with diaphragm in horizontal position) first face up and then face down, striking one hand gently with the other. Revolving the unit is also helpful. The above should not be done with current on, as damage to the unit might result. Under unduly moist conditions, units can be set in warm sunshine or under an electric-light globe to drive out moisture.

Considerable confusion exists as to the resistance of microphones and microphone buttons. In some cases the D.C. resistance is practically the same as the A.C. impedance, and in others it is entirely different. Referring to the diagram of Fig. 13 we have a microphone button in series with a 4½-volt battery, shunted by a potentiometer for voltage adjustment as needed. Considering the D.C. resistance of the microphone as 200 ohms, we will have a current of 7½ milliamperes flowing in this circuit if voltage is 1½ volts. This value of 200 ohms D.C. resistance is also its approximate A.C. resistance or impedance. The alternating-current impedance of a carbon microphone is not always its apparent talking resistance, but rather the ratio of the power absorbed by it to the square of the current flowing through it. The general assumption is that the A.C. resistance of a carbon microphone is about 80% of its apparent talking resistance.

In the case of a two-button microphone, an entirely different condition takes place. Referring to Fig. 14 it will be noted that we have one source of current, three dry cells, and the two buttons of the microphone are in parallel; thus the microphone presents a parallel circuit. Each leg being 200 ohms, the total overall resistance is 100 ohms and thus, with 1½ volts of battery in the circuit, a total current of 15 m.a. will flow. Its actual D.C. resistance, as far as the battery supply is concerned will be 100 ohms. Its A.C. impedance, however, as connected to the primary of the microphone transformer, is entirely different; since the two buttons, with relation to the transformer, are connected in series, thus presenting some 350 to 400 ohms A. C. impedance. In regard to the transformer, the microphone is now considered an acoustically driven A.C. generator, with an impedance of approximately 400 ohms; and thus the transformer, to efficiently match this value, must have a primary winding of approximately 400 ohms effective impedance, and must be provided with a center tap to take care of the microphone's D.C. exciting current.

Carbon hiss can be reduced considerably by connecting an 0.1- to 0.25-mf. midget paper condenser to buttons of a 2-button carbon microphone, or from button to body of a single-button mike. This condenser may, for convenience be connected at the transformer; in which case the two condenser leads are connected to the outside lugs of the primary side of transformer.

For satisfactory results, a microphone transformer must be used with any microphone. It should have a primary impedance to match the microphone buttons; and a secondary impedance ot 100,000 ohms or more, to feed grid circuit of any standard amplifier tube. The center tap allows a 50,000-ohm output for use direct into push-pull.

SENSITIVITY OF CARBON MICROPHONES

There is a definite relation between three factors in all carbon microphone installations: Sensitivity, Feedback, and Damping; and this is the reason why two-button microphones are usually built in three degrees of sensitivity—(A), Medium; (B), Extra Sensitive; (C), Damped. "A" is considered standard. The "B" model is for use where extreme sensitivity is required and where there is no danger of coupling or feedback; while "C" is for use where outside noises or background sounds must be kept out and where feedback or coupling between horns and microphone is liable to take place. This model is of the sensitivity of what is known as a "close talker."

The more the microphone is damped, the better the frequency response over the entire range, and the less the peaks and dips found in its response chart. Damping also eliminates resonance and tends to clearer enunciation. For quality, therefore, a microphone must be damped to some degree. Quality of reproduction will be improved by the use of a damped microphone and slightly greater power in the amplifier. In other words, the amplifier should be so constructed or used as to perform the entire purpose of amplification and, if it is so constructed with a reserve which can be used where needed, in connection with a damped microphone, even of the simpler and cheaper models, it will give much better quality of output than an installation wherein the amplifier is used at its utmost power and the sensitivity of the microphone is depended upon for volume.

CONDENSER MICROPHONES

Where more faithful reproduction is desired, and cost is no item for consideration, this instrument is found to have a better response-characteristic as compared to the carbon microphone.

This type of instrument consists of a stretched diaphragm which serves as the front plate of the condenser. It is separated from the back plate by 1/1000-in. air space, which also serves as a damping medium to the diaphragm. The head or preamplifier (schematic given in Fig. 15) places an electrical charge on the plates, and as the plates are in series with the grid circuit of the first tube, a small change in the position

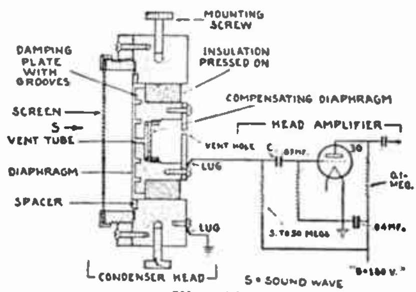


Fig. 16
The internal arrangement of the electrostatic or condenser microphone.

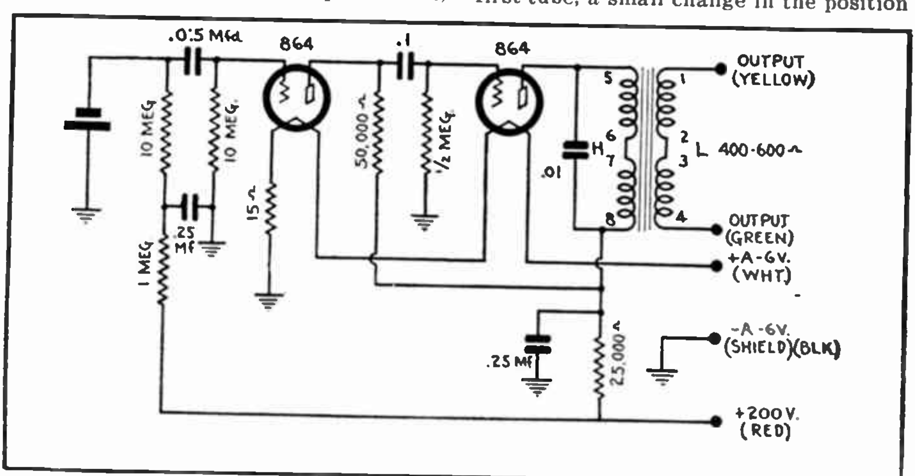


Fig. 15
Two-stage, condenser-microphone, pre-amplifier circuit.

of one of the plates will thereby vary the capacity and in turn will vary the electrical charge on the grid of the tube. The constructional details may be studied in Fig. 16.

The output of the condenser microphone with the self-contained head amplifier varies from -56 to -36 DB. This level is comparable with the carbon microphone but the instrument has the advantage of ruggedness and of course the absence of "Carbon hiss" or background noise.

CRYSTAL MICROPHONES

The principle of operation of the crystal microphone depends upon the piezo-electric effect. This effect is the voltage generated when certain crystals (in this case Rochelle Salts) are subjected to mechanical stresses such as bending or warping.

There are two distinct types of crystal microphones; the sound cell type, and the diaphragm type. The crystal sound cell construction is shown in Fig. 17. Each sound-cell unit consists of

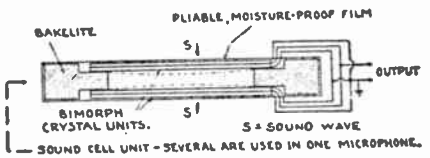


Fig. 17
The crystal microphone bi-morph element of the sound cell type.

two "bimorph" Rochelle Salt crystals, mounted in a bakelite frame. The "bimorph" elements each consist of two crystal plates, with electrodes attached, and cemented together. The sound vibrations striking the element of the two crystal unit causes a bending of the assembly and thus produces an A.F. voltage. The microphone and the mounting of the crystal elements is such that mechanical shocks have little effect on the unit as to generating a voltage.

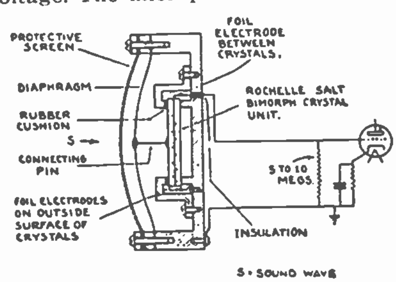


Fig. 18
The construction internally of the diaphragm type crystal microphone.

Because of the nature of the crystal plate assembly no diaphragm is required, the vibrations acting directly upon them. The response curve is over a very wide band of frequencies, from the super-audible to zero frequency. The output of the sound cell type is very low, requiring more amplification, but has the advantage of a full audible frequency pickup.

The diaphragm type of crystal microphone consists of two crystal plates cemented together with a foil electrode between them. The front plate is linked electrically and mechanically to the duraluminum dome shaped diaphragm. See Fig. 18, for the assembly details.

The diaphragm type crystal microphone delivers greater output, thus a preamplifier is not required. Because of

Fig. 19
(Courtesy Brush Development Co.)
A sound cell crystal microphone which has an output of approximately—60 db.

the mechanical inertia of the diaphragm and connecting link, the frequency response is limited, being more adaptable to the voice frequencies.

Fig. 19 illustrates a sound-cell instrument which has an output of -60DB. Fig. 20 illustrates the diaphragm type instrument which is approximately three and one quarter inches in diameter.

DYNAMIC (MOVING COIL) MICROPHONES

The operation of the dynamic microphone depends upon the same principle as the dynamic speaker, that is, a conductor under motion in a magnetic field will have an electromotive force induced into it.

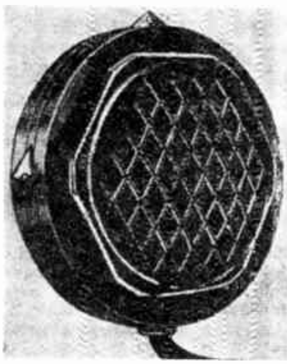


Fig. 20
(Courtesy American Microphone Co.)
A diaphragm type of crystal microphone which is 3¼ inches in diameter.

The diaphragm material is of very thin duraluminum, which in the better grade instrument is dome shaped for rigidity in order to obtain a piston action over the audio frequency range. The response characteristic is further improved by an air passage for the escapement of the backwave.

Very thin aluminum ribbon is used for the moving coil. The coil is cemented to the diaphragm, and is arranged to reciprocate in the circular airgap between the permanent magnet pole-pieces. The pole pieces are made of cobalt alloy steel which has been developed to retain the magnetism over long periods of time. The construction of the microphone is shown in Fig. 21, while Fig. 22 illustrates the complete instrument with the built-in transformer.

Fig. 22
(Courtesy American Microphone Co.)
The new "clipper" dynamic microphone may be waterproofed at the factory for permanent outdoor installations. The head here illustrated has built-in transformer to match into 200, 500 or 10,000 ohms.

The output ranges from -80 to -48 DB and is comparable with the condenser microphone, but may be used at some distance from the preamplifier because of its low impedance. The transformer may be adjusted to work into impedances of 200, 500, and 10,000 ohms. The frequency response is practically flat from 35 to 1000 cycles. It is very rugged, will stand considerable abuse, and has no inherent background noise.

VELOCITY OR RIBBON MICROPHONE

The velocity microphone is so constructed that the voltage induced in the ribbon is in proportion to the instanta-

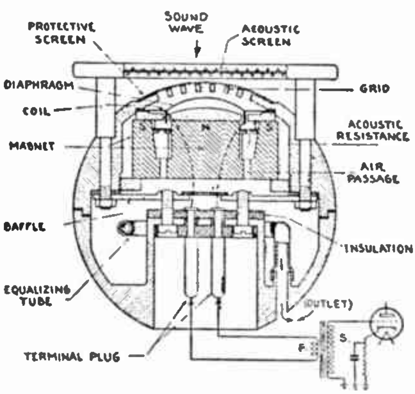
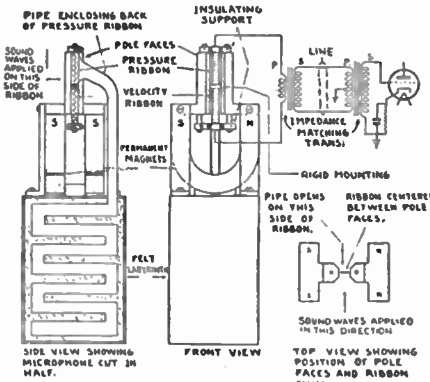
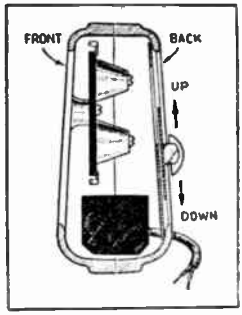


Fig. 21
Showing the intricate internal construction of the dynamic microphone.



Illustrating the internal mechanical arrangement of the velocity or ribbon microphone.

neous velocity of the air in the sound wave. The instrument is also referred to as a ribbon microphone, as a ribbon is used as the armature. The ribbon itself is made of very thin alloy of aluminum which is pleated or corrugated. It is suspended in the magnetic field of permanent magnets. The sound waves impinging on the ribbon cause it to vibrate, cutting the magnetic lines of force which in turn induce an A.F. voltage in the ribbon. The ribbon is connected in series with the primary of an impedance matching transformer, the transformer coupling to the preamplifier. As the mass of the ribbon is quite small, low mechanical inertia therefore permits an excellent frequency response. Fig. 23 illustrates the mechanical arrangement, and Fig. 24 shows the cased instrument.



The output is comparable with the condenser type microphone and therefore requires a two stage preamplifier. This builds up the level to approximately -30 DB.

As the instrument is a low impedance device, it is provided with a built-in coupling transformer. This transformer may be matched to a transmission line, allowing the amplifier to be at some distance, although shielding of the cable must be provided to guard against stray electrical fields.

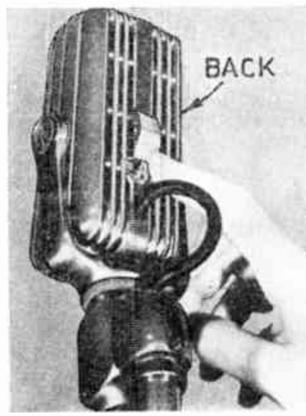


Fig. 24
(Courtesy Amperite Co.)
This ribbon or velocity microphone also incorporated an acoustic compensator.

The instrument is of rugged construction, and is somewhat directional, with the greatest response at right-angles to the plane of the ribbon. To further assist in improving the directional qualities, an acoustical labyrinth is employed to absorb one-half of the back-wave. The instrument is free from background noises.

MICROPHONE AND AMPLIFIER LEVELS

"There seems to be some uncertainty in the minds of radio men as to the output level which may be expected from a microphone and, as a natural result, there is likewise uncertainty as to the amplification that will be required to produce some certain final amplifier output for public-address work or to modulate a radiotelephone.

"Somewhat naturally, the radioman feels that the microphone manufacturer should state, once for all, what output level is to be expected from each type of "mike". As has been shown, this is not practical and any such figure would be the worst of misinformation. However, it is possible to lay down guiding rules and this will be done here in a brief way, with the hope that it will be of aid to the user ot microphones.

"Fig. 25 is a chart on the logarithmic scale. After a slight analysis, you can readily see that it has all mathematics of amplifiers, microphones, photo-electric cells, etc., worked out on a fairly usable scale and gives you an exact mental picture of the whole amplifier and acoustic set-up. On the right-hand scale you will find the power level in D.B. or decibels (referred to .006 watts as zero); while the diagonal lines represent the actual power in watts, milliwatts and microwatts. To further enlarge upon its usefulness we have placed the most popular output tubes at their various wattage handling capacities on the upper scale; while you will

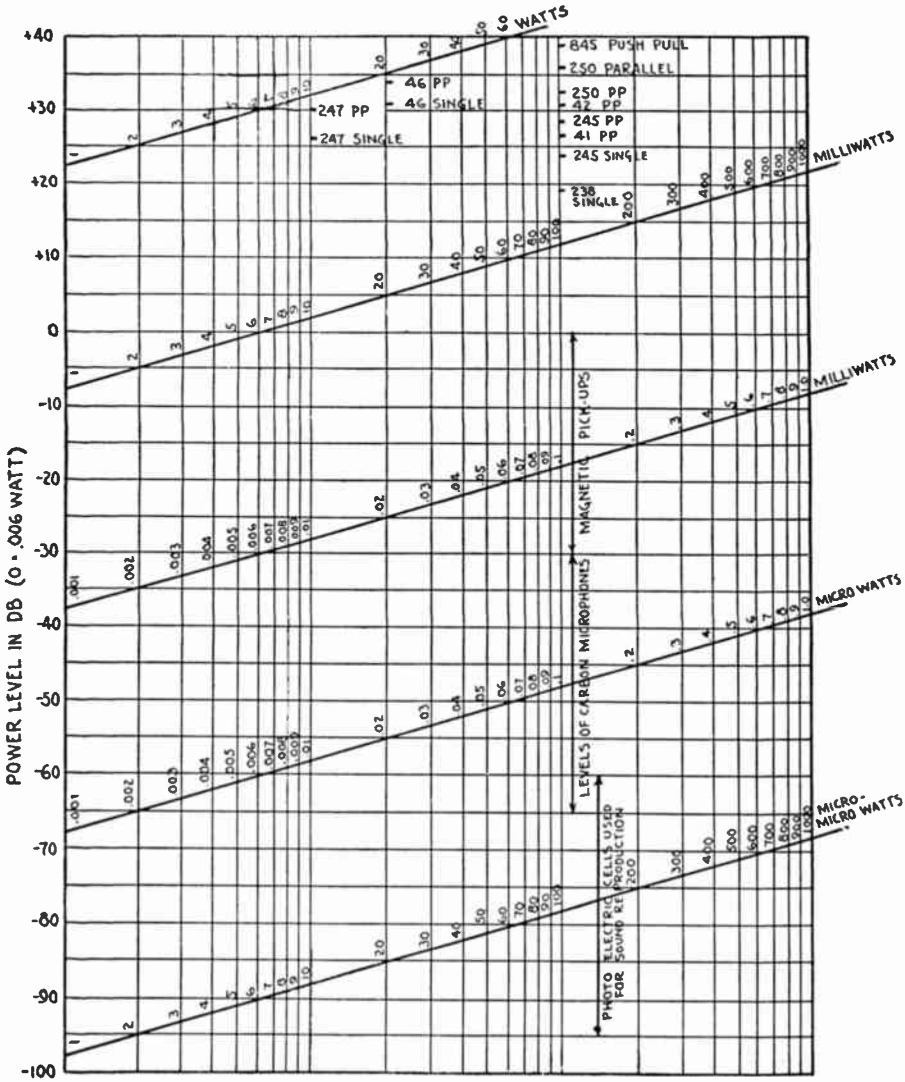


Fig. 25—THE DECIBEL CHART

Suppose we have a microphone known to deliver about "minus 50 D.B." when drawing 10 ma. per button and being spoken into from a distance of one foot. We need an amplifier output of 500 peak volts across a 10,000 ohm load. What must the amplifier be like?

500 volts peak=350 volts r.m.s. and, if connected across 10,000 ohms produces an output of E_2/R=(350) (350)/10,000=12.25 watts. This output level at once suggests a push-pull pair of 2A3 tubes coupled to the load through an output transformer, which will convert the 10,000-ohm load (plate to plate) as required by the 2A3 tubes (The turn ratio is 1.4/1 comparing secondary to whole primary.)

Meanwhile we see from the chart that 12.25 watts is about 33 D.B. "up" which is 83 D.B. above the microphone level. The amplifier gain overall should be about 90 D.B.; a rather high gain preferably broken into two sections—a "pre-amplifier" and a main amplifier separated from each other. This will be better appreciated if one considers that 90 D.B. gain in power is a multiplication factor of 1,000,000,000; so that a very small percentage of feedback causes distortion. If the input and output load impedances of the amplifier were equal, the voltage amplification would be 31,600. The final line-up is accordingly a three-stage main amplifier, and a one- or two stage pre-amplifier; the choice in the latter unit depending on the tubes used in the main amplifier.

(Continued bottom of next page)

also find the average range for magnetic pickup, the maximum and minimum power outputs of various carbon microphones and, below that, the various power outputs of various photo-electric cells as used in sound production work.

MICROPHONE LEVELS

"Now, with this chart to base on, let us get at the subject in which we are primarily interested. First of all, it is necessary to point out the fact that microphones run in considerable variation of grades, types and purpose. In general, the more sensitive a microphone, the less tone quality it has; while, the greater the fidelity of tone quality, the less its sensitivity. Likewise, the tone quality is generally directly proportional to price.

THE EFFECT OF DISTANCE

"There are two highly variable factors affecting the output of a microphone in general use. First, the volume of sound reaching the microphone (or the actuating pressure); and second, the amount of (D.C.) exciting current with which a carbon microphone is supplied. First let us consider the actuating sound pressure which would be a duplicate of a person speaking in a perfectly normal voice with his lips at a distance of 6 inches from the microphone. If this microphone happened to be a Universal 'Model LL' in the 'M' or Medium sensitivity grade, we would get an output of approximately -48 D.B., provided the button current on the microphone averaged 8 milliamperes per button. Should the speaker move one foot away from the microphone the volume of output would drop to -54 D.B., while, if he should move away to a distance of two feet, the output would drop to approximately -61 D.B., all other conditions remaining the same. Should he move up to the microphone and speak directly into it, the output level would be approximately -30 D.B.—a whale of a difference from the two foot distance—in fact, CONSIDERABLY MORE THAN ONE STAGE OF HIGH-QUALITY AMPLIFICATION.

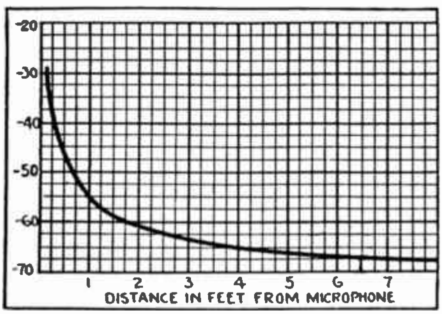


Fig. 26
(Courtesy Universal Microphone Co.)
Comparative output levels of a carbon mike at variable distance.

"The comparative output levels of microphones at variable distances are graphically illustrated in Fig. 26, which is generally quite surprising to those who have not given it consideration before. This chart really has nothing to do with a microphone at all. It simply illustrates the falling off of energy with increase in distance from the source, and is applicable to any sound-radiating body in free space."

ACOUSTIC COUPLING OR FEEDBACK

Very often there is feedback or coupling between the microphone and the speaker in public-address systems or wherever it is necessary to use a microphone in close proximity to the speaker; especially when both are used in the same room. Exponential horns cause less feedback than other types, as they are more directional, and can be pointed away from the microphone. Rooms with bare walls, or those having large expanses of glass windows, reflect the sound vibrations back to the microphone and cause considerable difficulty. Feedback is to be expected under certain conditions; and its remedy requires considerable experimenting in the placing of phone.

There is no hard and fast rule for the elimination of feedback. In general, keep the horns as far away from the microphone as possible; and, if they are directional, keep them pointed away from the microphone.

(Fig. 25—THE DECIBEL CHART—continued.)

Again, a similar problem but with a high-sensitivity microphone, spoken into at 3 inches, with 20 ma. per button and an output level of —22 D.B. The gain required is now from —22 to plus 33, or 55 D.B. This can be done nicely by the 3-stage main amplifier alone; as it is (from the chart) a power ratio of 12.25 watts/.04 milliwatts=300,000 or, for equal impedances, a voltage gain of 546.

CHAPTER III

Public Address Amplifiers

IN describing amplifiers in this chapter, constructional data will be purposely omitted. It is next to impossible to give such detail completely and yet describe the many types and varied sizes of amplifiers that are required in public-address work. Of course, important features will be pointed out, in addition to furnishing schematic wiring diagrams with all values of parts given of standard sizes.

In the larger amplifiers, the driver stages have been segregated from the power stage—for good mechanical as well electrical reasons. Most amplifiers above 20 watts are built in panel-rack form and, because of limited space in mechanical construction. the driver stages are generally placed on one shelf controlled from a front panel. Then again, the power supply needs of the driver stages in a large amplifier are different from the power stage. This, in very large amplifiers, may mean separate power-supply units (rectifiers and filters) for each—a tremendous amount of equipment and weight to attempt imposing on one chassis.

And, since the output of the driver stages in itself is often suitable for smaller requirements the efficiency and simplicity of this type of construction and description can be readily acknowledged. (See data on installation, instruction—Chapter IV—giving electrical reasons for separate construction.)

All amplifiers described are rated in accordance with R.C.A. or Cunningham tube data. "Class A" and "Class B" amplifiers are both described, and may be used for standard installations of various requirements.

It should be understood here that the ratings by the tube manufacturers are generally very conservative. Tests and measurements have proved that most power tubes are productive of a power output approximately 20% in excess of their specifications, when using plate voltages slightly higher than those recommended by the tube manufacturers. Where commercial amplifiers are rated higher than this 20% tolerance, it can be safely assumed that they are either over-rated or else employ excessively high plate voltages—a practice which not only materially shortens the life of the tubes but increases considerably the amount of distortion in the output.

TWO AND FOUR WATT BEAM POWER AMPLIFIER

In Fig. 27 is given the circuit of a midget amplifier which uses only three

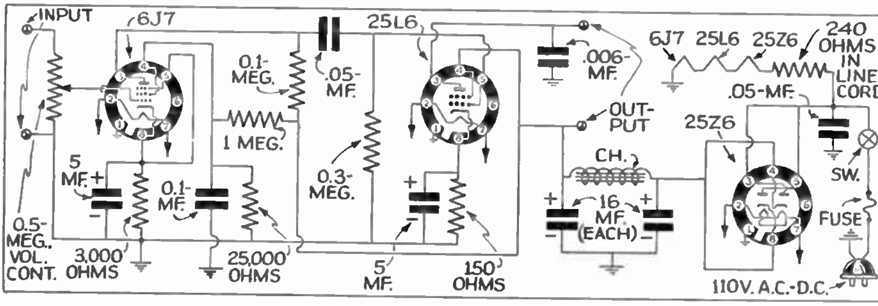


Fig. 27. Schematic diagram of the tiny P.A. amplifier.

Fig. 27A
The P.A. amplifier easily fits in the palm the hand!

tubes but is capable of delivering two watts of power to the speaker thru the use of the 25L6 line operated beam power tube. For four watts, two of these tubes may be operated in parallel using an additional 25Z6 rectifier tube to supply the extra current. The filaments of the two additional 25 volt tubes are placed in series with the three in the amplifier. For the four watt amplifier the cathode resistor is changed to a value of 75 ohms. The line ballast resistor is likewise changed from 240 to 50 ohms. This resistor should have a wattage rating of at least ten watts. The plate load impedance of the two watt amplifier is 2000 ohms while for the four watt amplifier it is 1000 ohms. The primary winding of the speaker transformer and the filter choke should be of such size to handle at least 100 milliamperes of current.

The 6J7 voltage amplifier tube is resistance coupled to the power tube grid and delivers sufficient gain for all general purposes.

The amplifier is suitable only for small coverage outdoors and will deliver ample power for a small auditorium seating an audience of 75 to 100 people. It is very suitable for a phonograph or for close microphone P.A. work, since the gain is not sufficient for sensitive microphone pickup. Distortion is low for Class A amplification using the beam power tube. The amplifier is illustrated in Fig. 27A.

EIGHT WATT, CLASS A, BEAM POWER AMPLIFIER FOR AC-DC OPERATION

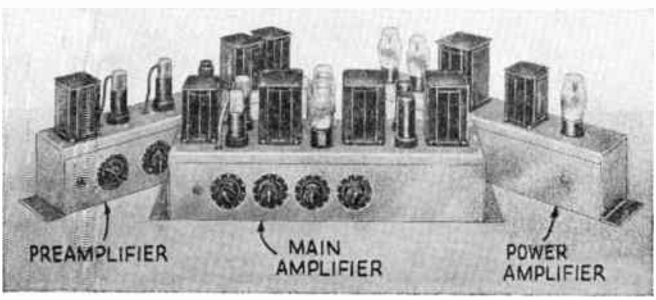
Fig. 28 shows the schematic of a stabilized Class A, AC-DC operated beam power amplifier that has an output of 8 watts at low distortion. To minimize second harmonic distortion, push-pull coupling is used. Distortion due to poor plate and screen grid voltage regulation is reduced through negative feedback. It will be noted that three separate feedback arrangements are used; that from the plate to the input of the 6J7s is used as a means of response control, and hum reduction; feedback from the grids of the output tubes to the cathodes of the 6C5s corrects distortion in that stage, including that of the driver transformer T2. The transformer was selected with the effects of feedback on the driver stage in mind. The third feedback takes place from the plates to the grids of the power tubes, and compensates for the supply voltage regulation and aids in minimizing the 3rd harmonic distortion.

The filaments are series operated, using a line ballast resistor of 75 ohms in series. A separate power supply is provided for a head or preamplifier that employs three six volt tubes. This power supply may be cut out by the switch SW. The amplifier incorporates a low frequency booster in the feedback circuit and an adjustable high frequency

Fig. 28A

(Courtesy Kenyon Trans. Corp.)

The appearance of the complete amplifier.



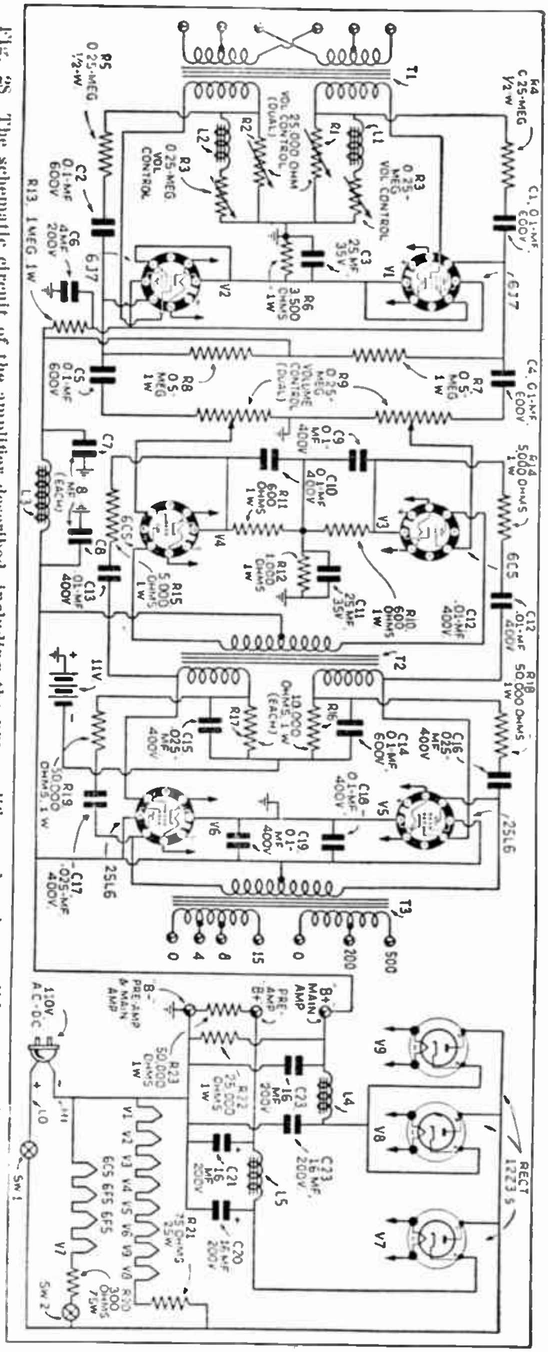


Fig. 28 The schematic circuit of the amplifier described, including the preamplifier and main amplifier—controller by inverse feedback.

booster in the input. The input is arranged for high and low impedance pickups and microphones. It may be suitably coupled to a low impedance line at either end. The output may also be coupled to 4, 8 and 15 ohm voice coils. As the universal line operation limits the voltage available the speaker field or fields must be separately excited.

The system will satisfactorily cover an audience of from 200 to 500 people. The output is ample from two large speakers. Permanent magnet type dynamic speakers are very satisfactory for this unit. Fig. 28A shows the completed amplifier, which is made up in three units.

SIXTEEN WATT, CLASS AB, VOLUME EXPANDER AMPLIFIER

Fig. 29 illustrates a 16 watt push-pull amplifier using 6F6 tubes in Class AB amplification. For volume expansion, the De Rosa Bridge expander employing two 6.8 volt 3 candlepower automobile headlight bulbs, is inserted between the first and second stages.

The principle of operation of the De Rosa bridge expander is based on the change of resistance of an enclosed tungsten filament as its temperature is raised by the passage of a large current. Two bulbs are connected in a Wheatstone Bridge arrangement as is shown by the heavy lines in Fig. 29. When the voltage across points "A" and "C" is increased, the current in both sides of the bridge is increased and more heat is evolved in the lamp filaments causing a rise in temperature, and because of the high temperature coefficient of the wire, an unbalance occurs causing a current to flow between the "B" and "D" terminals of the bridge. The distortion from this system is very low in comparison with most expander circuits. It is also adaptable as an add-on unit to existing amplifiers. The transformer T1 is a universal output transformer of high plate impedance to 1.5 to 2.5 ohm secondary. Transformer T2 is exactly the same but is reversed in the circuit. The output tubes are 6F6s. The cathode resistor for these tubes should be 350 to 400 ohms. 6L6 beam power tubes may be used in which event the system will deliver approximately 30 watts to the speaker or speakers. If these tubes are used the bias resistor should have a value of 200 ohms. The power transformer, filter chokes, and output transformer should be of ample size to insure adequate voltage regulation. A 2000 ohm speaker field may be substituted for the choke Ch2.

While no input transformer is shown, any type may be used providing the load impedance of the primary matches that of the tubes used, and the impedance of the secondary matches the line or voice coil used.

This system may be used for small theatre sound installations, recording studio or audition tests of broadcast talent. Full output will provide coverage to 1000 people indoors, and for outdoor use, it can be heard for several blocks, which of course will be dependent upon the local noise level.

TWENTY FIVE WATT DIRECT-COUPLED BEAM POWER CLASS AB2 AMPLIFIER

Figs. 30 and 30A show the schematic and illustration of a class AB_2 beam power amplifier which employs direct coupling between stages, with the second stage giving cathode inversion for the push-pull operation of the 6L6 tubes.

The power supply should be of ample size to give excellent voltage regulation. The amplifier input is arranged for two high impedance channels and four low impedance channels. The latter may be connected in series in pairs for two button carbon microphone input. The output transformer secondary may be coupled to 2, 4, 8 and 16 ohm voice coils, or to 250 and 500 ohm low impedance lines.

This system is suitable for medium P. A. installations for indoor work with coverage up to 1500 people in the au-

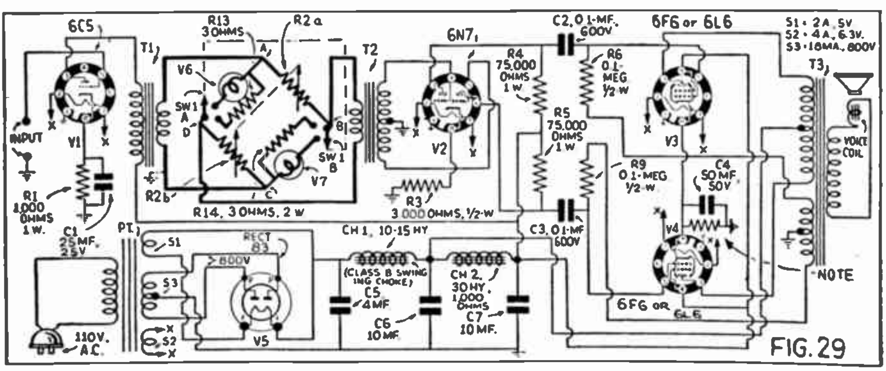


Fig. 29

The latest, corrected diagram of the new expander (heavy lines) connected in a beam-power

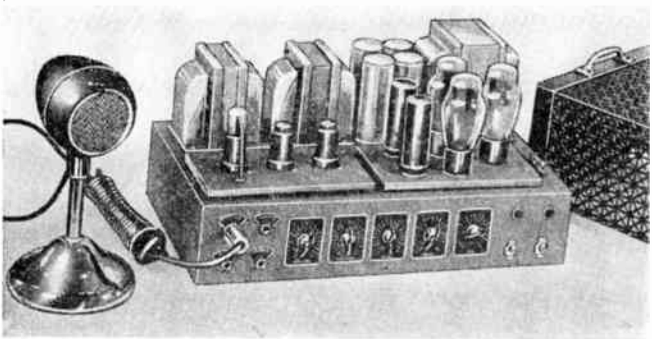


Fig. 30A (Courtesy Amp. Co. of America) The appearance of the Direct Coupled power amplifier.

dience. For outdoor work it is suitable for sound truck, exhibition parks and other outdoor meetings.

FORTY TO SIXTY WATT, CLASS AB2 BEAM POWER AMPLIFIER

In Fig. 31 is given the schematic of a 40 to 60 watt, Class AB2 Beam Power amplifier of considerable interest. In this arrangement Class B output is obtained with a Class AB2 arrangement. Volume expansion is included. A Tuning eye tube, 6E5, is used as an indicator for either output or expansion indication. Input jacks are provided for a Velocity or Ribbon, crystal (this jack may be used for a carbon microphone with additional coupling transformer) microphones. Electrostatic or condenser and dynamic type microphones are connected to the Ribbon microphone jack. A jack is also provided for connection of high impedance phonograph pickups. Each of these channels has its own individual volume control. Controls are also provided for the adjustment of the degree of volume expansion and also for tone. A switch is provided for the connecting of the 6E5 indicator tube for either output or volume expansion indication. The output transformer may be coupled to 4, 8 and 16 ohm voice coils. Provision is also made for connection into 200 or 500 ohm lines. Line power consumption is approximately 150 watts. The overall gain is 140 DB. At the crystal microphone input it is 98 DB, while at the phonograph jack it is 68 DB. With the expander in the circuit the gain of the 6L7 stage changes with the intensity of the signal. At the no-signal level its gain is very low. This condition seems to practically eliminate all tube and microphone noises normally encountered in such high gain amplifiers. Negative or inverse feedback is employed to minimize 3rd harmonic distortion, while the push-pull arrangement balances out the 2nd harmonic.

The coverage possibilities are about the same as given for the 25 watt direct-coupled system described above but with considerable reserve. Fig. 31A illustrates the amplifier with cover removed.

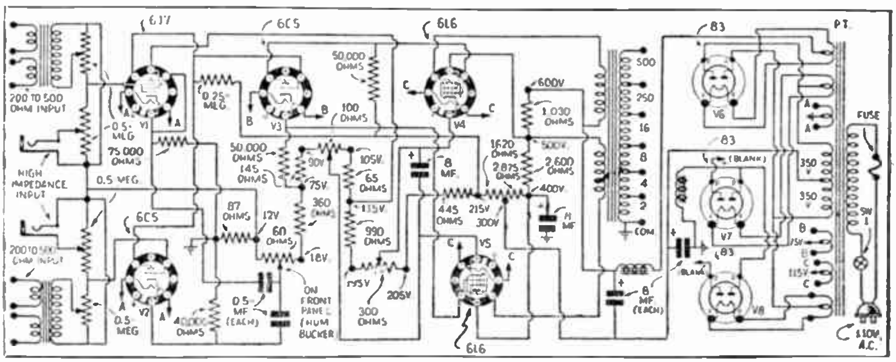


Fig. 30
The schematic of the Direct Coupled Amplifier.

FORTY-WATT "CLASS A"

Two amplifiers are used for this power output, the driver illustrated in Fig. 29 consisting of two stages feeding into resistance-coupled push-pull "6F6s". The driver has a peak output of 16 watts.

When connected to the power stage (schematic is Fig. 32) it provides a Five-stage amplifier of tremendous power output. The power stage employs 2-845's (50 watters) and two 866 mercury rectifiers in full-wave rectification.

This amplifier is excellent for addressing outdoor gatherings of 10,000 people, for airplane sound installation, or for broadcast purposes as a modulator to a 50-watt transmitter.

The output transformer in the power stage is not shown; but any reasonable tapped output, designed to operate from these tubes, may be employed.

Photos of the driver and power amplifiers are shown in Figs. 29 and 32A respectively.

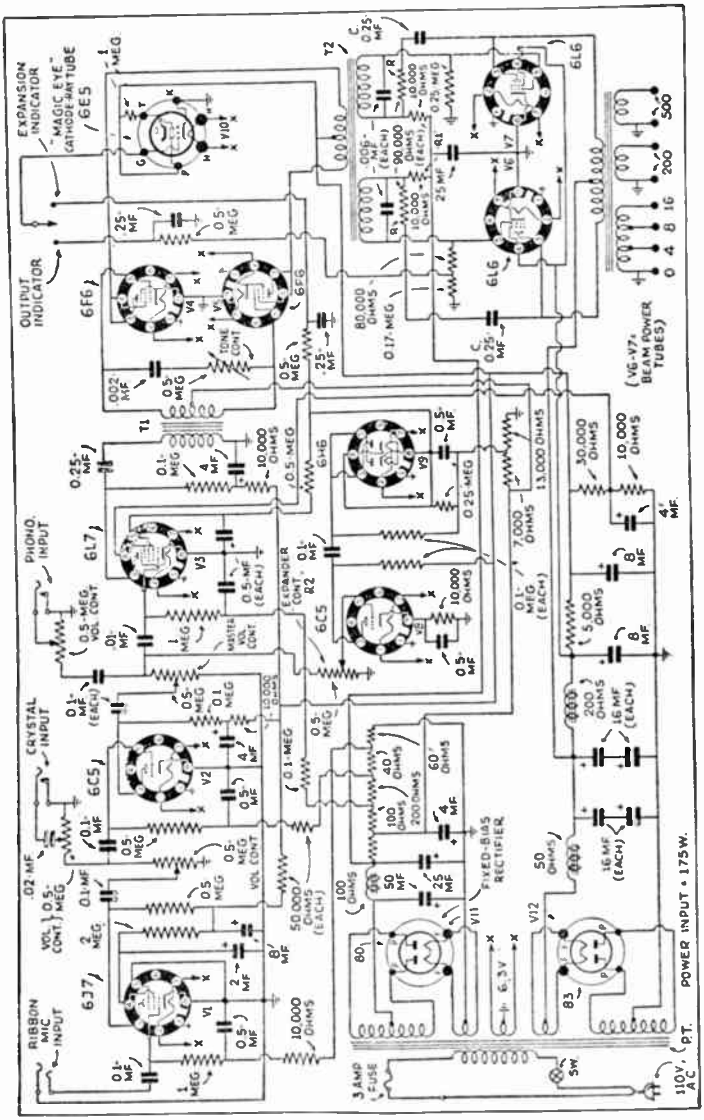


Fig. 31. The circuit of the 31 W. amplifier described, including volume expander and 6E5 indicator.

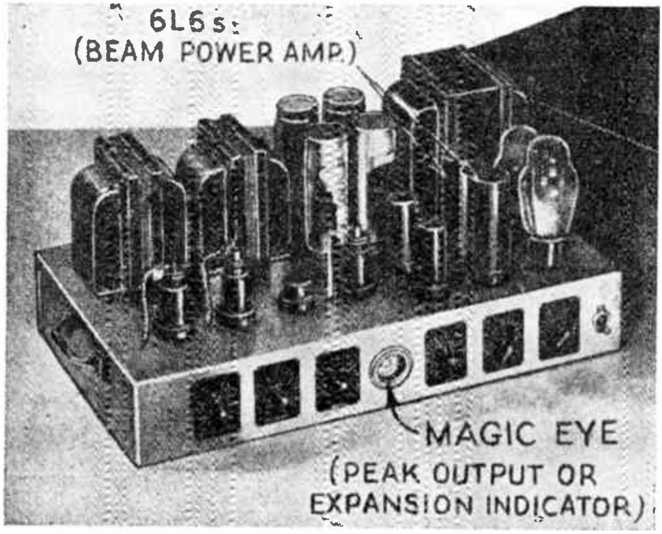


Fig. 31A
(Courtesy Amp. Co. of America)
Showing the chassis of the amplifier with the cover removed.

FIFTY-WATT "CLASS B"

The unit illustrated in Figs. 33 and 33A is a 50 watt Class "B" power stage. A driver, such as shown in Fig. 29, is necessary to drive it. The tubes used are four '59's in push-pull parallel, two '83's (mercury-vapor rectifiers) forming a full-wave rectifier for power supply for these tubes. Input is for 500-ohm line with tapped output impedances, as shown in the schematic.

A feature of this amplifier is the reasonable tube cost for replacement—which is much lower than for the 845's. It is admirably suited for large outdoor arenas, stadiums, ball parks, etc.

120 WATT SUPER POWER AMPLIFIER

In Fig. 34 is shown an amplifier which with the exception of the rectifier tubes uses beam power tubes exclusively for the power amplifying purposes. The medium power beam tube 6V6 is used as the input stage. A unique arrangement is employed in the circuit in that cathode transformer coupling is employed. The cathode of the 1st 6V6 is coupled by transformer to push-pull 6V6 tubes. The plates of these tubes are coupled to push-pull 6L6 tubes for one channel, while the cathodes of the driving 6V6 push-pull stage are transformer coupled to the second 6L6 channel. This arrangement provides inverse feedback. By close inspection it can be seen that the plate and cathode output transformers are arranged in a bridge circuit. This minimizes distortion to approximately 2 percent in each 6L6 channel. As can be seen the driver stage plate load is split into two sections, one half in the plate circuit and the other half in the cathode circuit. This enables the four 6L6 tubes to be driven to full power output without introducing excessive grid circuit impedance, as the splitting of the driver stage plate load equally divides the reflected impedance.

The input is provided with two primary windings, each of which are tapped at 1, 2, 3, 4, 8, 125 and 250 ohms impedance. Each output channel transformer has two secondary windings for connection to 2, 4, 8 or 16 ohm voice coils. Also connection may be made to 250 or 500 ohm lines.

It will be noted that four 83 mercury vapor type rectifier tubes are employed which deliver approximately 650 milliamperes under peak output of the amplifier. To protect the components of the amplifier it has been necessary to provide a high voltage supply time-delay relay. The peak output of the amplifier is of the order of 168 watts. At such output level a certain amount of distortion is permissible. The system is very suitable for outdoor work where the coverage requirements are more to

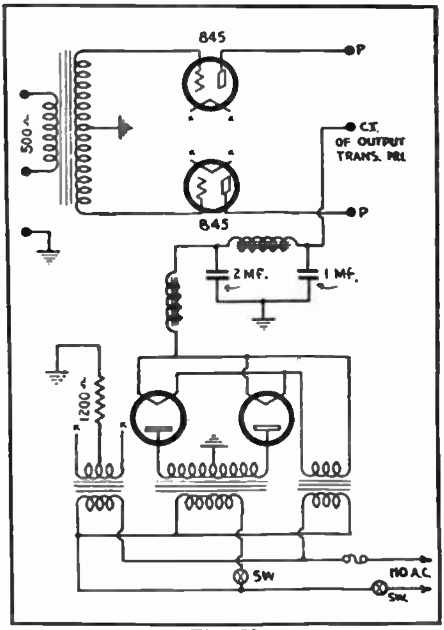


Fig. 32
Diagram of a "Class A" 40 watt power stage. The amplifier in Fig. 29 is designed to drive this stage.

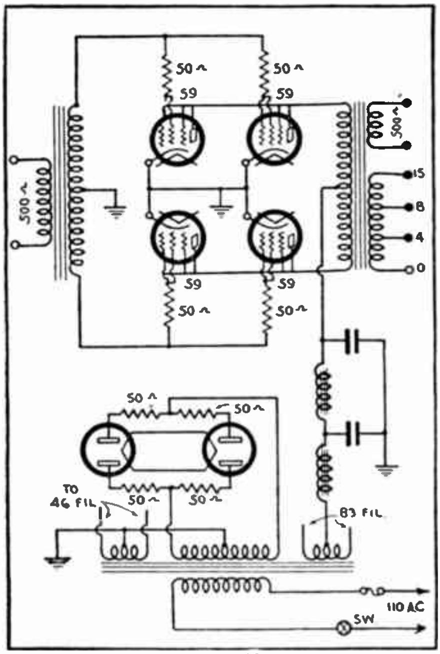


Fig. 33
A "Class B" 50-watt power stage. Input and output transformers are included. Special consideration must be given to the design of the output transformer, especially the primary winding which must be capable of carrying the very high plate current required by the two tubes.

attract attention of the masses rather than to supply them with high fidelity reproduction. Fig. 34A illustrates the amplifier.

SPECIAL AMPLIFIERS

The amplifiers described above are all for standard or conventional requirements where A.C. is obtainable. There are occasions, however, where these amplifiers will not serve, without special changes or additional equipment entailing added expense, which the customer of a P.A. system may not wish to consider. For example, where only direct current is available, the expense of a rotary converter or motor generator set for transforming the D.C. to A.C. may kill a sale.

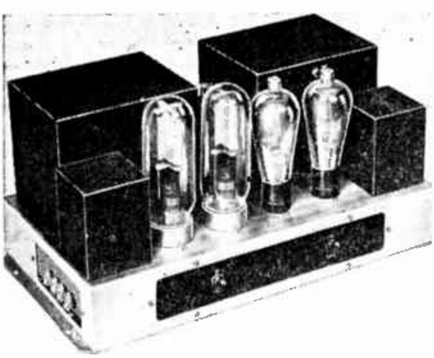


Fig. 32A
(Courtesy Simplex Electric Co.)
Photograph of power stage diagramed in Fig. 28A. Rectifier tubes and power supply for this stage are included.

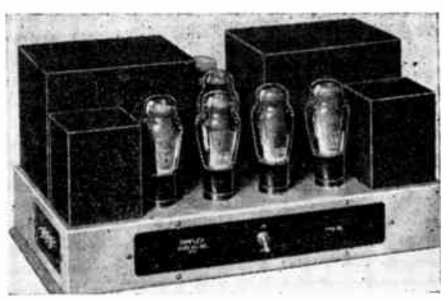


Fig. 33A
(Courtesy Simplex Electric Co.)
Photograph of the "Class B" 50-watt amplifier. This power output is obtained from four '59 "Class B" tubes in push-pull parallel.

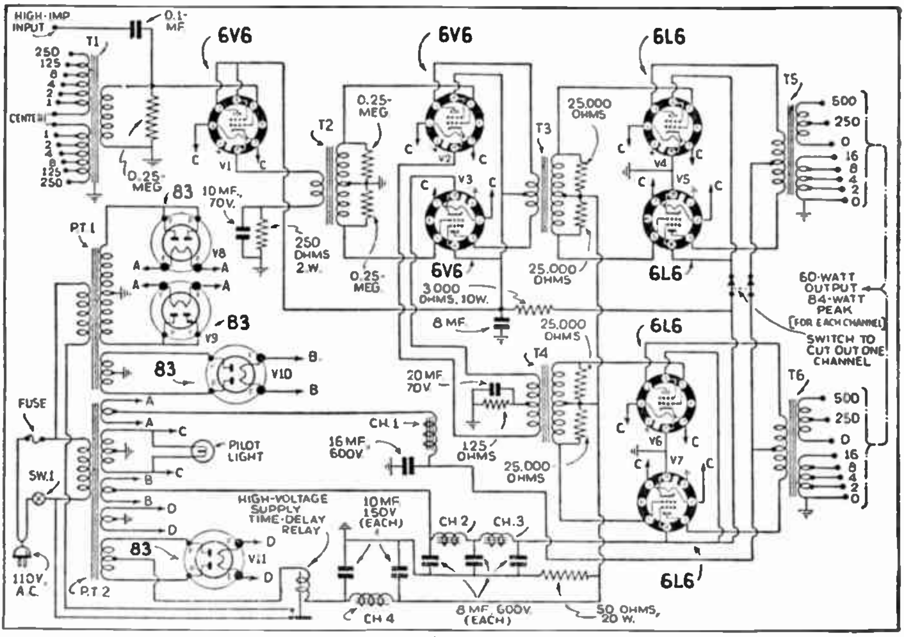


Fig. 34

The schematic of the Super Beam power amplifier. This amplifier should be driven by a suitable preamplifier driver.

If the installation requirements call for a small amplifier, for small audiences or for indoor work, then it is recommended that a D.C. amplifier illustrated in Fig. 35 (schematic wiring diagram) be employed. By using separate bias (C batteries) a power output of six watts is obtained. The tubes are all designed especially for D.C. operation—a high mu '77, resistance-coupled to a '37 into push pull '48's. Phonograph and microphone input taps are included, as well as tapped-impedance output ranging from 4 to 500 ohms for multiple number of speakers.

32 WATT UNIVERSAL POWERED BEAM POWER AMPLIFIER

For more than a decade the design of universal operated (6 V. storage battery and 110 V. A.C.) public address amplifiers has progressed but little, expe-

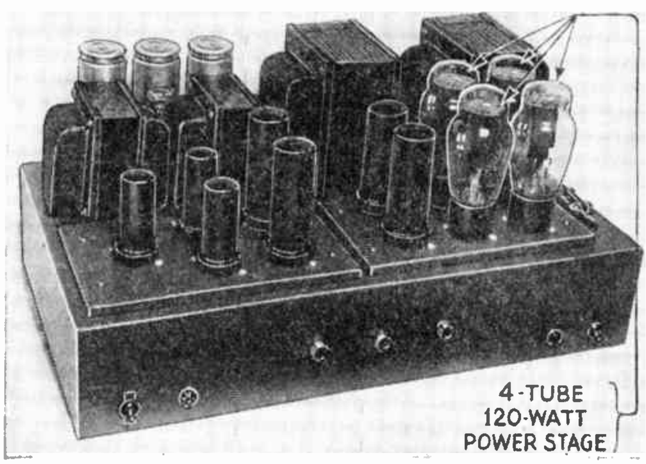


Fig. 34A (Courtesy Amp. Co. of America) Illustrating the appearance of the super amplifier which uses cathode transformer coupling.

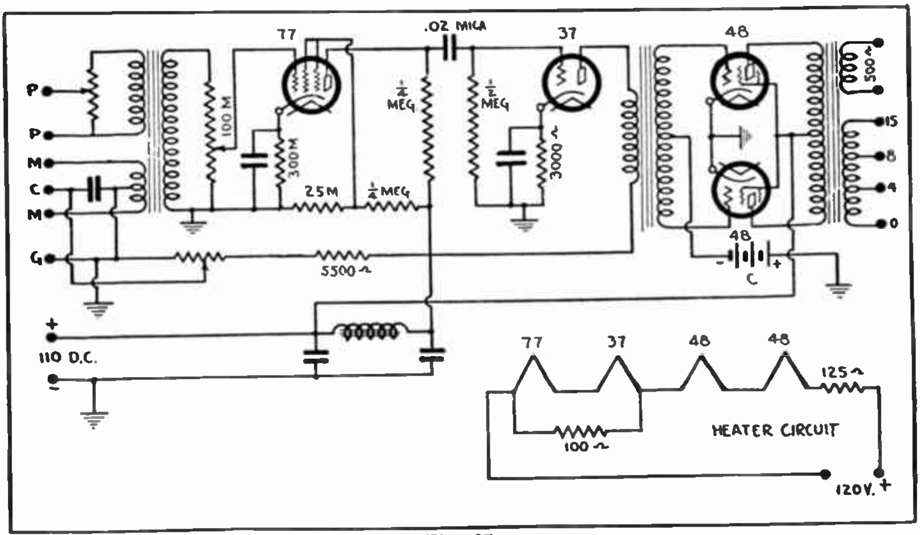


Fig. 35

(Courtesy Simplex Electric Co.) A wiring diagram of a "Class A" 6-watt 110 volt D.C. amplifier.

riencing no fundamental improvements excepting the "absorption" of developments gradually brought about in general-purpose amplifiers.

As no concentrated and intense engineering has been applied to universal amplifiers, this phase of the P.A. field has been sadly neglected by amplifier engineers.

Successful design of an efficient high-fidelity universal amplifier for all practical P.A. applications depends upon 5 fundamental factors, each of which must be carefully considered and properly incorporated in the finished amplifier. (It is, of course, taken for granted that the modern "universal" amplifier should be designed around the new beam-type power output tubes.)

1. Economical operation from 6 V. D.C.
2. Equivalent performance from 110 V. A.C. and 6 V. D.C.
3. Fixed voltage power sources for supplying 6L6 plate (400 V.) and screen-grid voltage (300 V.) without the use of voltage-dropping resistor.
4. Adequate audio power output with minimum distortion (2 per cent total).
5. Permanent and trouble-free performance from 6 V. power sources.

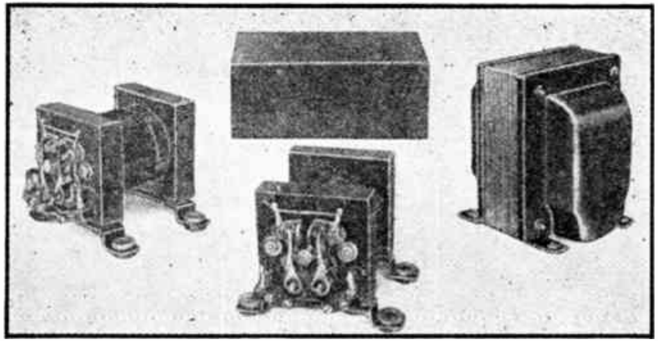
In Fig. 36 is given the schematic of such a universal powered amplifier. Provision has been made for adequate voltage regulation whether operated from the 6 volt or 110 AC supply. As can be seen the 6 volts DC is converted to AC by a specially designed motor driven alternator.

ELEMENTS OF THE NEW POWER UNIT

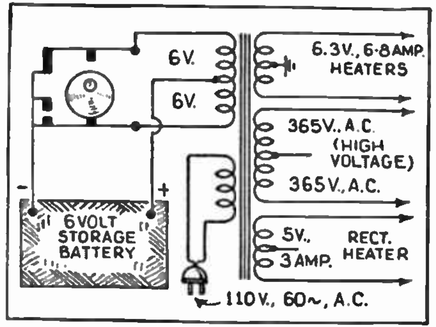
The alternatos consists essentially of a compact, noiseless and highly efficient motor, upon the shaft of which is firmly fastened an eccentric cylindrical metal cam. This cam "makes" and "breaks" the 4 contact arms with tungsten "points" welded on. As the motor shaft revolves 2,500 r.p.m., approximately 42 circuit interruptions of each set of contacts are produced per second.

Similar to automobile-radio receiver vibrators, the outside tungsten points are connected to the ends of a 12 V. center-tapped primary of a 40-cycle power transformer, the center-tap of which is connected in series with the 6 V. storage battery and the 2 movable tungsten contacts. Due to the "chopping" of the battery current by the 2 sets of contacts, 6 V. of pulsating D.C. is present in the primary winding.

Coverage of this amplifier is similar to that of any other amplifier of like output.



Left—The storage-battery converter unit and its double sound-proof case.



Right — Transformer wound with both 110-V. and 6-V. windings; hence useable with motor converter unit or on A.C. Note that this is only the basic, theoretical circuit.

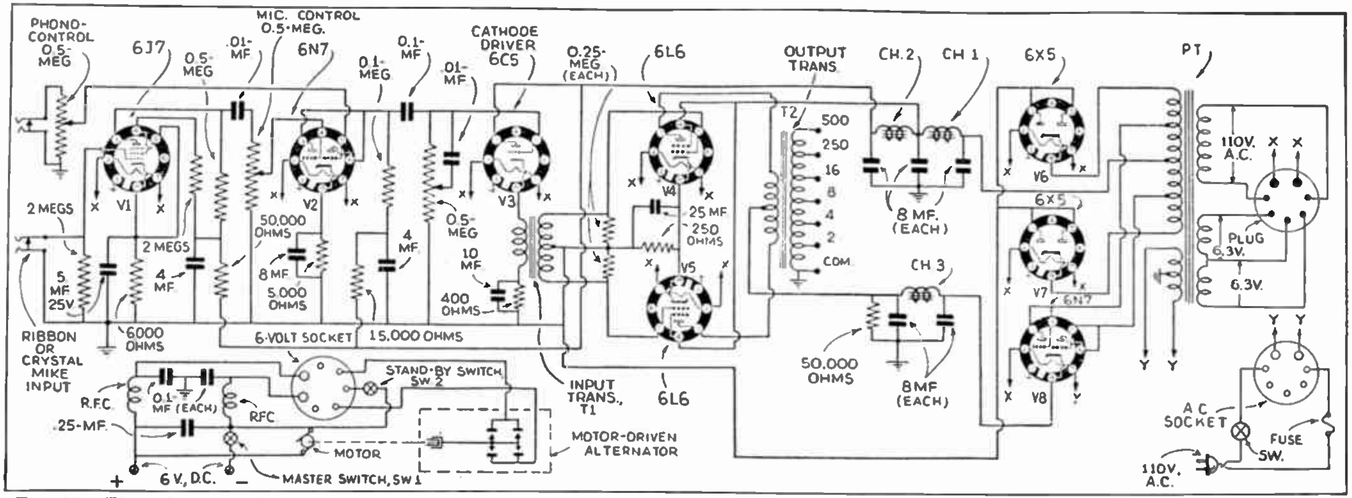


Fig. 36. The schematic of the 32-W. beam power amplifier showing how the operation from either 6-V. D.C. or 110 A.C. is accomplished.

CHAPTER IV

Installation and Instruction

FIGURING REQUIREMENTS

IT is generally conceded by all installation engineers that, no matter how good the amplifier and associated equipment may be, unless the installation is proper and made with regard for definite and set rules in installation practice, the best results can never be obtained. First, however, it is necessary to be able to analyze the requirements of a P.A. job. By that is meant the equipment necessary for satisfactory projection of sound under certain conditions and for a given location. How to figure on the type and size of amplifier, number of speakers, type of horns, matching transformers, etc., seems to be a considerable puzzle, not only to newcomers but to many veterans in this field.

Location and coverage are always the primary considerations in determining size and type of amplifier. An installation made outdoors naturally requires a great deal more of amplified sound than one indoors. If a large stadium must be covered—then the amplifier must of necessity be large. **The Power output of an amplifier to be selected can be derived by first ascertaining the number of necessary speakers to be employed and the size of the units—with ample margin for reserve power.**

Reserve power is necessary in outdoor installations to overcome noise level; in indoor installations, to overcome the additional absorption of an audience, since a given amount of sound will be louder in an empty auditorium than when that auditorium has every seat occupied.

Let us assume an average auditorium installation to be made. Seating capacity between 1000 and 1500 people, dimensions of auditorium about 125 feet width, 100 feet length, height about 45 feet, with an average type balcony. Two speakers would be all that is required for this case—although one speaker unit also would do if a wide-flare theatre type horn was used (see Fig. 37).

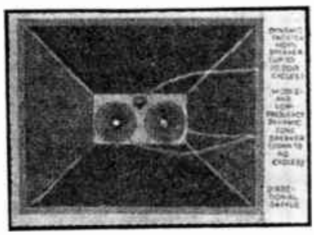


Fig. 37
An "All-Frequency" theatre reproducer that uses three speakers, covering low, medium and high frequencies.

This is permissible only if the acoustics of the auditorium are good (see Chapter V on acoustics), since the sound waves must be so directed that they are kept off bare ceilings and plaster walls—particularly the rear walls—if good reproduction and high intelligibility of speech is to be obtained.

A 100-foot projection of sound is not considered excessive, particularly in an auditorium of this type where the reinforcement of sound. to fill it satisfactorily, with a full audience would require only a moderate amount of amplification.

The two speakers, in this case. might well be of the dynamic cone type (see Fig. 38)—five to eight watts power handling capacity, and properly baffled. They should be suspended, one at each end of the stage, and approximately half way up the proscenium opening. Obviously, to satisfactorily drive these units, an amplifier of from 10 to 15 watts power output is required. Since the speakers will seldom be driven to

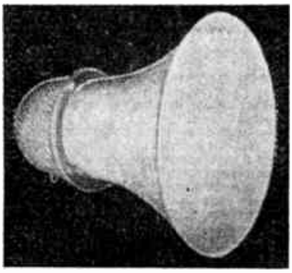


Fig. 38
A giant parabolic reflector for a dynamic speaker.

full capacity, sufficient reserve is included when 15 watts of power is available.

The horn or directional baffle is chosen when the sound wave emanating from the horn is to be controlled. This is highly desirable, as mentioned previously, where an auditorium is not treated for acoustic imperfection, in order to keep the sounds from striking bare walls, which may reflect them and prolong their "decay" which is the cause for excessive reverberation. By tilting and arranging the horns properly (as said before, like a beam of light from a searchlight) the sound wave direction is accomplished.

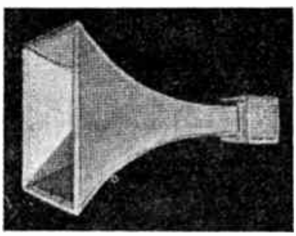


Fig. 39
A square mouth exponential designed for a dynamic speaker.

A horn which meets the above conditions, providing there is space and a means of disguising it, is shown in Fig. 39. An ideal place to locate this unit would be at the top of the proscenium arch (in center) providing there is no aesthetic objection. In this location it should be tilted downwards so that the axis of the bell prolonged would strike about half way down the orchestra. The flare of this speaker is 30° (degrees) upwards from a horizontal line through the center and 45° downward. It is 60° each side of a vertical line through the center. These measurements are important for figuring the directional properties of a horn.

The trumpet-type horn can also be used for indoor use, where special conditions (such as setting equipment up and removing it within an evening, (for rental service) require a lightweight horn that is portable; it should have demountable features. A trumpet of this type, shown in Fig. 40, when taken apart consists of three pieces, the largest one of which only totals 37 inches. The total length is six feet.

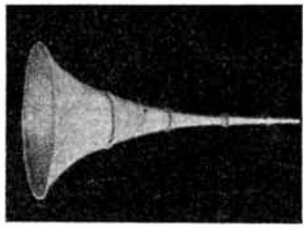


Fig. 40
A trumpet type round mouth 6 ft. exponential horn.

Getting back to amplifier power output, we shall now take a large installation into consideration to illustrate how to determine the equipment to be selected; such as the amplifier (power output), number of speakers, location of speakers, etc. Let us assume in this instance a P.A. installation to be made in a large stadium, such as a ball park, racetrack, or outdoor meeting place. Here the problems involved are much more complicated. In some cases, where the area to be covered is great and the noise level high, a considerable number of speakers will be necessary. If the speakers are placed in the stands, one for approximately each hundred feet should be figured on. If an arrangement such as shown in Fig. 41 is desired, the distance between poles with six trumpets mounted on each can be figured on as closely approximating 500 feet. There is a disadvantage, however, in an arrangement of this sort—that the two speakers not facing the stands do not contribute much in the way of coverage —unless there are spectators on the field, or the seating stands are constructed in a circle. In the latter case, the speaker-mounting pole should be in the

Fig. 41
A tower cluster and sound truck for outdoor P.A. work.

center of the arena—which in most cases is not feasible.

It can be safely assumed that from five to eight speakers would cover most average outdoor requirements, and, if each speaker delivers 5 watts of power, plenty of volume will be obtained. In this case, a 50-watt power amplifier stage with suitable driver stages will be necessary.

For simplicity's sake, those without P.A. experience (and therefore not in position to gauge the required number of speakers accurately without installation practice) can refer to the data on amplifiers in Chapter Three. Amplifiers of various outputs are illustrated and their approximate coverage is included.

HORN VERSUS DYNAMIC BAFFLE

The question has often arisen in regards to choosing between a trumpet type speaker and a dynamic unit placed either within a horn or behind a baffle.

There can be no question over the fact that, for projecting sound over long stretches or areas, the horn or trumpet is best. Concerning the type of unit to employ, it is generally recommended that the dynamic cone be used only with straight baffles or wide flare horns for best frequency response. The reason for this is best illustrated by referring to Fig. 42. Note the location and shape of the low-frequency waves as they emanate from the cone. These waves are lost in a horn designed for projection of sound, unless the flare or angle of the horn is so great that it is useless as a sound projecting and directing device. Some horns effect a compromise

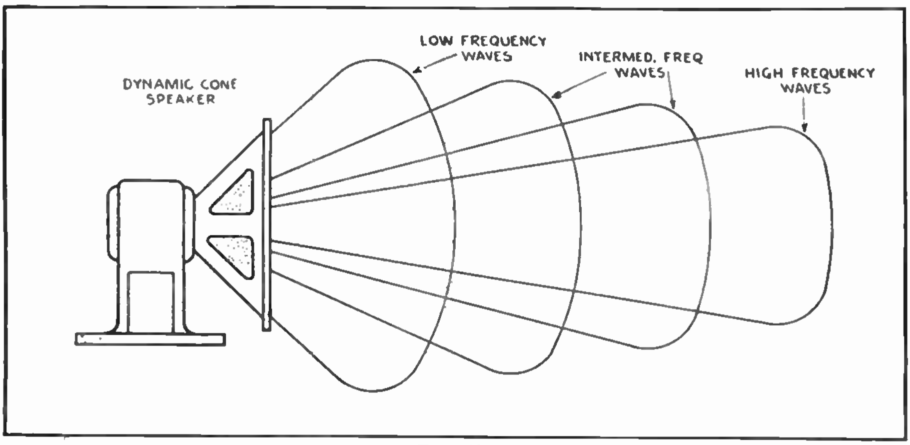


Fig. 42
Illustrating the area covered by sound emanations from cone dynamic speakers, with respect to their frequencies. Low-frequency sound always is distributed nearest the cone, in the form shown.

Fig. 43
18 inch dynamic speaker of the concert auditorium type.

in their design, to obtain a directive quality with projection features. But using a wider flare or angle horn is best. A great deal of the low frequencies heard from a long horn are really due to so called "horn resonance," since if a cone is mounted to a long shaped trumpet, the low frequency waves will be squashed and thus distorted. Dynamic cone speakers are especially suited for dance halls, dining halls where orchestral music is to be amplified, or similar installations where the sound need not be directed or shot out over large areas and particularly where good reproduction is required. The dynamic cone for P.A. should be ruggedly constructed and designed for heavy-duty use, besides being capable of handling large power inputs without rattling. A unit of this type, designed especially for P.A. work is shown in Fig. 43.

Fig. 44
(Courtesy Bud Speaker Co.)
A dynamic unit with polarity "marked."

For horn or trumpet use, units are constructed as shown in Fig. 44. They are available in different sizes for operation with various size P.A. or theatre amplifying equipment. They are rated as to peak-load capacity but range in continuous operating capacity. Voice coil impedance is usually 15 ohms at 1000 C.P.S. Field excitation is usually 6-8 volts.

HIGH-FREQUENCY REPRODUCER

The latest practice, when installing special high-fidelity reproducing equipment is to include a high-frequency reproducer in conjunction with other speakers which are capable of low frequency response. The use of such a speaker is essential for reproduction of the high frequencies which constitute a large part of the harmonics and overtones in musical reproduction. A suitable filter should be used which provides a high-pass channel for this unit. The number of high-frequency reproducers to use in conjunction with low-frequency speakers depends on the installation or distribution of sound, although usually it may take two low-frequency speakers to one of this new type. A photo of this unit is shown in Fig. 45. The power input to this unit

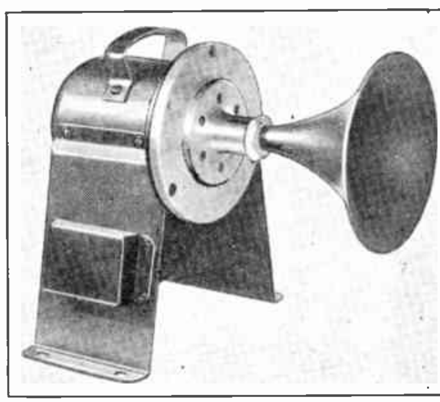


Fig. 45
(Courtesy Jensen Radio Mfg. Co.)
A high-frequency response speaker (dynamic type) which, when used with a suitable filter network and in combination with flat-response speakers, will give excellent results in reproduction.

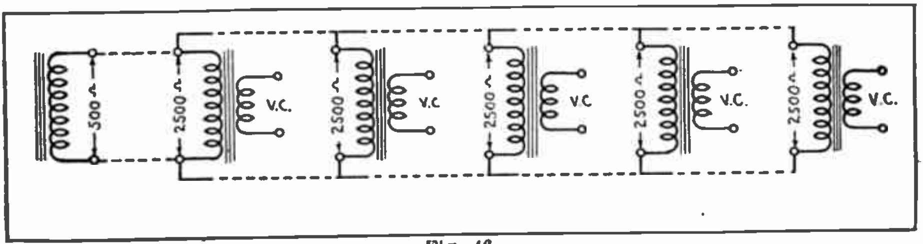


Fig. 46
Method of connecting voice coils of multiple number of speakers in parallel arrangement to work into 500-ohm line.

(Model A) is limited to five watts. It is of dynamic principle and construction, and no baffle is required for it.

SPEAKER INSTALLATION HINTS

(1) The Placement of Speakers—their locations and angles (where horn type is used) must be made with the consideration of maximum distribution uppermost in mind. Horn speakers must be chosen with proper flare for indoor work, and so directed that the minimum of sound reaches rear wall or side walls that are not treated to prevent reflection of sound waves.

(2) Phasing of Speakers, where more than one are used, must be uniform, that is, the polarities of field and voice coils must be such that the diaphragms or cones move in and out together. This is imperative where speakers are placed together, or where more than one unit couples to a horn or trumpet. If speakers are out of phase, the air is compressed around one speaker while it is rarefied around the other—the result being that a good deal of the sound balances out before being projected far and a good many frequencies are lost, which makes for unnaturalness or distortion.

Cone units, such as are shown in Fig. 43 have the voice-coil polarities marked; the positive side (high-potential end) is painted red—the other post black. When connecting these voice coils in parallel, connect all reds together and all blacks. If a series arrangement is desired, red of one unit connects to black of the other, etc.

The field windings are also marked plus and minus—and must be connected to positive and negative terminals on the storage battery (if 6v. to 8-volt fields). Reversing the field polarity will also throw a unit out of phase.

The phasing of cone dynamics requires another more laborious procedure, which must be performed when the installation is completed. Refer to Fig. 46 illustrating voice coil connections, parallel, or series and parallel arrangements. With the field voltages turned "on" (turn amplifier "on" if field exists only when amplifier is "on"), apply a make-break potential of 4.5 volts (C-Battery) to the secondary terminals of the 500-ohm line or output transformer. DO NOT HOLD BATTERY CONNECTIONS TO TERMINALS TOO LONG. Never use a voltage in excess of 4.5 volts; never change "C" battery wires around during this procedure. Make contact for about a second, then break (one lead). Another man must be at the speakers to feel the direction of each cone's movement. THEY MUST ALL MOVE ALIKE—in similar direction. Where a unit moves in opposite direction, simply reverse either the field or the voice coils leads—whichever is most convenient.

(3) For indoor P.A. work, particularly in auditoriums, try to analyze the speaker requirements correctly. Too many speakers will cause over-distribution and emphasize any poor acoustics. The sound will therefore be "boomy" and unintelligible. Too few speakers will result in under-distribution, shown by uneven volume through auditorium and possible dead spots where the sound will be heard only faintly.

(4) Where long speaker lines are necessary, because of their remote location from amplifier, use the 500-ohm tap on the output transformer. Transmission impedance of output should be betwen 200 and 600 ohms, and the reason for this is that the characteristics of

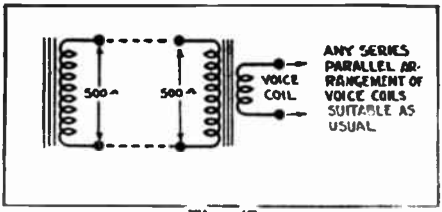


Fig. 47
Single speaker installation using 500-ohm transmission level, eliminating long-line defects.

impedance at low values (around 8 to 16 ohms) are:

(A) high current, but low voltage;

(B) strong electromagnetic fields around the wire, which may cause feedback or cross-talk;

(C) D.C. resistance of lines (due to length) is appreciable.

At high values of impedance (5000 ohms or higher):

(A) low current, but high voltage;

(B) small electromagnetic effects;

(C) D.C. resistance of lines negligible;

(D) BUT the capacity between the two lines is appreciable.

Therefore, installation practice has been to compromise and use transmission impedance between 200 and 600 ohms as being the most ideal.

(5) Voice coils should be arranged in series, parallel, or series-parallel, so that the combined total of impedance efffectively matches the secondary of the line matching transformer. Where a single speaker is concerned, employ the circuit in Fig. 47. Where five voice coils are employed, use speaker transformers and the arrangement shown in Fig. 46. The primary winding of the speaker-matching transformer has an impedance of 2500 ohms. Five of them in parallel result in an impedance of 500 ohms, which will work into the 500-ohm line transformer. As explained before, the impedance of the line is ignored, because of its relatively low value as compared to the transmission impedance. A series-parallel arrangement is shown in Fig. 48. Here two sets of 500-ohm (speaker-primary) impedances are wired so that the combined impedance is still 500 ohms and matches the line transformer.

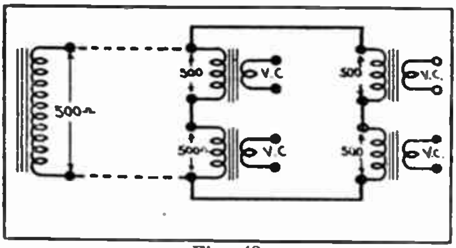


Fig. 48
Connecting four speakers in a series-parallel arrangement so that their combined impedance remains at 500 ohms.

The formula for calculating impedances in series (when on separate cores) is similar to that for resistances in series; that is $R_1+R_2+R_3$, etc. Parallel connection of impedances (on separate cores) is similar to that for resistances in parallel:

$$\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}, \text{ etc.}$$

For other combinations (see Chapter III) with tapped-output transformers employed in the various amplifiers.

(6) In all outdoor work, see that horns and units are mounted in weatherproof housings. Trumpets can be so mounted that they are easily removed (in case of storm) or provision may be made for a canvas to completely cover them. Some horns and units are made "weather proof" but additional precautions will serve to add to that assurance of safety.

AMPLIFIER INSTALLATION HINTS

(1) For indoor work, use BX or conduit unless the P.A. system is of such small size that it isn't necessary. By all means, on all other installations, follow the local fire underwriter's code for installing electrical equipment. For outdoor work—if the installation is to be permanent—use conduit, galvanized, preferably. The amplifier proper must, of course, be placed indoors or in a booth specially constructed so that weather effects or outside interference or tampering with the equipment is eliminated.

Microphones are placed where most convenient for use; receptacle plugs being wired at the locations selected.

(2) It is always advisable to ground one side of the input (center tap of microphone transformer) and the side of the output—to eliminate possibility of reaction between input and output. Also ground all conduit or BX sheating.

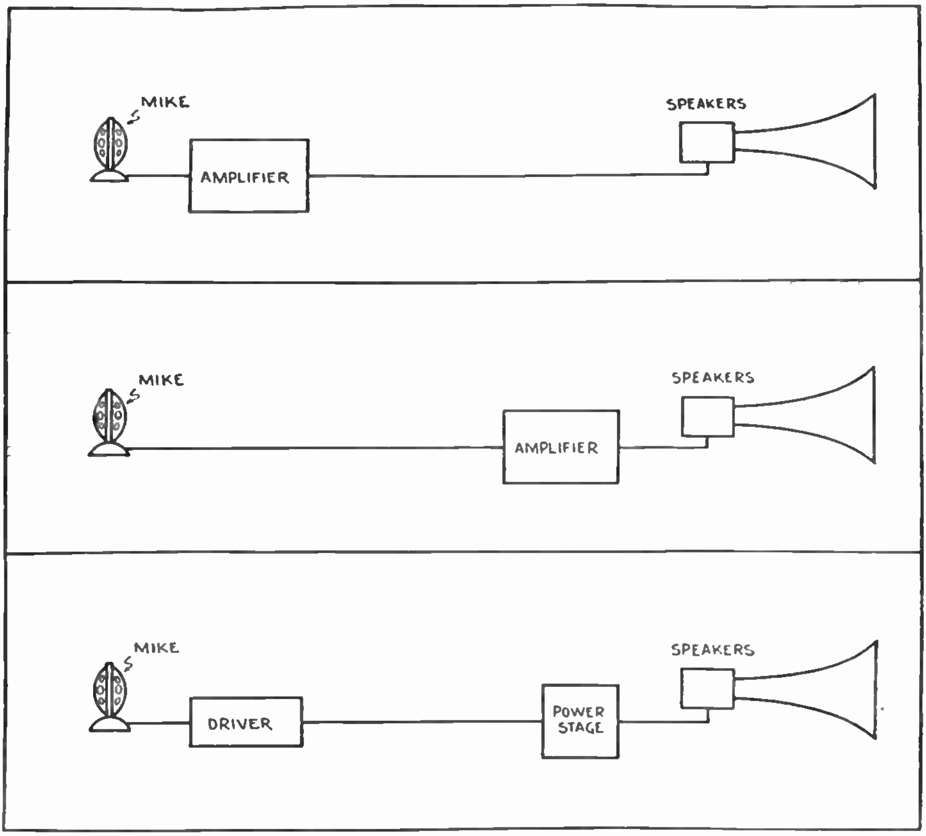


Fig. 49. One method of installing the amplifier where the speaker is at remote point.
Fig. 50. A better method, amplifier remote from microphone input.
Fig. 51. Best method of installing—Refer to text for explanation.

(3) The location of amplifier equipment where large installations are made (power output of 50 watts) may be made in three different ways:

(a) Complete amplifier is placed at microphone end with controls for regulating volume. See Fig. 49. Convenient for controlling the gain but poor transmission.

(b) Amplifier at speaker location. Control of the amplifier is limited and transmission level may be so low that line noise may be appreciable. See Fig. 50.

(c) The best method, consists of placing the driver stage with all necessary controls at the microphone end; then installing the power stage at the speaker end. See Fig. 51. Thus all controls are conveniently located, and the transmission level, though low, is still high enough to be above the noise level of the line.

MICROPHONE HOWL OR WHISTLE

Generally caused by acoustic feedback. To eliminate the possibility of "oscillation" due to reaction between magnetic fields around input and output wires, use shielded cable for the microphone leads to the receptacle plug.

Acoustic feedback (causing whistle or ringing in output) is due to placement of microphones too close to speakers, or within the speaker acoustic fields. The remedies for this type of trouble are thoroughly gone into in the chapter dealing with microphones.

CHAPTER V

Acoustics

A GOOD knowledge of this subject is imperative, if the installation engineer of public-address equipment is desirous of knowing his work thoroughly, or if he feels that he should be equipped to install equipment successfully, in any location or under any conditions. Since many school auditoriums, churches, banquet halls, etc., are logical places for amplifying equipment, consequently reverberation, echoes, treatment of bare walls, the best location for speakers from an angle of clear and intelligible reproduction, must all be given consideration and dealt with.

Sound is vibrations of air, which are reflected when they strike bare walls or hard surfaces. This reflection of sound is what prolongs it—causing the vibrations to conflict with each other so that, to the ear, they may become unintelligible. The term applied to this reflection of sound is "reverberation"; and the "reverberation time" is the number of seconds (or fraction thereof) it takes the sound to "decay" or die out after the source of sound ceases.

Sabine's formula for the measurement of time period of reverberation is:

$$T = \frac{.05V}{A}$$

where

T=The reverberation time in seconds
V=Volume of room or auditorium
A=Total units of absorption in room or auditorium

"V" is obtained by simply multiplying length x width x height. Where balconies exist the average height is used, deductions being made for the floor space existing between orchestra and balcony, or between balconies.

"A" is obtained by totalling every square foot of absorption, which is in turn obtained by measuring the square footage of every material employed in the surface construction of the auditorium and multiplying it by its co-efficient of sound absorption. These co-efficients of sound absorption have been determined for practically all materials, and each square foot is rated by comparison with one square foot of open window space, which is accepted as 100% absorptive, and therefore has a co-efficient of unity.

TABLE ONE
COEFFICIENTS OF ABSORPTION

	Units per Square Foot
Open window	1.00
Plaster	.025 to .034
Concrete	.015
Brick set in Portland Cement	.025
Marble	.01
Glass, single thickness	.027
Wood sheathing	.061
Wood, varnished	.03
Cork tile	.03
Linoleum	.03
Carpets	.15 to .29
Cretonne cloth	.15
Curtains in heavy folds	.50 to 1.00
Hairfelt ½" (Johns-Manville)	.31
Hairfelt 1" (Johns-Manville)	.59
Flaxlinum ½"	.34
Sabinite Acoustical Plaster	.21
Acousti-Celotex, Type BB, painted or unpainted	.70
Acousti-Celotex, type B, painted or unpainted	.47
Sanacoustic Tile, 1" rock wool filler	.74
Nashkote, Type A, ¾" thick	.27

INDIVIDUAL OBJECTS

Audience, per person	4.7
Plain Church pews linear ft.	1.8
Upholstered Church pews, per linear ft. up to	1.6
Plain Plywood auditorium chairs each	.24
Completely upholstered chairs	3.0

(The above co-efficients are taken from the published works and test data of Professor Wallace C. Sabine, Professor F. R. Watson, and the Bureau of Standards. They are for the standard pitch of 512 vibrations per second.)

Let us take, for example, an auditorium whose total length is 80 feet, width 60 feet, and average height 40 feet. The total volume is then 192,000 cubic feet.

Then, by measuring the balcony and main floor areas (length x width) we find that the total is approximately 5,500 square feet. If these floors are of unfinished wood, the co-efficient of absorption for this material is obtained from Table One—which is .061 x 5,500, or 325 units of absorption.

Here the seats must be considered and should be considered as 75% effective in cancelling out floor absorption. Thus, if this auditorium has 500 seats of the hard plywood type, we have 500 x 0.24 or 120 units. 25% of the floor absorption (325 units) = 81 units more or a total of 201 units.

The stage floor, generally of varnished or finished wood, has 24 units of absorption (800 sq. ft. x .03).

The ceiling and walls, two side walls and rear, total 13,600 square feet and, since these are generally of plaster and glass a co-efficient of .03 is employed—thus producing 408 units of absorption.

Let us assume that 1500 square feet of aisle carpet is used—and at .22 which is the co-efficient of absorption for carpet (Table One) we have 330 additional units.

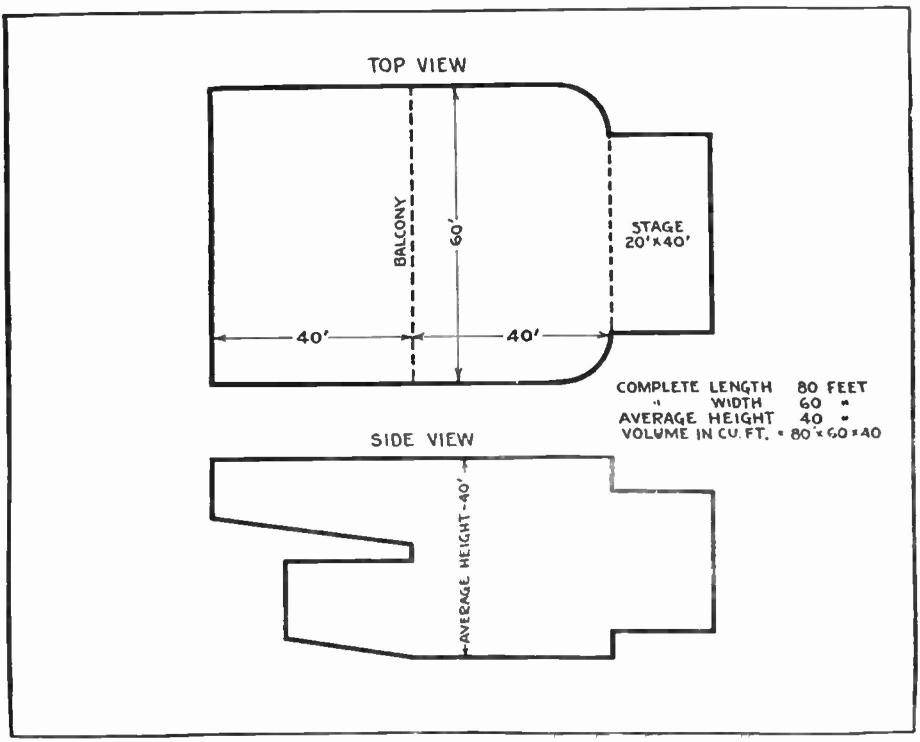


Fig. 52
Top and side views of an auditorium whose acoustic conditions are being analyzed.

The total of all these units will be:

	Units
Balcony and main floors (wood)	
7.200 x .015 = 324 x .25 =	81
500 seats x .24 =	120
Ceiling and Walls (plaster and glass) 13.600 x .03	408
Stage floor (finished wood)	
800 x .03	24
Aisle Carpet	
1500 x .22	330
Total	963

Since we now know the total units of absorption and the volume of the auditorium. from Sabine's formula we have

$$T = \frac{.05 \times 192.000}{963} = 10 \text{ seconds}$$

This figure of 10 seconds is high, if we refer to Table Two and note that the optimum time for an auditorium of this size should be approximately 1.5 seconds for good sound. However, if we compute the conditions that will exist if one-third, two-thirds, and full audience are in this auditorium we will still find that the optimum time is not reached.

TABLE TWO
OPTIMUM PERIODS OF REVERBERATION

(The following table is prepared from published data compiled by Professor F. R. Watson.)

	Seconds
Below 7.000 cubic feet	1.0
7,000 to 20.000	1.1
20,000 to 45,000	1.2
45.000 to 85,000	1.3
85,000 to 145,000	1.4
145,000 to 225,000	1.5
225,000 to 330.444	1.6
330,000 to 465,000	1.7
630,000 to 835,000	1.9
835,000 to 1,100,000	2.0

Since seating capacity of this auditorium is 500 persons, and the coefficient of absorption per person is 4.7, but cancels out the equivalent absorption of that many chairs, we find that the absorption at

1/3 audience = 783 units
2/3 audience = 1566 units
Full audience = 2350 units

By including these figures in the calculation. we have

$$(1)\ T = \frac{05 \times 192{,}000}{1044 + 783 - 66} = 5.4 \text{ seconds}$$

1/3 audience

$$(2)\ T = \frac{.05 \times 192{,}000}{1044 + 1566 - 132} \quad 3.8 \text{ seconds}$$

2/3 audience

$$(3)\ T = \frac{.05 \times 192{,}000}{1044 + 2350 - 198} \quad 3 \text{ seconds}$$

Full Audience

Thus, even with full audience the optimum time of 1.5 seconds is not reached.. Since most auditoriums are seldom filled to capacity (unless, in some cases they really are) by taking the time period at 2/3 audience which is 3.8 seconds. Now—employing Sabine's formula further, but solving for "A" (absorption required to reduce time period 2.3 seconds) we have

$$A = \frac{.05V}{T}$$

$$\text{or } A = \frac{.05 \times 192{,}000}{2.3}$$

A = 4169 units of absorption, which are necessary to reduce the reverberation time to optimum value at two-thirds audience. By referring back to Table One we can select any of the standard materials for treatment whose co-efficients are given. Thus, if we choose acousti-Celotex with a co-efficient of .70 per square foot, we find that 5955 square feet (4169 ÷ .70) will give us the proper amount of absorption desired.

This material should be placed in panel form on the side walls, rear walls (particularly) and front ceiling. Stage wall should also be treated, to eliminate the reverberation at those points which would reflect back to the microphone and creat effects of boominess.

There is a simpler method of obtaining the "reverberation time" of an auditorium. This is quick and approximate —and is simply the procedure of blowing a 512-cycle whistle or pipe at average intensity for about as long as it takes to fill the auditorium with sound (this condition will be easily recognized after some practice). Then, from the instant the blowpipe ceases, measure

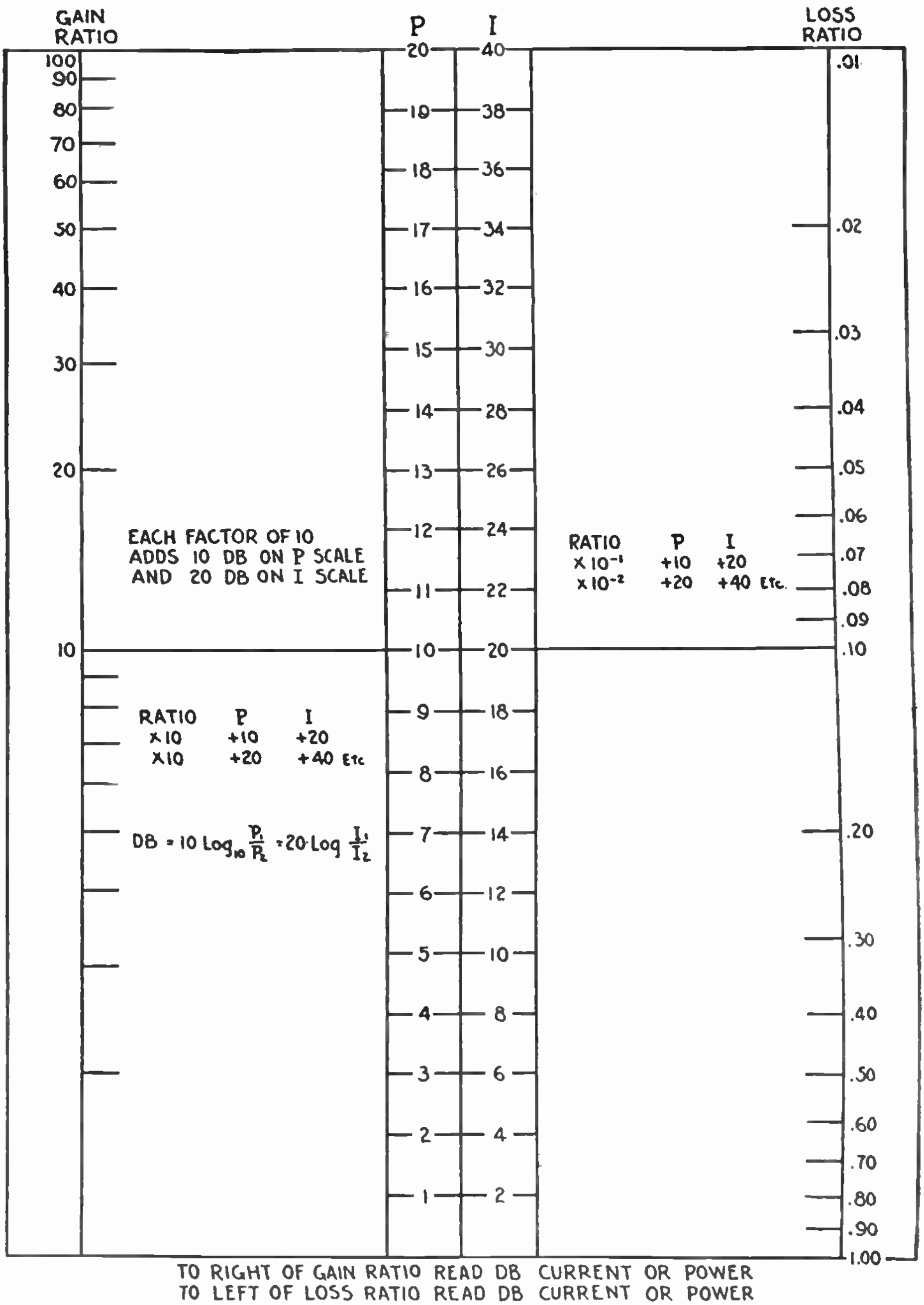


Fig. 53

Chart for determining directly the gain or loss in D.B., which will be found directly to the right of the gain-ratio scale. The loss in D.B. can be measured at the left of the loss scale.

with a stop-watch until the sound completely dies out.

. This procedure should be carried out at least three times for each location, and in various places or "spots"; particularly underneath balconies, domes, recesses, or pockets in ceilings or walls, on stage, and in the center of the auditorium. Each time a "time period" is obtained with the pipe and stop-watch, it should be jotted down. When through with all the measurements, simply divide by the total number of times the measurements was taken, and in that manner "the average time period of reverberation" is obtained.

By subtracting this time from the optimum time specified in Table Two (for the particular auditorium being figured on) then employing the formula

$A = \frac{.05V}{T}$, the amount of absorption necessary for treatment is obtained. After which, the desired material can be selected and the auditorium then properly "decorated" with it.

Always treat the rear wall of an auditorium in preference to the other points—since the effect of any factor that causes reverberation is increased with the distance.

Balcony ledges should be next favored and, of course, the side walls, particularly those in that large area existing between the stage and where the balcony construction begins.

Directional horns are of great help in keeping sound off bare walls, thus aiding in minimizing reverberation. Where the expense of complete treatment is too great for the building owners, this type of speaker is to be recommended and used.

CHAPTER VI

Servicing and Formulae

THE instruments necessary, and the electrical knowledge required by a P. A. engineer are much greater than that required by an average radio technician. He must of course know electricity; laws and theory; radio—since audio amplifiers are a component part of radio receivers, and since a good many installations employ radio tuners (R. F. stages and detector) to supply the sound to be projected (for example, hotel installations and others), mathematics—at least elementary and intermediate algebra without which the slight mathematics in this book will not be understood; and finally mechanics, particularly that which pertains to electrical equipment. In connection with the last, it is advisable to mention that automatic phonograph devices are employed with most P. A. equipment—a device which will remove the record when completed and place another in position. These units are of many types and varied construction, which must be quickly analyzed and understood in the event that adjustments are necessary. Phonograph motors vary too, some operating on the induction principle using electromagnets and a revolving disc; others are of the synchronous type and designed for a definite frequency for constant speed operation. Still other phonomotors (i.e. two-speed 78 and 33 1/3 R. P. M.), those designed for A.C.-D.C. operation (which will be necessary for portable P. A. work), and the principles involved absolutely require a knowledge of electrical theory and laws.

Concerning the servicing of P. A. installations, from past experience it can be safely said that where a well-designed and constructed amplifier is installed, less than 10 per cent. of the service troubles that occur are due to power-supply or amplifier components breaking down.

The P. A. engineer must of course have a circuit and tube analyzer (the more complete and up-to-date—the better) and tools to properly service public address equipment. He should know audio amplifier circuits and values reasonably well, so that he can form a mental picture where the trouble is most likely to be when the voltage or current reading obtained with the analyzer are incorrect. His first move, when called to service a job, should be to make a study of the complete installation. amplifier and power supply employed, and the care or efficiency with which the installation was made.

A summary of various troubles and remedies generally encountered is herewith given,

LOW VOLUME

(1) Weak Microphone battery supply, materially reducing the current thoughout mike buttons and thereby reducing the output from the mike to the amplifiers. Replace batteries, if they measure low.

(2) Microphone insensitivity, due to abuse, moisture, or carbon granules packing. Replace microphone.

(3) Weak tubes: check each tube with analyzer and note if plate current of each is proper. In push-pull stages, both tubes must have approximately similar emission (plate-current) readings.

(4) Low field voltage; the fields of each speaker must be properly excited, or there will be a material loss in volume.

(5) Speakers out of phase; the cones in dynamic speakers, or diaphragms in horn units. must all "push" or "pull" at the same instant or else volume will suffer—especially when speakers are placed together or more than one horn unit is coupled to a horn. (See Chapter Three on phasing speakers.)

(6) Low line voltage; this can be generally expected to occur in rural communities or other places where the power supply feeds several towns. Low line-voltage materially reduces all tube voltages which, in turn, reduces their output.

(7) Open voice or field coil; this condition will reduce volume considerably especially where a series-parallel voice-coil arrangement is employed. Two or more speakers will be inoperative, depending on the series-parallel combination.

DISTORTION—POOR QUALITY

(1) Weak tubes; check all tnbes for emission. especially the power tubes. Where push-pull is employed, both tubes should have similar plate-current readings (tolerance of 10%).

(2) Speakers out of phase; check speakers as explained in Chapter Three.

(3) Low field excitation; field must have proper excitation or the frequency-response of the speaker will be poor, because of insensitivity of unit to weaker impulses. Check field voltages, and compare with specifications of manufacturer of unit.

(4) Bias resistor open; generally reflected in analyzer reading for plate voltage of that stage in which resistor is open.

(5) Speaker overload; volume being run too high, which will cause speaker to chatter and distort. If greater power must be had, larger speakers will be necessary.

(6) Voice coil off-center; can be checked by ascertaining if speaker is at low Volume. If speakers distort or rattle at high volume, they are probably striking the pole pieces. Re-center, or replace.

(7) Defective microphone; diaphragm has been bent or wrinkled through abuse. Some diaphragms are

stretched or "tuned," and dropping the mike will generally upset this adjustment. Try phonograph pick-ups to phono input taps, if provision for this is made, and note reproduction.

(8) Amplifier components, such as transformer, grid or plate resistors, defective—because some fault has changed their characteristics or value. Check resistance of winding or resistors with ohmmeter, or replace suspected unit and re-test.

(9) Impedance mismatch—at either input or output end. Read instructions for matching in Chapter Three carefully.

NO SOUND

(1) Check tubes—a burnt-out tube, except where push-pull or parallel tubes are used, will prevent energy from being transferred from one stage to the next. (In push-pull or parallel arrangements, distortion results if one tube has burned out.)

(2) Defective microphone; batteries (for mike current) completely dead; or carbon granules "packed" from arcing, which occurs when mike current is turned "off." The magnetic reluctance in the primary of the microphone transformer, when current is turned "off," causes an arc sufficient to burn up the carbon so that, instead of fine granules, solid masses are formed. Placing condensers across each button will reduce this arc and reduce this trouble. See chapter for carbon microphones for this information.

(3) Open transformer or resistor; place analyzer plug in each socket. If no voltage readings are obtained, when the selector switch is placed in different position corresponding to socket-terminal markings, check that stage of amplifier carefully for possible defect.

(4) No plate voltage, on all tubes, is caused by a power-supply unit defect. Check condensers (filter); although, if this unit is shorted, the plates of the rectifier tube become red under the load. Check high-voltage winding of power transformer, chokes (the speaker field if a small amplifier is used and the speaker field is employed as a choke), and voltage-divider resistors. Check rectifier tube—it may be defective.

(5) Tubes don't light; check fuse—most good amplifier power supply units are fused. If O. K., test power switch. Smell transformer to see if it is burnt. If suspicious of this unit, remove all tubes, and, with a continuity meter, insert test leads in filament or heater terminals to determinate if filament-supply winding is O. K. Be sure line plug makes good contact within receptable.

GENERAL SERVICE HINTS

(1) D. C. amplifiers will operate only when the plug is inserted in the receptacle properly; that is, if the polarity is correct. A positive potential must be impressed on the plates of the tubes, and a reversed plug will make the amplifier inoperative.

(2) For an emergency repair, where an audio coupling transformer has burned out, substitute resistance coupling (temporarily if desired) by simply inserting a coupling condenser (.02-mf. recommended) between plate and grid of the two tubes, and a plate resistor with high enough current-carrying capacity (wattage rating) to supply plate current for that tube into which it works. Generally, 75,000 to 150,000 ohms will be found satisfactory. The grid resistor should be 250,000 to 500,000 ohms. This supplies to "Class A" stages only.

(3) Always carry a spare microphone and dry-battery cells to a P. A. service call. Many installations have no spare parts equipment and, should the microphone be suspected, a quick check can be made. Where the microphone batteries are dead, new cells installed quickly will add to the prestige of the technician as a rapid trouble-shooter.

(4) Never criticize an installation, but make suggestions for improving if necessary. Knocking another man's work to get a job, or for impression's sake, will leave a bad taste if the customer has had any business experience himself (which is very likely). Perhaps the installation was made under difficulties such as limited time, poor equipment, or long ago, before the improvements you recommend were known. Suggest changes that might be made as being new, standard practice. Just remember that the best of us are

not infallible—and try to get the job of "overhauling" the installation in a sportmanlike manner.

FORMULA AND DATA

For new comers to this field an explanation regarding various expressions used in this work will not be amiss. Some are commonly used in radio work, and because of this, an attempt will be made to avoid repetition.

TRANSMISSION UNIT

Of late years the transmission unit was adopted and for a while for lack of a more suitable name, was simply known as "T. U." In honor of the late Dr. Alexander Graham Bell, the inventor of the telephone, the term "T. U" was changed to "BEL": since "T. U" was considered too large for convenient use as a standard. Hence one-tenth of this unit is now internationally used. and is called the "decibel" (D. B.)

THE DECIBEL

The "decibel" is defined as ten times the common logarithm of the ratio between any two powers or,

$$DB = 10\ LOG_{10}$$

$$\frac{P_1}{P_2} = 10\ LOG_{10} \frac{I^2 R_1}{I^2 R_2}$$

This expresses the amplification ratio in a logarithm form. which bears a direct relation to the characteristics of the human ear. While the power ratio between two sounds may be measured as 1,000, actually, the ear detects the louder of the two as being only thirty levels higher than the weaker signal.

The "decibel" neglects differences in sound which would not be detected by the human ear. A difference of one "DB" can just be noted by the average ear. That is, the signal must be measured as being twenty-five per cent. louder, before this difference in amplification can be uoted by the ear. A loss or gain DB Chart is given in Fig. 53.

CURRENT RATIOS

Considering the ratio of two currents or voltages. the gain or loss in "DB" is expressed as:

$$20 \times LOG \frac{I_1}{I_2} \text{ or } 20 \times LOG_{10} \frac{E_1}{E_2}$$

(assuming both input and output impedances are equal, so that the square of their ratios would be equal to the power ratio.) The reason for the introduction of the factor 20 is now apparent; for, when a number is squared, its logarithm is doubled.

When the input and output impedances of an amplifier are not equal, our current gain becomes:

$$DB = 20 \times LOG_{10} \frac{I_1 \sqrt{R_1}}{I_2 \sqrt{R_2}}$$

The voltage gain:

$$DB = 20 \times LOG_{10} \frac{\frac{E_1}{\sqrt{R_1}}}{\frac{E_2}{\sqrt{R_2}}}$$

PROBLEMS

Ex. What "DB" gain corresponds to a power ratio of 1,000; of 100; of 10?

Answer. 30 D. B.; 20 D. B.; and 10 D. B.

Ex. An amplifier has a power gain of 60 D. B., what is the power ratio?

Answer. (Here the reverse of the process in the calculation of D. B. from power ratio is used.

P = Power ratio

$10 \times LOG\ P = 60$

$LOG\ P = 60/10 = 6$

$P = 10_6 = 1{,}000{,}000$

Ex. What is the approximate current ratio?

Answer. (The current ratio is equal to the square root of the power ratio).

$$\frac{I_1}{I_2} = \sqrt{\frac{P_1}{P_2}} = \sqrt{10_6} = 10_3 = 1{,}000.$$

Ex. An amplifier delivers an output of 1,000 milliwatts; the input power is 5 milliwatts. Assuming equal input and output impedances, what is its output power ratio? Compute the gain in Decibles:

Answer.

$$\frac{P_1}{P_2} = \frac{1000}{5} = 200$$

$10 \times LOG\ 200 = 23$ D.B.

Ex. An amplifier delivers an output power of 700 milliwatts. We wish to employ an amplifier of greater output. Would we be justified in substituting an amplifier delivering an output power of 1,000?

Answer. No, because the gain in D. B. of our present amplifier is 10 × LOG 700 = 28.4 D. B.; of the new amplifier, 10×LOG 1000=30 D. B.

The added gain (30 — 28.4 = 1.6 D.B.) would be a change barely noticeable.

CALCULATING AMMETER SHUNTS.

By the addition of a shunt resistance of the proper value, the range of an ampere-meter can be doubled or increased to any desired multiple of its former scale. We will present simple calculations from which the experimenter can determine the value of shunt resistance required to increase the range of his ammeter or milliammeter. Before doing so, it is necessary to procure or ascertain the internal resistance of the meter, which will be readily supplied by the manufacturer or can be measured.

The formula for the calculation is:

$$Rs = \frac{Ia}{Is} \times Ra$$

Where Rs is the resistance of the shunt.

Ra is the internal resistance of the meter.

Ia is the full scale deflection of the meter in amperes.

Is is the current through the shunt.

Example

Suppose we have a meter with a full-scale deflection of one milliampere. We wish to increase the range of the meter so that it will indicate curents as high as 50 milliamperes. We find the internal resistance of the meter to be 30 ohms. To calculate the required shunt resistance:

Total current we wish to read = .05 amperes.

Current through meter = .001 ampere.

Current through shunt = .001 ampere subtracted from .05 ampere = .049 ampere.

Resistance of meter = 30 ohms.

Hence Ia = .001 ampere

Is = .049 ampere

Ra = .03 ohms

Rs = .001 ÷ .049 × 30 = 0.612 ohms.

Therefore a shunt resistance of .612 ohms will increase the range of our meter to a full-scale deflection of 0-50 milliamperes.

MULTIPLYING FACTOR

The multiplying factor of any meter equipped with a shunt can be determined from:

$$\frac{Rs + Ra}{Rs}$$

From whence, as in the example last given:

$$\frac{.612 + 30}{.612} = 50$$

CAPACITY REACTANCE

To find Reactance of a condenser:

$$X = \frac{1{,}000{,}000 \text{ ohms}}{6.3xfxC}$$

where f = frequency in cycles

C = capacity in microfarads.

Thus, if we have a 1 mf. condenser and we wish to ascertain its reactance (A.C. resistance) at 100 cycles, we have

$$X = \frac{1{,}000{,}000}{6.3 \times 100 \times 1} = 1508 \text{ ohms}$$

To find impedance of a circuit containing capacity and resistance:

$$X \text{ (ohms)} = \sqrt{R_2 + X_2}$$

Where R = resistance

X = reactance of condenser

To find the reactance of an inductance:

X = 6.3xfxL

where f = frequency

L = inductance in henries

Thus, if we have an inductance of 1 henry and wish to calculate its reactance at 60 cycles

then X = 6.3 x 60 x 1, or 378 ohms.

To find the impedance of a circuit containing inductance, capacity, and resistance we must consider that a condenser tends to produce changes in a current, whereas inductance opposes any change—i.e. the two buck each other. The formula employed are XL—XC (or XC—XL, whichever is larger) = X

where XL = reactance of inductance

XC = reactance of condenser

Then $\sqrt{X_2 + R_2}$ is the resultant impedance of the circuit.

For example, assuming that we have a condenser and inductance whose reactance are 100 ohms and 225 ohms respectively, and the resistance of the circuit which they are in is 100 ohms, then to find the impedance of this arrangement:

(Xl) (Xc)

225 — 100 = 125 (resultant reactance)

$\sqrt{100^2 + 125^2}$

$\sqrt{15,625 + 10,000} = \sqrt{25,625}$

=160 ohms impedance

- 160 ohms impedance

CONCLUSION

The information contained in this book is by no means all that the P. A. man should know. It has been with no little difficulty that technical, or mathematical expressions have been avoided as much as possible, so that the layman or average "good' radio man could understand it. Salient points about amplifiers, speakers, microphones, and installation practice have been taken care of.

For more advanced information on amplifiers or acoustics, reference can be made to contemporary literature.

CHAPTER VII

USEFUL CHARTS AND TABLES

THE FOLLOWING CHARTS AND TABLES ARE PROVIDED FOR THE P.A. AND RADIO SERVICE-MAN AS TIME SAVERS IN THEIR DAILY ENDEAVORS. VARIOUS OF THESE TABLES HAVE BEEN DAILY REFERENCE MATERIAL FOR THE AUTHOR IN HIS WORK AND IT IS HOPED THE USERS OF THIS MANUAL WILL FIND THEM EQUALLY VALUABLE IN THEIR WORK.

B.B.B.

R. M. A. COLOR CODE For RESISTORS

Unit—OHMS

Body Color		End Color		Dot Color	
Black	0	Black	0		
Brown	1	Brown	1	Brown	0
Red	2	Red	2	Red	00
Orange	3	Orange	3	Orange	000
Yellow	4	Yellow	4	Yellow	0,000
Green	5	Green	5	Green	00,000
Blue	6	Blue	6	Blue	000,000
Purple	7	Purple	7	Purple	0,000,000
Gray	8	Gray	8	Gray	00,000,000
White	9	White	9	White	000,000,000

R. M. A. COLOR CODE For CONDENSERS

Unit—mmf.
Micro-microfarad

First Dot		Second Dot		Third Dot	
Black	0	Black	0		
Brown	1	Brown	1	Brown	0
Red	2	Red	2	Red	00
Orange	3	Orange	3	Orange	000
Yellow	4	Yellow	4	Yellow	0,000
Green	5	Green	5	Green	00,000
Blue	6	Blue	6	Blue	000,000
Purple	7	Purple	7	Purple	0,000,000
Gray	8	Gray	8	Gray	00,000,000
White	9	White	9	White	000,000,000

TABLE OF AUDIO FREQUENCY LIMITS OF VARIOUS MUSICAL INSTRUMENTS

INSTRUMENT	LOWER LIMIT		UPPER LIMIT	
	Physical Pitch Key	Frequency C.P.S.	Physical Pitch Key	Frequency C.P.S.
Pipe Organ	-	16	-	16000
Piano	C_2	64	c^2	1024
Human Voice:				
Bass	F_2	85.3	F	341.3
Baritone	G_2	96	G	384
Tenor	C_1	128	B^1	480
Alto	F_1	170.6	F^1	682.6
Soprano	B	240	F^1	682.6
Bass Viol	E_3	40	B	240
Cello	C_2	64	F^1	682.6
Viola	C_1	128	D^2	1152
Violin	G_1	192	G^3	3072
Kettle Drum	F_2	85.3	F^1	682.6
Bass Tuba	F_3	44	F	341.3
Bassoon	B_2	60	B^1	480
Bass Clarinet	F_2	85.3	B^1	480
Trombone	F_2	85.3	B^1	480
French Horn	A_1	106.6	A_2	853.3
Trumpet	E_1	160	B_2	960
Clarinet	E_1	160	G_2	1536
Oboe	C	256	G_2	1536
Flute	C	256	D^3	2304
Piccolo	C^1	512	D^4	4608
Human Ear	-	16	-	16000

MUSICAL SCALE

KEY	FREQUENCY C.P.S. Inter'n'l Pitch	FREQUENCY C.P.S. Physical Pitch
A_3	-	-
B_3	-	30
C_3	-	32
D_3	-	36
E_3	-	40
F_3	-	-
G_3	-	48
A_2	-	-
B_2	-	60
C_2	64.6	64
D_2	72.5	72
E_2	81.4	80
F_2	86.3	85.3
G_2	96.8	96
A_1	108.7	106.6
B_1	122	120
C_1	129.3	128
D_1	145.1	144
E_1	162.9	160
F_1	172.6	170.6
G_1	193.7	192
A	217.5	213.3
B	244.1	240
C	258.6	*256
D	290.3	288
E	325.8	320

KEY	FREQUENCY C.P.S. Inter'n'l Pitch	FREQUENCY C.P.S. Physical Pitch
F	345.2	341.3
G	387.5	384
A^1	435	426.6
B^1	488.2	480
C^1	517.3	512
D^1	580.6	576
E^1	651.7	640
F^1	690.5	682.6
G	775	768
A^2	870	853.3
B^2	976.5	960
C^2	1034.6	1024
D^2	-	1152
E^2	-	1280
F^2	-	-
G^2	-	1536
A^3	-	-
B^3	-	1920
C^3	-	2048
D^3	-	2304
E^3	-	2560
F^3	-	-
G^3	-	3072
A^4	-	-
B^4	-	3840
C^4	-	4096
D^4	-	4608
E^4	-	5120

* - Middle C

TABLE OF IMPEDANCES

in Henries Inductance	Approximate Impedance "Z" in Ohms		
	1000 C.P.S.	400 C.P.S.	60 C.P.S.
1 h	6500 ohms	2500 ohms	390 ohms
2 h	12500 "	5100 "	750 "
5 h	31500 "	11250 "	1900 "
10 h	64000 "	26000 "	3800 "
20 h	125000 "	50000 "	7500 "
30 h	200000 "	75000 "	12000 "
40 h	260000 "	110000 "	15000 "
50 h	320000 "	130000 "	19000 "
60 h	390000 "	160000 "	23000 "
70 h	450000 "	175000 "	27000 "
80 h	510000 "	200000 "	31000 "
90 h	570000 "	225000 "	35000 "
100 h	650000 "	250000 "	39000 "

Capacity in Microfarads	Approximate Impedance "Z" in Ohms		
	1000 C.P.S.	400 C.P.S.	60 C.P.S.
.001 MF	160000 ohms	400000 ohms	3000000 ohms
.005 "	32500 "	72000 "	520000 "
.01 "	16000 "	40000 "	265000 "
.02 "	8000 "	20000 "	132600 "
.05 "	3250 "	8000 "	53000 "
.1 "	1600 "	4000 "	26000 "
.5 "	325 "	800 "	5500 "
1.0 "	160 "	400 "	2700 "
5.0 "	32 "	76 "	530 "
10.0 "	16 "	40 "	250 "

TABLE FOR DETERMINING CORRECT TURNS RATIO FOR CORRECT IMPEDANCE MATCHING

IMPEDANCE MATCHING SIMPLIFIED

Impedance matching transformers must have a turns ratio equal to the square root of the ratio of the 2 impedances. In the table below, "Z ratio" is the number obtained by dividing the larger impedance by the smaller. The "T ratio" is the required turns ratio for a good match. Example: the load for a 47 pentode is 7,000 ohms; voice coil of speaker is 6 ohms, ratio, 1,167. The number nearest to this is 1,156, indicating a 34 to 1 transformer. This will be **step-down** as the larger number of turns always connects to the larger impedance. For impedance ratios below 121, square numbers below 11; choose the square that is nearest the impedance ratio; original number is then transformer ratio. For smaller impedance ratios, fractional T ratios may be necessary. Thus a 3½ to 1 transformer matches a Z ratio of 12, also 13.

TABLE OF "Z" AND "T" RATIOS

Z Ratio	T Ratio	Z Ratio	T Ratio	Z Ratio	T Ratio	Z Ratio	T Ratio
121	11	361	19	729	27	1225	35
144	12	400	20	784	28	1296	36
169	13	441	21	841	29	1369	37
196	14	484	22	900	30	1444	38
225	15	529	23	961	31	1521	39
256	16	576	24	1024	32	1600	40
289	17	625	25	1089	33	1681	41
324	18	676	26	1156	34	1764	42

DYNAMIC SPEAKER BAFFLE TABLE

Lowest Frequency Desired	Length of Air Path
16 C. P. S.	16.87 FEET
20 C. P. S.	13.5 FEET
30 C. P. S.	9.0 FEET
40 C. P. S.	6.75 FEET
50 C. P. S.	5.4 FEET
60 C. P. S.	4.5 FEET
70 C. P. S.	3.856 FEET
80 C. P. S.	3.375 FEET
90 C. P. S.	3.0 FEET
100 C. P. S.	2.75 FEET
125 C. P. S.	2.153 FEET
150 C. P. S.	1.8 FEET
200 C. P. S.	1.5 FEET
500 C. P. S.	6.48 INCHES
1000 C. P. S.	3.25 INCHES

The important point to notice in the above table is that the required length of the air path decreases as the frequency goes up. At 1000 cycles, for example, the air path need be only 3½ inches. Since the average distance from the center of the front to the center of the back of an ordinary 10 inch diameter cone is something like 6 inches it follows that the cone itself is an effective baffle at high frequencies. Therefore the baffle we place around the cone is only important at low frequencies and its size should be determined by the lowest frequency we desire to reproduce. If we want to reproduce down to 60 cycles we must have an air path of 4½ feet; (see table above) if 30 cycles is the lower limit then the air path must be 9 feet.

AIR PATH IS MEASURED FROM CENTER OF REAR OF CONE AROUND THE BAFFLE TO CENTER OF FRONT OF CONE.

RESISTANCE-COUPLED AMPLIFIER CHART

C = BLOCKING CONDENSER (µf)
Ce = CATHODE BY-PASS CONDENSER (µf)
Cd = SCREEN BY-PASS CONDENSER (µf)
Ebb = PLATE-SUPPLY VOLTAGE (Volts)
Eo = VOLTAGE OUTPUT (Peak Volts)
Rc = CATHODE RESISTOR (Ohms)
Rd = SERIES SCREEN RESISTOR (Megohms)
Rg = GRID RESISTOR (Megohms)
RL = PLATE RESISTOR (Megohms)
V.G. = VOLTAGE GAIN

TRIODE TYPES: 2A6, 75

Ebb [1]	90									180									300									Ebb [1]
RL	0.1			0.25			0.5			0.1			0.25			0.5			0.1			0.25			0.5			RL
Rg [2]	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	Rg [2]
Rc	6300	6600	6700	10000	11000	11500	16200	16600	17400	2600	2900	3000	4300	4800	5300	7000	8000	8800	1900	2200	2300	3300	3900	4200	5300	6100	7000	Rc
Cc	2.2	1.7	1.7	1.24	1.07	0.9	0.75	0.7	0.65	3.3	2.9	2.7	2.1	1.8	1.5	1.3	1.1	0.9	4	3.5	3	2.7	2	1.8	1.6	1.5	1.2	Cc
C	0.02	0.01	0.006	0.01	0.006	0.003	0.005	0.003	0.0015	0.025	0.015	0.007	0.015	0.007	0.004	0.007	0.004	0.002	0.03	0.015	0.007	0.015	0.007	0.004	0.007	0.004	0.002	C
Eo [3]	3	5	6	5	7	10	7	10	13	16	22	23	21	28	33	25	33	38	31	41	45	42	51	60	47	62	67	Eo [3]
V.G. [4]	23 [d]	29 [b]	31 [c]	34 [b]	40 [c]	40	39	44	48	29	36	37	43	50	53	52	57	58	31	39	42	48	53	56	58	60	63	V.G. [4]

TRIODE TYPE 6F5

Ebb [1]	90									180									300									Ebb [1]
RL	0.1			0.25			0.5			0.1			0.25			0.5			0.1			0.25			0.5			RL
Rg [2]	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	Rg [2]
Rc	4400	4800	5000	8000	8800	9000	12200	13500	14700	1800	2000	2200	3500	4100	4500	6100	6900	7700	1300	1600	1700	2600	3200	3500	4500	5400	6100	Rc
Cc	2.5	2.1	1.8	1.33	1.18	0.9	0.76	0.67	0.58	4.4	3.3	2.9	2.3	1.8	1.7	1.3	0.9	0.83	5	3.7	3.2	2.5	2.1	2	1.5	1.2	0.93	Cc
C	0.02	0.01	0.005	0.01	0.005	0.003	0.005	0.003	0.0015	0.025	0.015	0.006	0.01	0.006	0.004	0.006	0.003	0.0015	0.025	0.01	0.006	0.01	0.007	0.004	0.006	0.004	0.002	C
Eo [3]	4	5	6	6	7	10	8	10	12	16	23	25	21	26	32	24	33	37	33	43	48	41	54	63	50	62	70	Eo [3]
V.G. [4]	28 [d]	34 [b]	35 [c]	39 [b]	43 [c]	44	43	46	48	37	44	46	48	53	57	53	63	66	42	49	52	56	63	67	65	70	70	V.G. [4]

TWIN-TRIODE TYPES: 6A6, 6N7, 53 (ONE TRIODE UNIT)

Ebb [1]	90									180									300									Ebb [1]
RL	0.1			0.25			0.5			0.1			0.25			0.5			0.1			0.25			0.5			RL
Rg [2]	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	Rg [2]
Rc	1900	2250	2500	4050	4950	5400	7000	8500	9650	1300	1700	1950	2950	3800	4300	5250	6600	7650	1150	1500	1750	2850	3400	4000	4850	6100	7150	Rc
C	0.025	0.01	0.006	0.01	0.006	0.003	0.006	0.003	0.0015	0.03	0.015	0.007	0.015	0.007	0.0035	0.007	0.0035	0.002	0.03	0.015	0.007	0.015	0.0055	0.003	0.0055	0.003	0.0015	C
Eo [3]	13	19	20	16	20	24	18	23	26	35	46	50	40	50	57	44	54	61	60	83	86	75	87	100	76	94	104	Eo [3]
V.G. [4]	16	19	20	20	22	23	22	23	23	19	21	22	23	24	24	24	25	25	20	22	23	23	24	24	23	24	24	V.G. [4]

TWIN-TRIODE TYPE 79 (ONE TRIODE UNIT)

(COURTESY R.C.A.)

Ebb [1]	90									180									300									Ebb [1]
RL	0.1			0.25			0.5			0.1			0.25			0.5			0.1			0.25			0.5			RL
Rg [2]	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	Rg [2]
Rc	2050	2200	2350	4000	4250	4650	6150	6850	7500	1050	1250	1350	2050	2450	2750	3450	4100	4650	800	1000	1100	1650	2050	2350	2850	3600	4450	Rc
C	0.04	0.015	0.009	0.015	0.006	0.004	0.006	0.004	0.002	0.04	0.02	0.009	0.02	0.01	0.005	0.009	0.0035	0.002	0.025	0.01	0.006	0.01	0.0055	0.003	0.0055	0.003	0.0015	C
Eo [3]	5.8	8.4	9.5	7.1	9.7	12	8.8	12	15	21	27	31	26	34	40	30	39	44	40	57	60	56	66	77	61	75	82	Eo [3]
V.G. [4]	23 [b]	29 [c]	29	31 [c]	33	35	34	38	40	27	31	34	37	41	42	42	44	45	29	34	36	39	42	43	44	46	46	V.G. [4]

TRIODE TYPES: 56, 76

Ebb[2]	90								
RL	0.05			0.1			0.25		
Rg[2]	0.05	0.1	0.25	0.1	0.25	0.5	0.25	0.5	1
Rc	2500	3200	3800	4500	6500	7500	11100	15100	18300
Cc	2	1.6	1.25	1.05	0.82	0.68	0.48	0.36	0.32
C	0.06	0.03	0.015	0.03	0.015	0.007	0.015	0.007	0.0035
Eo[3]	16	21	23	19	23	25	21	24	28
V.G.[4]	7	7.7	8.1	8.1	8.9	9.3	9.4	9.7	9.8

Ebb[2]	180								
RL	0.05			0.1			0.25		
Rg[2]	0.05	0.1	0.25	0.1	0.25	0.5	0.25	0.5	1
Rc	2400	3000	3700	4500	6500	7600	10700	14700	17700
Cc	2.5	1.9	1.65	1.45	0.97	0.8	0.6	0.45	0.4
C	0.06	0.035	0.015	0.035	0.015	0.008	0.015	0.007	0.0045
Eo[3]	36	48	55	45	55	57	49	59	64
V.G.[4]	7.7	8.2	9	9.3	9.5	9.8	9.7	10	10

Ebb[2]	300								
RL	0.05			0.1			0.25		
Rg[2]	0.05	0.1	0.25	0.1	0.25	0.5	0.25	0.5	1
Rc	2400	3100	3800	4500	6400	7500	11100	15200	18300
Cc	2.8	2.2	1.8	1.6	1.2	0.98	0.69	0.5	0.4
C	0.08	0.045	0.02	0.04	0.02	0.009	0.02	0.009	0.005
Eo[3]	65	80	95	74	95	104	82	96	108
V.G.[4]	8.3	8.9	9.4	9.5	10	10	10	10	10

TYPES: 6C5 (TRIODE), AND 6C6, 6J7, 57 (AS TRIODES)

Ebb[2]	90								
RL	0.05			0.1			0.25		
Rg[2]	0.05	0.1	0.25	0.1	0.25	0.5	0.25	0.5	1
Rc	2800	3400	3800	4800	6400	7500	11400	14500	17300
Cc	2	1.62	1.3	1.12	0.84	0.66	0.52	0.4	0.33
C	0.05	0.025	0.01	0.025	0.01	0.005	0.01	0.006	0.004
Eo[3]	14	17	20	16	22	23	18	23	26
V.G.[4]	9	9	10	10	11	12	12	12	13

Ebb[2]	180								
RL	0.05			0.1			0.25		
Rg[2]	0.05	0.1	0.25	0.1	0.25	0.5	0.25	0.5	1
Rc	2200	2700	3100	3900	5300	6200	9500	12300	14700
Cc	2.2	2.1	1.85	1.7	1.25	1.2	0.74	0.55	0.47
C	0.055	0.03	0.015	0.035	0.015	0.008	0.015	0.008	0.004
Eo[3]	34	45	54	41	54	55	44	52	59
V.G.[4]	10	11	11	12	12	13	13	13	13

Ebb[2]	300								
RL	0.05			0.1			0.25		
Rg[2]	0.05	0.1	0.25	0.1	0.25	0.5	0.25	0.5	1
Rc	2100	2600	3100	3800	5300	6000	9600	12300	14000
Cc	3.16	2.3	2.2	1.7	1.3	1.17	0.9	0.59	0.37
C	0.075	0.04	0.015	0.035	0.015	0.008	0.015	0.008	0.003
Eo[3]	57	70	83	65	84	88	73	85	97
V.G.[4]	11	11	12	12	13	13	13	14	14

DUPLEX-DIODE TRIODE TYPE 6Q7

Ebb[2]	90								
RL	0.1			0.25			0.5		
Rg[2]	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2
Rc	4000	4200	4300	7200	7600	8000	11500	12300	13700
Cc	2.07	1.7	1.5	1.17	1.2	0.9	0.72	0.6	0.45
C	0.02	0.01	0.005	0.01	0.006	0.003	0.006	0.003	0.0015
Eo[3]	5	8	9	8	11	13	9	13	17
V.G.[4]	23[a]	28[b]	29[c]	31[b]	32	33	31	33	37

Ebb[2]	180								
RL	0.1			0.25			0.5		
Rg[2]	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2
Rc	1600	1900	2100	3400	4000	4500	6000	7100	7900
Cc	3	2.5	2.3	1.6	1.3	1.05	0.86	0.76	0.63
C	0.02	0.01	0.005	0.01	0.005	0.003	0.006	0.003	0.002
Eo[3]	19	26	29	25	31	37	30	36	41
V.G.[4]	28	33	35	36	38	40	39	40	41

Ebb[2]	300								
RL	0.1			0.25			0.5		
Rg[2]	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2
Rc	1200	1500	1700	2600	3000	3600	4600	5500	6200
Cc	4.4	3.6	3.05	2.4	1.66	1.45	1.2	0.9	0.9
C	0.03	0.015	0.007	0.015	0.007	0.004	0.007	0.004	0.002
Eo[3]	35	52	53	43	52	62	47	60	66
V.G.[4]	34	39	40	42	45	45	45	5	47

(COURTESY R.C.A.)

DUPLEX-DIODE TRIODE TYPE 6R7

Ebb[2]	90								
RL	0.05			0.1			0.25		
Rg[2]	0.05	0.1	0.25	0.1	0.25	0.5	0.25	0.5	1
Rc	2500	2600	2900	3500	4400	5000	7600	9800	11300
Cc	2	1.7	1.27	1.2	0.9	0.77	0.54	0.42	0.38
C	0.05	0.03	0.01	0.03	0.01	0.006	0.015	0.007	0.003
Eo[3]	14	18	20	15	19	21	15	18	21
V.G.[4]	8	9	10	10	10	11[a]	10	11	11

Ebb[2]	180								
RL	0.05			0.1			0.25		
Rg[2]	0.05	0.1	0.25	0.1	0.25	0.5	0.25	0.5	1
Rc	1700	2100	2500	3000	4100	4600	6700	8800	10000
Cc	2.3	1.9	1.5	1.3	0.9	0.8	0.54	0.4	0.33
C	0.05	0.03	0.01	0.03	0.01	0.006	0.01	0.006	0.003
Eo[3]	31	40	45	35	43	46	33	40	47
V.G.[4]	9	9	10	10	10	10	10	10	11

Ebb[2]	300								
RL	0.05			0.1			0.25		
Rg[2]	0.05	0.1	0.25	0.1	0.25	0.5	0.25	0.5	1
Rc	1600	2000	2400	2900	3800	4400	6300	8400	10600
Cc	2.6	2	1.6	1.4	1.1	1	0.7	0.5	0.44
C	0.055	0.03	0.015	0.03	0.015	0.007	0.015	0.007	0.004
Eo[3]	50	62	71	52	68	71	54	62	74
V.G.[4]	9	9	10	10	10	10	10	11	11

DUPLEX-DIODE TRIODE TYPES: 55, 85

Ebb[1]	90									180									300									Ebb[1]
RL	0.05			0.1			0.25			0.05			0.1			0.25			0.05			0.1			0.25			RL
Rg[2]	0.05	0.1	0.25	0.1	0.25	0.5	0.25	0.5	1	0.05	0.1	0.25	0.1	0.25	0.5	0.25	0.5	1	0.05	0.1	0.25	0.1	0.25	0.5	0.25	0.5	1	Rg[2]
Rc	3800	4600	5400	6620	9000	10300	15100	20500	24400	3200	4100	5000	6200	8700	10000	14500	20000	24000	3200	4100	5100	5900	8300	9600	14300	19400	23600	Rc
Cc	1.4	1.1	0.86	0.7	0.55	0.5	0.31	0.25	0.2	1.8	1.6	1.2	0.9	0.7	0.57	0.43	0.29	0.24	1.9	1.5	1.2	0.8	0.54	0.43	0.3	0.22	0.2	Cc
C	0.06	0.03	0.015	0.04	0.015	0.007	0.015	0.007	0.004	0.06	0.045	0.02	0.04	0.015	0.008	0.015	0.008	0.004	0.08	0.045	0.015	0.03	0.015	0.006	0.01	0.006	0.003	C
Eo[3]	16	19	23	17	22	25	18	23	26	33	44	49	37	47	50	40	48	53	50	74	85	64	82	88	71	84	94	Eo[a]
V.G.[4]	4.5	4.9	5.1	5.1	5.4	5.5	5.3	5.5	5.6	4.9	5.2	5.3	5.3	5.5	5.5	5.6	5.7	5.7	5.2	5.5	5.6	5.5	5.7	5.8	5.7	5.7	5.8	V.G.[4]

DUPLEX-DIODE PENTODE TYPES: 2B7, 6B7, 6B8

Ebb[1]	90									180									300									Ebb[1]
RL	0.1			0.25			0.5			0.1			0.25			0.5			0.1			0.25			0.5			RL
Rg[2]	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	Rg[2]
Rd	0.37	0.5	0.6	1.18	1.1	1.35	2.6	2.8	2.9	0.44	0.5	0.6	1.18	1.2	1.5	2.6	2.8	3	0.5	0.55	0.6	1.2	1.2	1.5	2.7	2.9	3.4	Rd
Rc	2000	2200	2000	3500	3500	3500	5000	6000	6200	1000	1200	1200	1900	2100	2200	3300	3500	3500	950	1100	900	1500	1600	1800	2400	2500	2800	Rc
Cd	0.07	0.07	0.06	0.04	0.04	0.04	0.04	0.04	0.04	0.08	0.08	0.07	0.05	0.06	0.05	0.04	0.04	0.04	0.09	0.09	0.08	0.06	0.06	0.08	0.05	0.05	0.05	Cd
Cc	3	3	2.8	1.9	2.1	1.9	1.5	1.55	1.5	4.4	4.4	4	2.7	3.2	3	2.1	2	2.2	4.6	5	4.8	3.2	3.5	4	2.5	2.3	2.8	Cc
C	0.02	0.01	0.006	0.008	0.007	0.003	0.004	0.003	0.003	0.02	0.015	0.008	0.01	0.007	0.003	0.005	0.003	0.002	0.025	0.015	0.009	0.015	0.008	.0.004	0.006	0.003	0.0025	C
Eo[3]	19	28	29	26	33	32	22	29	27	30	52	53	39	55	53	47	55	53	60	89	86	70	100	95	80	120	90	Eo[3]
V.G.[4]	24	33	37	43	55	65	63	85	100	30	41	46	55	69	83	81	115	116	36	47	54	64	79	100	96	150	145	V.G.[4]

PENTODE TYPES: 6C6, 6J7, 57

Ebb[1]	90									180									300									Ebb[1]
RL	0.1			0.25			0.5			0.1			0.25			0.5			0.1			0.25			0.5			RL
Rg[2]	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	Rg[2]
Rd	0.37	0.44	0.44	1.1	1.18	1.4	2.18	2.6	2.7	0.44	0.5	0.5	1.1	1.18	1.4	2.45	2.9	2.7	0.44	0.5	0.53	1.18	1.18	1.45	2.45	2.9	2.95	Rd
Rc	1200	1100	1300	2400	2600	3600	4700	5500	5500	1000	750	800	1200	1600	2000	2600	3100	3500	500	450	600	1100	1200	1300	1700	2200	2500	Rc
Cd	0.05	0.05	0.05	0.03	0.03	0.025	0.02	0.05	0.02	0.05	0.05	0.05	0.04	0.04	0.04	0.03	0.025	0.02	0.07	0.07	0.06	0.04	0.04	0.05	0.04	0.04	0.04	Cd
Cc	5.2	5.3	4.8	3.7	3.2	2.5	2.3	2	2	6.5	6.7	6.7	5.2	4.3	3.8	3.2	2.5	2.8	8.5	8.3	8	5.5	5.4	5.8	4.2	4.1	4	Cc
C	0.02	0.01	0.006	0.008	0.005	0.003	0.005	0.0025	0.0015	0.02	0.01	0.006	0.008	0.005	0.0035	0.005	0.0025	0.0015	0.02	0.01	0.006	0.008	0.005	0.005	0.005	0.003	0.0025	C
Eo[3]	17	22	33	23	32	33	28	29	27	42	52	59	41	60	60	45	56	60	55	81	96	81	104	110	75	97	100	Eo[3]
V.G.[4]	41	55	66	70	85	92	93	120	140	51	69	83	93	118	140	135	165	165	61	82	94	104	140	185	161	350	240	V.G.[4]

(COURTESY R.C.A.)

[1] Voltage at plate equals Plate-Supply Voltage minus voltage drop in RL and Rc. For other supply voltages differing by as much as 50% from those listed, the values of resistors, condensers, and gain are approximately correct. The value of voltage output, however, for any of these other supply voltages equals the listed voltage output multiplied by the new plate-supply voltage divided by the plate-supply voltage corresponding to the listed voltage output.

[2] For following stage

[3] Voltage across Rg at grid-current point.

[4] Voltage Gain at 5 volts (RMS) output unless index letter indicates otherwise.

[a] At 2 volts (RMS) output.

[b] At 3 volts (RMS) output.

[c] At 4 volts (RMS) output.

[d] At 2.2 volts (RMS) output.

POWER RESISTORS

Table of current capacity and allowable voltages.

Resistance in Ohms	3 Watt Resistor		10 Watt Resistor	
	Amperes	Volts	Amperes	Volts
1	1.730	1.730	3.163	3.163
1.5	1.410	2.115	2.572	3.858
2	1.224	2.448	2.235	4.470
2.5	1.097	2.742	2.000	5.100
3	1.000	3.000	1.835	5.505
3.5	.970	3.395	1.689	5.911
4	.866	3.440	1.579	6.316
5	.774	3.870	1.414	7.070
7.5	.632	4.740	1.154	8.655
10	.547	5.470	1.000	10.000
15	.447	6.705	.816	12.240
20	.389	7.780	.708	14.160
25	.346	8.650	.632	15.800
30	.316	9.480	.577	17.310
35	.292	10.220	.534	18.690
40	.274	10.960	.500	20.000
50	.245	12.250	.447	22.350
75	.200	15.000	.365	27.375
100	.173	17.300	.316	31.600
150	.141	21.150	.258	38.700
200	.122	24.400	.223	44.600
250	.109	27.250	.200	50.000
300	.100	30.000	.182	54.600
350	.097	33.950	.169	59.150
400	.086	34.400	.158	63.200
500	.077	38.500	.141	70.500
750	.063	46.650	.115	86.250
1,000	.054	54.000	.100	100.000
1,500	.044	66.000	.081	121.500
2,000	.038	76.000	.070	140.000
2,500	.034	85.500	.063	157.000
3,000	.031	93.000	.057	171.000
3,500	.030	105.000	.053	185.500
4,000	.027	108.000	.050	200.000
5,000	.024	120.000	.044	220.000
7,500	.020	150.000	.036	270.000
10,000	.017	170.000	.031	310.000
15,000	.014	210.000	.025	375.000
20,000	.012	240.000	.022	440.000
25,000	.011	265.000	0.20	500.000
30,000	.010	300.000	.017	510.000
35,000	.009	315.000	.015	525.000
40,000	.008	320.000	.014	560.000
50,000	.007	350.000	.013	650.000
75,000	.006	450.000	.011	825.000
100,000	.005	540.000	.010	1,000.000

RADIO-CRAFT'S AUGMEN

Gauge No. B.&S.	Diam. in mils.*	Diam. in m m.	Cross-sectional area Cir. mils	Sq. Inches	Sq. m m.	Turns per linear inch[2] D.C.C.	D.S.C. or S.C.C.	Enamel	S.S.C.
0000	460.0	11.68	211600	.1662	107.2	—	—	—	—
000	409.6	10.40	167800	.1318	85.03	—	—	—	—
00	364.8	9.266	133100	.1045	67.43	—	—	—	—
0	324.9	8.252	105500	.08289	53.48	—	—	—	—
1	289.3	7.348	83690	.06573	42.41	—	—	—	—
2	257.6	6.544	66370	.05213	33.63	—	—	—	—
3	229.4	5.827	52640	.04134	26.67	—	—	—	—
4	204.3	5.189	41740	.03278	21.15	—	—	—	—
5	181.9	4.621	33100	.02600	16.77	—	—	—	—
6	162.0	4.115	26250	.02062	13.3	—	—	—	—
7	144.3	3.665	20820	.01635	10.55	—	—	—	—
8	128.5	3.264	16510	.01297	8.36	7.1	7.4	7.6	—
9	114.4	2.906	13090	.01028	6.63	7.8	8.2	8.6	—
10	101.9	2.588	10380	.008155	5.26	8.9	9.3	9.6	—
11	90.74	2.305	8234	.006467	4.17	9.8	10.3	10.7	—
12	80.81	2.053	6530	.005129	3.31	10.9	11.5	12.0	—
13	71.96	1.828	5178	.004067	2.62	12.0	12.8	13.5	—
14	64.08	1.628	4107	.003225	2.08	13.3	14.2	15.0	—
15	57.07	1.450	3257	.002558	1.65	14.7	15.8	16.8	—
16	50.82	1.291	2583	.002028	1.31	16.4	17.9	18.9	18.9
17	45.26	1.150	2048	.001609	1.04	18.1	19.9	21.2	21.2
18	40.30	1.024	1624	.001276	.82	19.8	22.0	23.6	23.6
19	35.89	.9116	1288	.001012	.65	21.8	24.4	26.4	26.4
20	31.96	.8118	1022	.0008023	.52	23.8	27.0	29.4	29.4
21	28.46	.7230	810.1	.0006363	.41	26.0	29.8	33.1	32.7
22	25.35	.6438	642.4	.0005046	.33	30.0	34.1	37.0	36.5
23	22.57	.5733	509.5	.0004002	.26	31.6	37.6	41.3	40.6
24	20.10	.5106	404.0	.0003173	.20	35.6	41.5	46.3	45.3
25	17.90	.4547	320.4	.0002517	.16	38.6	45.6	51.7	50.4
26	15.94	.4049	254.1	.0001996	.13	41.8	50.2	58.0	55.6
27	14.20	.3606	201.5	.0001583	.10	45.0	55.0	64.9	61.5
28	12.64	.3211	159.8	.0001255	.08	48.5	60.2	72.7	68.6
29	11.26	.2859	126.7	.00009953	.064	51.8	65.4	81.6	74.8
30	10.03	.2546	100.5	.00007894	.051	55.5	71.5	90.5	83.3
31	8.928	.2268	79.70	.00006260	.040	59.2	77.5	101.	92.0
32	7.950	.2019	63.21	.00004964	.032	62.6	83.6	113.	101.
33	7.080	.1798	50.13	.00003937	.0254	66.3	90.3	127.	110.
34	6.305	.1601	39.75	.00003122	.0201	70.0	97.0	143.	120.
35	5.615	.1426	31.52	.00002476	.0159	73.5	104.	158.	132.
36	5.000	.1270	25.00	.00001964	.0127	77.0	111.	175.	143.
37	4.453	.1131	19.83	.00001557	.0100	80.3	118.	198.	154.
38	3.965	.1007	15.72	.00001235	.0079	83.6	126.	224.	166.
39	3.531	.0897	12.47	.000009793	.0063	86.6	133.	248.	181.
40	3.134	.0799	9.888	.000007766	.0050	89.7	140.	282.	194.
41	2.75	.0711	7.841	.000006160	.0040	—	—	—	—
42	2.50	.0633	6.220	.000004885	.0032	—	—	—	—
43	2.25	.0564	4.933	.000003873	.0025	—	—	—	—
44	2.00	.0502	3.910	.000003073	.0020	—	—	—	—
45	1.75	—	3.66	—	—	—	—	—	—
46	1.50	—	2.25	—	—	—	—	—	—
50	1.00	—	—	—	—	—	—	—	—

*A mil is 1-1000 of an inch. **For hard drawn copper, increase resistance values 2%.

TED COPPER WIRE TABLE

Turns per Square Inch[2]			Feet per pound			Resistance of wires (ohms per 1000 ft)		Copper wire carrying capacity (amperes)	
S.C.C.	Enamel S.C.C.	D.C.C.	D.C.C.	(copper) S.C.C.	Bare	Copper**	Advance (approx)	at 1000 C.M. per amp	at 1500 C.M. per amp
—	—	—	—	—	1.561	.0499	—	211.6	140.7
—	—	—	—	—	1.968	.0629	—	167.8	111.3
—	—	—	—	—	2.482	.0793	—	133.1	88.9
—	—	—	—	—	3.130	.1000	—	105.5	70.3
—	—	—	—	—	3.947	.1260	—	83.7	55.7
—	—	—	—	—	4.977	.1592	—	66.4	44.1
—	—	—	—	—	6.276	.2004	—	52.6	35.0
—	—	—	—	—	7.914	.2536	—	41.7	27.7
—	—	—	—	—	9.980	.3192	8.88	33.1	22.0
—	—	—	—	—	12.58	.4028	11.21	26.3	17.5
—	—	—	—	—	15.87	.5080	14.19	20.8	13.8
—	—	—	19.6	19.9	20.01	.6045	17.9	16.5	11.0
—	—	—	24.6	25.1	25.23	.8077	22.6	13.1	8.7
87.5	84.8	80.0	30.9	31.6	31.82	1.018	28.0	10.4	6.9
110	105	95.5	38.8	39.8	40.12	1.284	35.5	8.2	5.5
136	131	121	48.9	50.2	50.59	1.619	44.8	6.5	4.4
170	162	150	61.5	63.2	63.80	2.042	56.7	5.2	3.5
211	198	183	77.3	79.6	80.44	2.575	71.7	4.1	2.7
262	250	223	97.3	100	101.4	3.247	90.4	3.3	2.2
321	306	271	119	124	127.9	4.094	113.0	2.6	1.7
397	372	329	150	155	161.3	5.163	145.0	2.0	1.3
493	454	399	188	196	203.4	6.510	184.0	1.6	1.1
592	553	479	237	247	256.5	8.210	226.0	1.3	.86
775	725	625	298	311	323.4	10.35	287.0	1.0	.68
940	895	754	370	389	407.8	13.05	362.0	.81	.54
1150	1070	910	461	491	514.8	16.46	460.0	.64	.43
1400	1300	1080	584	624	648.4	20.76	575.0	.51	.34
1700	1570	1260	745	778	817.7	26.17	725.0	.41	.27
2060	1910	1510	903	958	1031	33.00	919.0	.32	.21
2500	2300	1750	1118	1188	1300	41.62	1162	.25	.17
3030	2780	2020	1422	1533	1639	52.48	1455	.20	.13
3670	3350	2310	1759	1903	2067	66.17	1850	.16	.11
4300	3900	2700	2207	2461	2607	83.44	2300	.13	.084
5040	4660	3020	2534	2893	3287	105.20	2940	.10	.067
5920	5280	—	2768	3483	4145	132.70	3680	.079	.053
7060	6250	—	3137	4414	5227	167.30	4600	.063	.042
8120	7360	—	4697	5688	6591	211.00	5830	.050	.033
9600	8310	—	6168	6400	8310	266.00	7400	.039	.026
10900	8700	—	6737	8393	10480	335.00	9360	.032	.021
12200	10700	—	7877	9846	13210	423.00	11760	.025	.017
14000	13400	6510	9309	11636	16660	533.40	14550	.020	.013
16600	15150	6950	10666	13848	21010	672.60	18395	.016	0.10
18000	16750	7450	11907	18286	26500	848.10	24100	.012	.008
—	—	—	14222	24381	33410	1069.00	32660	.009	.006
—	—	—	17920	30610	42130	1323.00	38880	.008	.005
—	—	—	22600	38700	53100	1667.00	47040	.006	.004
—	—	—	28410	48600	66970	2105.00	58070	.005	.003
—	—	—	35950	61400	84460	2655.00	75500	.004	.0025
—	—	—	—	—	—	—	96000	—	—
—	—	—	—	—	—	—	130700	—	—
—	—	—	—	—	—	—	—	—	—

[2]The figures given are approximate only, since the thickness of the insulation varies with different manufacturers.

POWER RESISTORS

Table of current capacity and allowable voltages

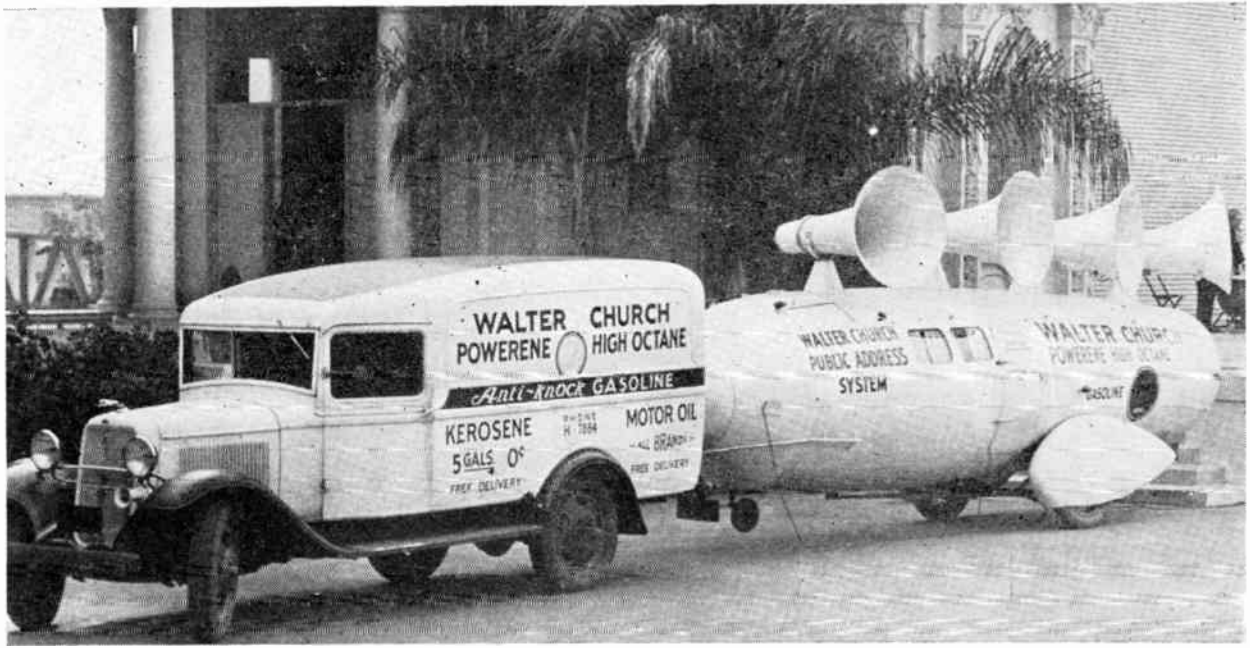
Resistance in Ohms	25 WATT RESISTOR		50 WATT RESISTOR	
	Amperes	Volts	Amperes	Volts
1	5.000	5.000	7.070	7.070
1.5	4.083	6.124	5.773	8.659
2	3.420	6.840	5.000	10.000
2.5	3.154	7.885	4.474	11.185
3	2.939	8.817	4.083	12,249
3.5	2.672	9.342	3.778	13.223
4	2.500	10.000	3.420	13.680
5	2.236	11.160	3.154	15.770
7.5	1.826	13.695	2.581	19.357
10	1.598	15.980	2.236	22.360
15	1.298	19.470	1.829	27.435
20	1.119	22.380	1.598	31.960
25	1.000	25.000	1.414	35.350
30	.912	27.360	1.298	38.940
35	.844	29.540	1.197	41.895
40	.791	31.640	1.119	44.760
50	.700	35.000	1.000	50.000
75	.574	43.050	.818	61.350
100	.500	50.000	.700	70.000
150	.432	64.800	.577	86.550
200	.353	70.600	.500	100.000
250	.316	79.000	.447	111.750
300	.291	87.800	.432	129.600
350	.269	94.150	.378	132.300
400	.250	100.000	.353	141.200
500	.224	112.000	.316	158.000
750	.186	139.500	.257	192.650
1000	.158	158.000	.220	220.000
1500	.129	193.500	.182	273.000
2000	.112	224.000	.159	318.000
2500	.100	250.000	.141	352.500
3000	.091	273.000	.129	387.000
3500	.085	297.500	.119	416.500
4000	.079	316.000	.111	444.000
5000	.071	355.000	.100	500.000
7500	.058	445.000	.081	607.500
10000	.050	500.000	.070	700.000
15000	.043	645.000	.057	855.000
20000	.035	700.000	.050	1,000.000
25000	.031	775.000	.044	1,100.000
30000	.029	870.000	.040	1,290.000
35000	.026	910.000	.037	1,290.500
40000	.025	1,000.000	.035	1,400.000
50000	.022	1,100.000	031	1,550.000
75000	.018	1,350.000	.025	1,875.000
100000	.015	1,500.000	.022	2,200.000

TABLE OF
CONVERSION RATIOS

MULTIPLY	BY	TO OBTAIN
Amperes	1,000,000,000,000	Micromicroamperes
Amperes	1,000,000	Microamperes
Amperes	1,000	Milliamperes
Cycles	.000,001	Megacycles
Cycles	.001	Kilocycles
Farads	1,000,000,000,000	Micromicrofarads
Farads	1,000,000	Microfarads
Farads	1,000	Millifarads
Henrys	1,000,000	Microhenrys
Henrys	1,000	Millihenrys
Horsepower	.7457	Kilowatts
Horsepower	745.7	Watts
Kilocycles	1,000	Cycles
Kilovolts	1,000	Volts
Kilowatts	1,000	Watts
Kilowatts	1.341	Horsepower
Megacycles	1,000,000	Cycles
Mhos	1,000,000	Micromhos
Mhos	1,000	Millimhos
Microamperes	.000,001	Amperes
Microfarads	.000,001	Farads
Microhenrys	.000,001	Henrys
Micromhos	.000,001	Mhos
Micro-ohms	.000,001	Ohms
Microvolts	.000,001	Volts
Microwatts	.000,001	Watts
Micromicrofarads	.000,000.000,001	Farads
Micromicro-ohms	.000,000.000,001	Ohms
Milliamperes	.001	Amperes
Millihenrys	.001	Henrys
Millimhos	.001	Mhos
Milliohms	.001	Ohms
Millivolts	.001	Volts
Milliwatts	.001	Watts
Ohms	1,000,000,000,000	Micromicro-ohms
Ohms	1,000,000	Micro-ohms
Ohms	1,000	Milliohms
Volts	1,000,000	Microvolts
Volts	1,000	Millivolts
Watts	1,000,000	Microwatts
Watts	1,000	Milliwatts
Watts	.001	Kilowatts
Diam. Circle	3.1416	Circumference circle
Diam. Circle	.886	Side Equal Square
Inches	2.54	Centimeters

TABLE OF
TWIST DRILLS FOR TAPPING AND CLEARANCE

Screw No.	Thirds Per Inch	Tap Size	TWIST DRILL NUMBER		
			Metal Tapping	Plastic Tapping	Hole Clearance
2	48	2x48	No. 50	No. 49	No. 42
2	56	2x56	No. 48	No. 47	No. 42
2	64	2x64	No. 48	No. 47	No. 42
3	40	3x40	No. 47	No. 46	No. 37
3	48	3x48	No. 44	No. 43	No. 37
3	56	3x56	No. 44	No. 43	No. 37
4	32	4x32	No. 43	No. 42	No. 31
4	36	4x36	No. 41	No. 40	No. 31
4	40	4x40	No. 41	No. 40	No. 31
6	32	6x32	No. 33	No. 32	No. 27
6	36	6x36	No. 33	No. 32	No. 27
8	24	8x24	No. 30	No. 29	No. 17
8	32	8x32	No. 28	No. 27	No. 18
10	24	10x24	No. 25	No. 24	No. 9
10	30	10x30	No. 22	No. 21	No. 8
10	32	10x32	No. 20	No. 19	No. 8
12	20	12x20	No. 19	No. 18	No. 1
12	24	12x24	No. 15	No. 14	No. 1
12	28	12x28	No. 15	No. 14	No. 1
14	20	14x20	No. 10	No. 9	¼ In.
14	24	14x24	No. 6	No. 5	¼ In.



UNIQUE TRAILER PUBLIC ADDRESS SYSTEM

"The most powerful public address system ever put up," is Walter Church, San Diego, California, claim for his unique system which can be clearly heard for a distance of 6 miles! The huge loudspeaker horns cost $500. Built just for advertising purposes, at a cost of $3,000, this swanky system is loaned free for broadcasting public events or for use at charity programs.

It is mounted on an airplane fuselage the same as is used by United Airlines, and is painted white with black lettering, which combines to give it an unusual and attractive appearance. Its advertising value is of inestimable value to Mr. Church.

This address system is in such demand that it is often engaged several months in advance. It presents P.A. programs at the famous Ford Bowl in Balboa Park, for San Diego State College football games, etc.