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PUBLIC ADDRESS INSTALLATION AND SERVICE

Modern Methods of Servicing and Installing Public Address Equipment

by J. T. Bernsley

PUBLISHED BY
GERNSBACK PUBLICATIONS, Inc.
98 PARK PLACE—NEW YORK

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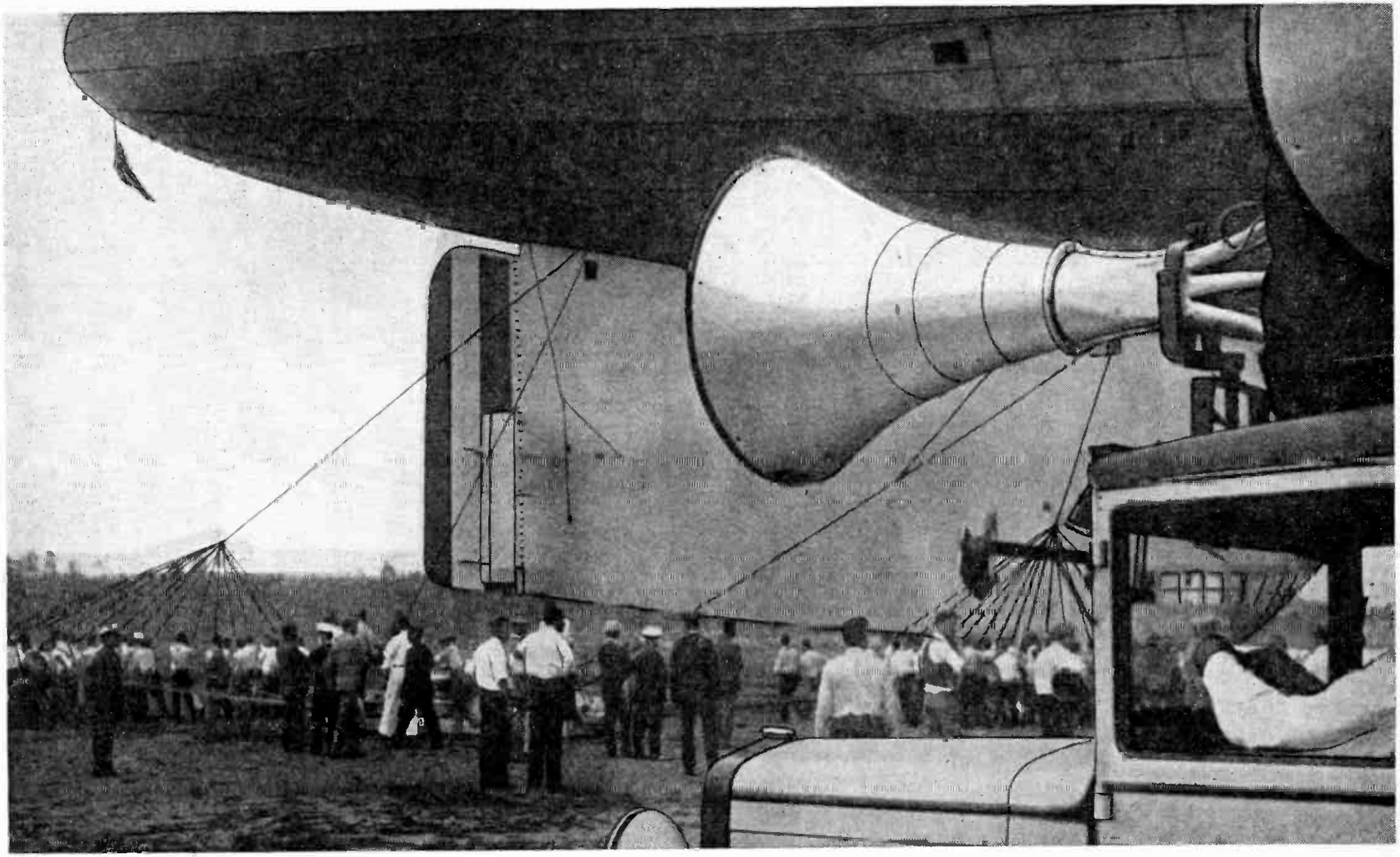
98 PARK PLACE **NEW YORK, N. Y.**

Contents

Printed in U. S. A.



P.A. equipment is being employed everywhere for sound projection. Airports, auditoriums, banquet halls or meeting rooms, sound trucks, portable systems for lecturing, theatres, are some of its uses. Thus, it can be seen, the types of installations are many and varied.

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.

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 inter-stage 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. All these complicate the problems.

But, as in everything else, we must "begin at the beginning." And, since audio amplifiers of various types have been used since the vacuum tube was invented we begin with a study of inter-stage coupling methods.

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).

This includes push-pull; since this incorporates either a transformer or resistance coupling, but has generally two transformers wound in single-unit fashion—so that the two tubes into which this unit works are electrically connected 180 degrees out of phase. Refer to Fig. 1 and 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. 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"

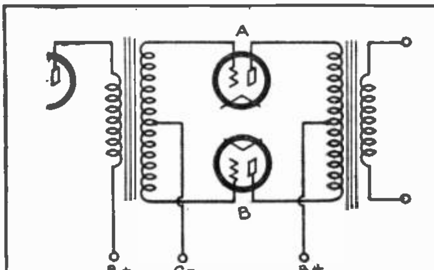


FIG. 1

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

harmonics in the output of each stage, produces greater power output, and allows use of a greater power input to the amplifier.

Resistance Coupling

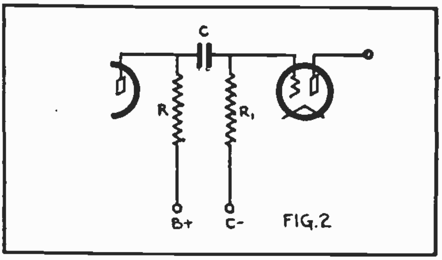


FIG.2

Methods of resistance coupling between two tubes.

Fig. 2 illustrates a resistance-coupled stage. Condenser "C" 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—otherwise a high positive bias would be impressed on the grid. This coupling (and blocking) condenser must not be too low in capacity, or its reactance to low frequencies in the audible range will be too high. This would result in reduced amplification, and the partial suppression of the lower notes. A value anywheres from .006- to .25-mf. is generally used, and should be preferably of "mica" dielectric construction.

The values of the resistors "R" and "R1" must also be carefully chosen. These resistances should be as large as possible, to obtain maximum transfer of energy from one tube to the following tube. However, if too large a plate resistance is used, the voltage drop across it is great; which consequently results in lower voltage being applied to the plate. 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 "R_1" 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.

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 pure resistances (generally carbon type or non-inductive wire-wound). Since no inductance, and resulting distributed capacity, exists in either plate or grid circuit there is no consequent 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 "C" (when 0.25-mf.) is negligible at 10,000 cycles and is still comparatively low at 60 cycles; thus permitting uniform transfer of all frequencies from the plate of one tube to the grid of the next.

In Fig. 3 we see another type of resistance-coupled stage, similar in principle but with the addition of "decoupling resistors." "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 or "A," "B," and "C" batteries which furnish the required voltages for the various tubes in the amplifier.

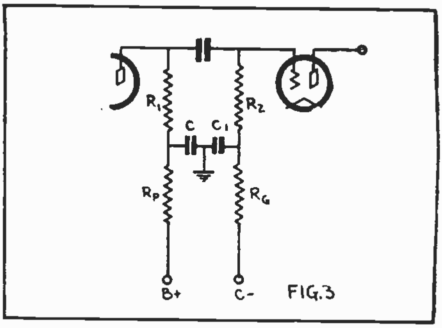
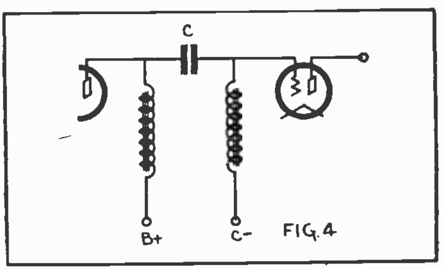


FIG.3

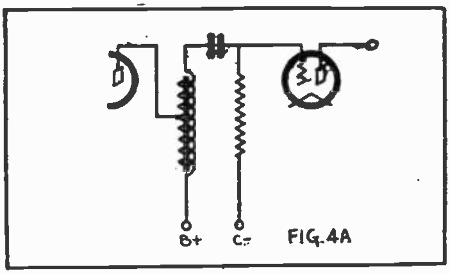
Resistance coupling of improved type, eliminating possibility of "motor-boating" or regeneration.

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"; thereby permitting lower initial "B" voltages and, consequently, a smaller power supply unit. 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, which then more readily go through the coupling condenser "C" to the grid of the next tube. (See Fig. 4) 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.

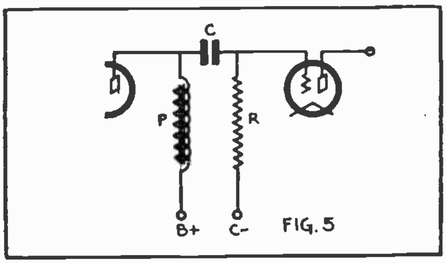


Method of impedance coupling.



Autoformer coupling—a compromise between impedance and transformer coupling.

Where the plate impedance winding is tapped as in Fig. 4A, 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.



Combination of resistance and impedance methods of coupling.

In Fig. 5 we 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.

Transformer Coupling

This method is similar to the autoformer coupling described above, except that, in the latter method, the primary or plate is conductively as well as inductively coupled to the secondary or grid winding.

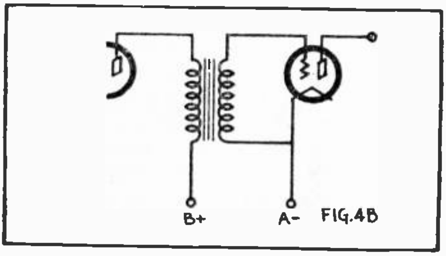


FIG.4B

Transformer coupling between stages.

In a transformer, the primary and secondary windings are inductively coupled only; energy being transferred from primary to secondary by magnetic induction. See Fig. 4B. Here we have the 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 condenser 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 supposedly 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. In the Loftin-White, the value of the coupling resistor "R" (Fig. 6) is

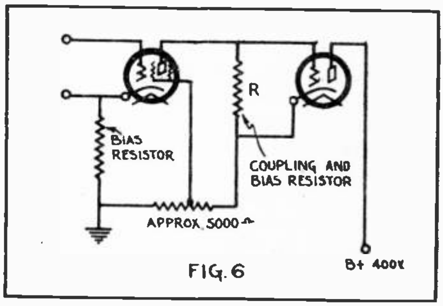


FIG. 6

Fundamental circuit of Loftin-White, or "Direct coupling." The two tubes are in series.

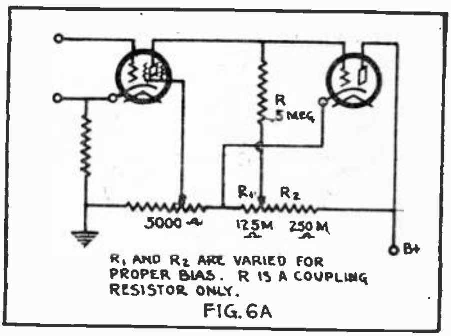


FIG. 6A

Improved and practical circuit for "Direct Coupling" extremely critical. However, if this method of coupling is used properly, very high gain with good quality output is obtained. Fig. 6 illustrates the fundamental Loftin-White circuit. "R" serves both as a coupling resistor and a biasing resistor, which is the reason for critical adjustment. In Figure 6A, "R" is only a coupling resistor, bias being obtained by varying "R1" and "R2".

This method of coupling was extremely popular when first introduced but, while theoretically excellent, has decreased in popularity because of the adjustments required.

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 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. 7. Note the use of "C"

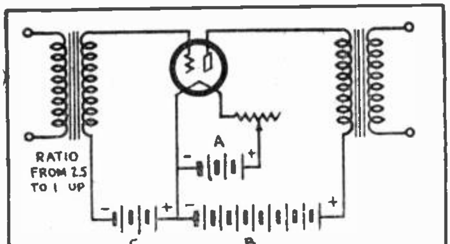


FIG.7

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.

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 "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 is 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 (such as the 210) that are not specifically designed for "Class B" operation may be used for such purposes by biasing them almost to the "cut-off" point (in case of the 210—approximately 80 volts).

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 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 inter-stage 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.

Voltage Amplifiers

Tubes functioning essentially as voltage-amplifying devices are generally of a high amplification factor and have 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" or "head 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.

Microphones

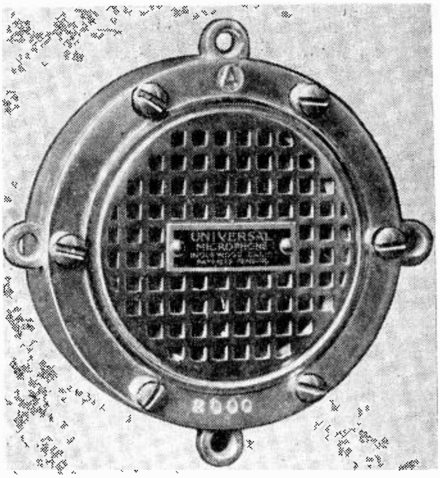


Fig. 8

(Courtesy Universal Microphone Co.) Photograph of single-button carbon microphone. Two connections to this unit are made—one to button, other to frame.

In public-address work, it is also necessary to understand the construction and operating principle 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 three types of microphones in general use in present P.A. work—the carbon, the condenser, and the velocity or "ribbon mike." Of the three, the carbon is the most extensively used, because the definite requirements of P.A. use necessitate a mike of comparatively high output. It requires, because of this characteristic, less stages of amplification—but is also popular because it is lowest in cost compared to the price of a good condenser or velocity "mike". For ordinary public-address work, even a fairly inexpensive two-button carbon mike is quite satisfactory, since the response characteristic of such a "mike" will adequately cover speech frequencies. For special amplifier work—such as broadcasting, audition purposes, or projection of orchestral music—the more expensive two-button, stretched-diaphragm type is generally employed.

The carbon microphone consists of a thin duraluminum diaphragm against which is placed a cup of carbon granules properly insulated from the diaphragm by loosely-placed cotton which also serves to keep the carbon in the cup. When sound waves strike against the diaphragm, it flexes or bends in accordance with the vibrations, and compresses or decompresses the granules. In this manner the resistance of the carbon is varied; and this in turn varies the flow of current, from a battery source, through a transformer winding. Thus, it can be readily seen, the carbon microphone operates as a valve or mechanical governor in an electrical circuit; the action of the valve or governor being controlled by the air vibrations.

A two-button microphone has two cups of carbon granules (called buttons) placed on each side of the diaphragm, thus producing a push-pull or double action as the diaphragm flexes back and forth.

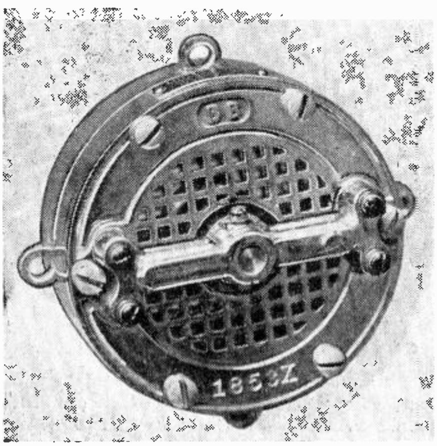


Fig. 9

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

Some very interesting information regarding carbon microphones is furnished by E. E. Griffin, Chief Engineer of the Universal Microphone Co. Ltd., and, by permission of that company, it is herewith reprinted.

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 will be 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 of microphones.

"It is seldom that a technician can talk without making pencil marks on paper; and this discussion will therefore begin with the printed equivalent of such pencil marks. With them before us, we can get down to business.

"Fig. 10 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. Just for an enlargement of our mental picture we have placed the most popular output tubes at their various wattage handling capacities on the upper scale; while you will also find the average range for magnetic pickup, the maximum and

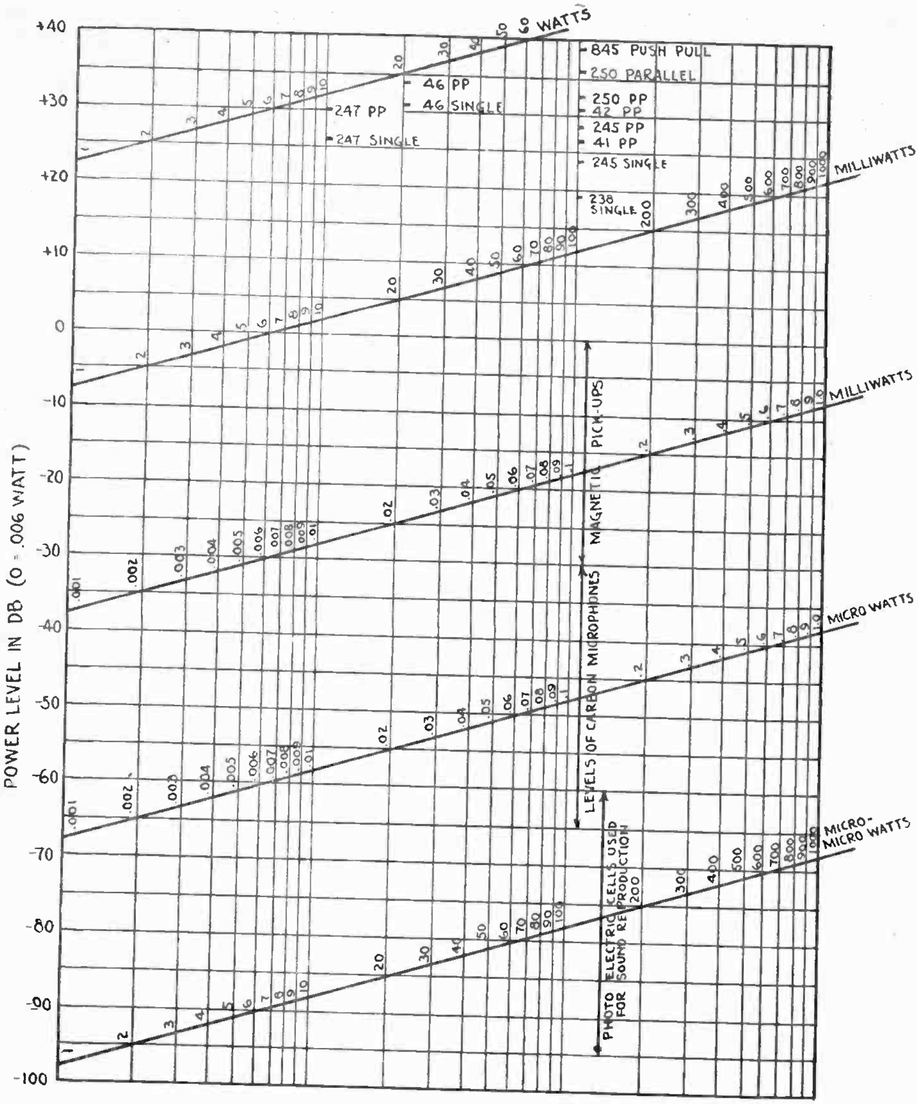


FIG. 10

(Courtesy Universal Microphone Co.)

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 secondary load into a 5,000-ohm load (plate to plate) as required by the 2A3 tubes. (The turn ratio is 1.4/1 comparing secondary to whole primary.)

(Continued bottom of next page)

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.

Zero Level

"As you no doubt know there is considerable confusion existing as to just what zero level on our present D.B. scale is supposed to be. Some authorities consider zero level as the threshold of audibility, while others take it as the output of a certain carbon microphone. This company has adopted the standard as set forth by the General Radio Co. (which standard is being gradually adopted throughout the motion-picture industry on the Coast). Accordingly, if you follow the zero line of the present chart through, you will find that it passes the diagonal "power" line at 6 milliwatts.

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 (Fig. 11); while, the greater the fidelity of tone quality, the less its sensitivity. Likewise, the tone quality is generally directly proportional to price.

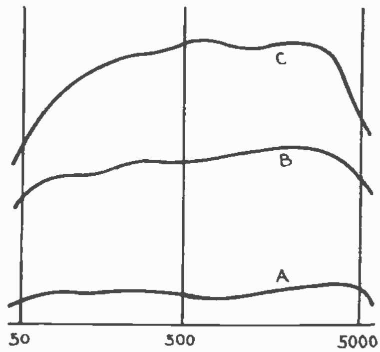


FIG. 11

Representative response curves for:

A—High quality studio mike.
B—Good, medium priced mike.
C—Low priced carbon mike.

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 it 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

(FIG. 10—THE DECIBEL CHART—continued.)

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.

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.

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 mave 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.

"The comparative output levels of microphones at variable distances are graphically illustrated in Fig. 12, 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.

Microphone Current

"In carbon microphones, the next variable factor is the variation of sensitivity, or output, with variation of button current; which you will find graphically illustrated in Fig. 13. Here it might be stated that the hiss or "carbon rush" level in the granular type of microphones also varies in approximately the same relation with button current as given by the graph, and is generally about 30 D.B. below its output level. The graph is taken on the same grade and type of microphone as we described heretofore; that is, a medium grade subjected to a sound pressure equivalent to a normal speaking voice spaced six inches from the face of the microphone. It is quite surprising to note that, with a current variation of from 2 milliamperes to 30 milliamperes, we can get a variation of output from -70 to -28 D.B.; which explains why it used to be common practice to include a potentiometer in the microphone circuit and have a continuously variable current range of from 0 to an enormous value. (These were the days when amplifiers generally fell

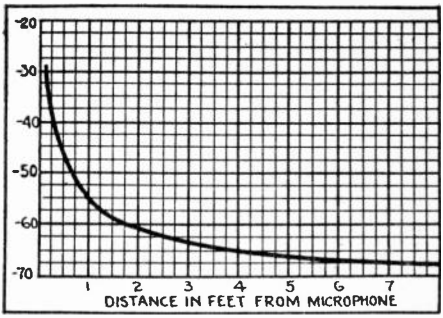


FIG 12

(Courtesy Universal Microphone Co.)

Comparative output levels of a carbon mike at variable distance.

short, and the microphone had to be depended upon to furnish enormously high output in order to drive them at a sufficient usable level.)

"From Figs. 12 and 13, it can be readily seen that, if a microphone is given the absolute maximum of current and a person talks directly into the microphone an output level closely approaching zero on our scale will be obtained. Considering the variations possible in both the button current and the sound pressure actuating the microphone it can be seen that an over-all variation of from 60 to 80 D.B. is possible. Greatest fidelity of response to variations in sound pressure will be had when the microphone is used at the

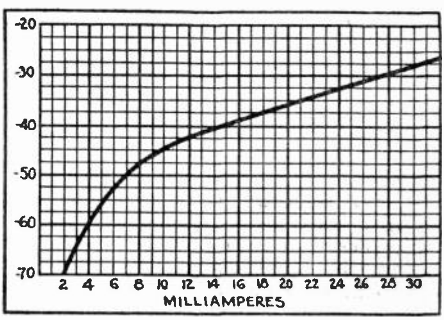


FIG. 13

(Courtesy Universal Microphone Co.)

Variation of sensitivity with button current.

lower levels. Our recommendations are a button current of from 5 to 10 milliamperes; while the spacing to the microphone will naturally vary with the particular model chosen.

Where Figures Lie

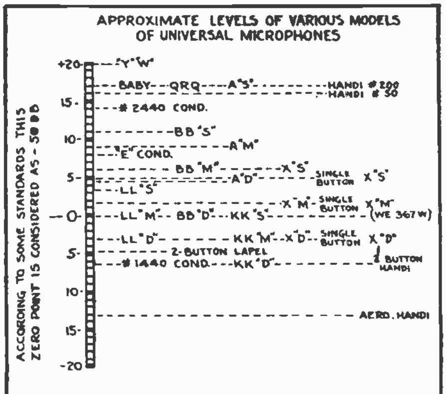


FIG. 14

(Courtesy Universal Microphone Co.)

Note that the zero level in this diagram differs from that in the other figures.

"In regard to this point, Fig. 14 is submitted to you and gives the various output levels of several types of carbon microphones, when used with a button current of 10 milliamperes and subjected to a sound pressure variation equivalent to a normal speaking voice spaced six inches from the microphone itself. In this chart, observe the little notation specifying the zero level on this scale as equal to -62 D.B. on the other charts. Reasonable as such a chart may appear, these volume levels are IN NO WAY representative of what the microphone's output would be in practice. In normal use the conditions are quite different. For instance, an aeroplane Handi-Mike would be used pressed tight against the mouth; which position, when considered in the light of Figure 12, would immediately raise its level some 25 D.B. In addition to this, the aeroplane type is used at a much higher current value per button than the 10 ma. current taken in Figure 14; and thus, in the end, its output might be in the neighborhood of -10 to -20 D.B. Another example is the Baby and QRQ: Either of these highly sensitive models, when spoken into directly, may have an output level closely approaching "zero level"—that is 6 milliwatts.

"These variations are so large as to be confusing to the user until he understands their causes as shown in Figs. 12 and 13. With these figures in mind, the information of such a tabulation as Fig. 14 can be translated with some correctness into the probable performance under the conditions actually to be used. Then, with the microphone's output fairly well known, the amplifier may be laid out to provide whatever gain may be necessary to rise from the level of the microphone to that of the amplifier's required output — always with due allowance for some spare gain, to compensate for adverse conditions, or for power-wasting devices such as "mixers" or "equalizers."

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. 15 we have a microphone button in series with a 1½-volt dry cell. Considering the D.C. resistance of the microphone as 200 ohms, we will have a current of 7½ milliamperes flowing in this circuit. 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. 16 it will be noted that we have one source of current, two 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.

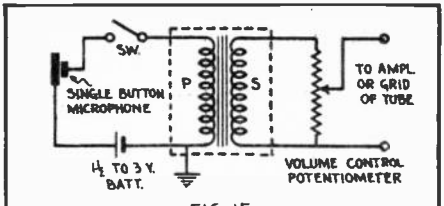


FIG. 15

Schematic wiring arrangement for single-button microphone.

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

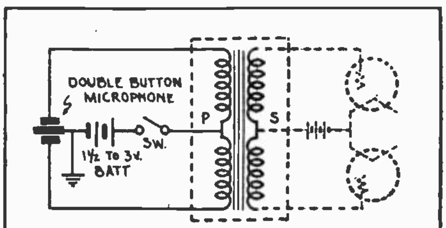
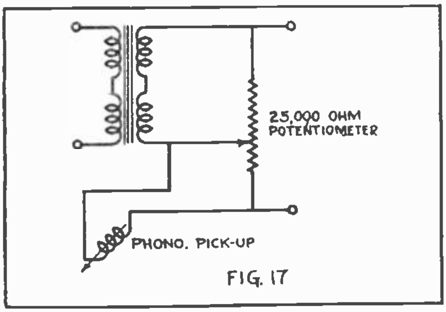


FIG. 16

Schematic wiring diagram of connections to a two-button carbon microphone.

impedance of 400 ohms which matches the microphone buttons; and a secondary impedance of 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.



Wiring arrangement for microphone-phonograph mixer.

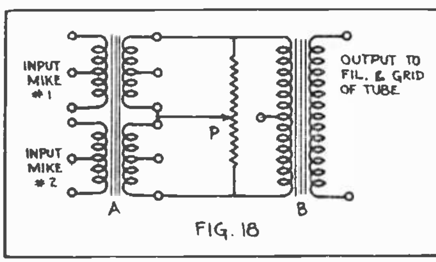
Acoustic Coupling or Feedback

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 the speaker in relation to the microphone. It is largely a case of cut and try in most cases; and, in exaggerated cases, volume must be sacrificed to entirely prevent it. Imagine the room you are working in as being walled entirely with mirrors, and your speaker a powerful searchlight; you can readily visualize how the microphone can be reached by reflected rays.

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. Also, do not point speakers toward any flat wall or surface that will reflect sound directly back to the microphone. Reduce the button current to the lowest possible, and keep the gain control below the feedback point.

Excessive A.C. hum in speakers is often the cause of feedback in public address systems. The low 50- or 60-cycle note of the A.C. amplifier sets up in the air a vibration that is picked up by the microphone. People become used to hearing it and do not notice it, but the microphone never becomes used to it. Do not allow any of the lines to pick up A.C. from adjoining lines. Careful grounding of all apparatus, and use of shielded cable, is necessary in most instances.

To prevent feedback and resonance under unfavorable acoustical conditions, and to tone a person's voice to a more pleasant position in the voice range, a tone control is used. This is connected to each button of the microphone, or to the outer wires of the primary of the transformer or input.



Wiring arrangement for two, two-button carbon microphones and mixer.

Sensitivity of Microphones

There is a definite relation between these three factors in all microphonic 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 a microphone is damped, the better the frequency response over the entire range, and the less the peaks and depressions 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 extremely faithful reproduction is required, and expense is no handicap, this type of microphone will be found to have an improved response—characteristic over the carbon type. A pre-amplifier is necessary, and is generally mounted in a common housing or case with the condenser unit. This type of microphone consists of two stretched diaphragms or plates placed close together, with air as the dielectric, so as to create a capacity or condenser effect. The amplifier placed in the head places an electrical charge on these two plates; and, because the condenser is in the grid circuit of the first stage of the amplifier, a small change in the position of one of the plates will thereby vary the capacity of the unit and thus vary the charge. For that reason this unit is sometimes termed an "electrostatic" condenser. These plates are of course not rigid, but flexible thin metal; so that air vibrations can readily create the necessary response motion in one of the plates.

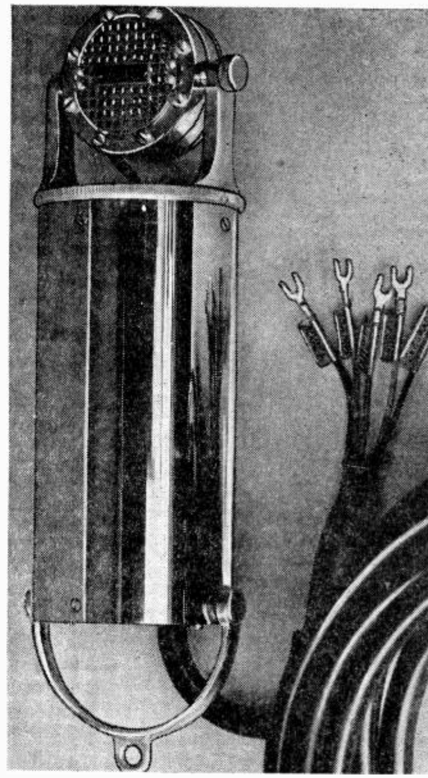


Fig. 19
(Courtesy Universal Microphone Co.)

Photograph of a condenser microphone. The pre-amplifier necessary is sometimes included within a common housing with the microphone.

The following information regarding output characteristics and color-code connections is also supplied by the Universal Microphone Co. Ltd. and pertains to their Models 1440 and 2440 condenser microphones:

RED .... 180 volts "B+"
WHITE .... 6 volts "A+"
BLACK .... 6 volts "A—"

(Negative B return optional to either "A+" or "A—")

GREEN ....
YELLOW .... 400 to 600-ohm output

Model 1440 has an output of approximately –56 D.B.

Model 2440 has an output of approximately –36 D.B.

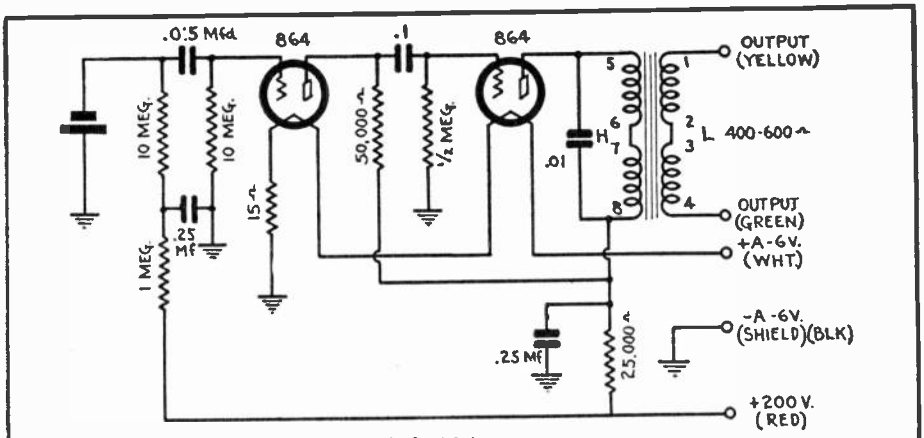


FIG. 19A

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

Common "A" and "B" supply may be used on most amplifying systems. However, in some cases, where the feedback is so strong as to be objectionable, on account of high-resistance "B" supply, a 250,000-ohm wire-wound resistor in series with the RED lead of the condenser cable, and bypassed by a 2-mf. filter condenser, will eliminate all difficulty. The bypass is used on the microphone side of the condenser microphone.

In testing, the RED or positive "B" lead should show 3 milliamperes on the Model 1440 and 4 milliamperes on the Model 2440. The filament current should be 0.25 ampere on all above models.

Fig. 19A is a schematic wiring diagram of a condenser "mike" and two-stage pre-amplifier, which is necessary for building up the output of the "mike" to the required voltage to work an average amplifier satisfactorily.

Ribbon or Velocity Mike

Unlike the condenser or carbon types of microphones, which are valves or mechanical governors, the velocity mike is a generator of electrical impulses similar to a phonograph pickup. The diaphragm is a thin corrugated aluminum alloy ribbon so placed in a magnetic field that, when it vibrates, it cuts the magnetic lines of force and generates electric impulses. Naturally, the magnetic flux must be confined to a small area, so that the least vibration of the ribbon caused by sound waves will work in a concentrated magnetic field and therefore be capable of generating electric currents proportional to the intensity of the sound wave.

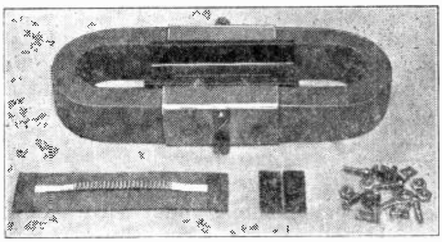


Fig. 20
(Courtesy Bruno Laboratories)
Construction of a ribbon or "velocity" microphone.

The output of this device is rated at -69 D.B. if zero level is 6 milliwatts, and it requires at least two stages of additional or "pre" amplification to boost it to the required strength to feed into an amplifier. If well built, its response characteristic is excellent. It is recommended for studio work or for P.A. work where absolute fidelity is required. This microphone is highly directional; thus making it ideal for eliminating pick-up of extraneous noises

Fig. 20A
(Courtesy Bruno Laboratories)
Photo of a ribbon microphone—excellent for high quality reproduction. A matching transformer of special characteristics is required.

or where acoustical imperfections exist. It does not require the talker to be close to the microphone; as a matter of fact, the manufacturer recommends that the announcer be at least two feet away.

The constructional details of a velocity or ribbon microphone are shown in Fig. 20.

Power-Supply Requirements

Power supply for amplifying systems may be obtained from batteries, A.C. or D.C. power lines (in the former, provision is made for rectification of the high voltage for plate supply), motor-generator sets, mechanical and rotary converters (from a 6-, 12-, or 32-volt D.C. source to 110-volt A.C.) and gasoline-driven generators.

In most cases where permanent installation is made, electric power is found available. If it is A.C., then any size system (power output) can be installed without complications resulting from a lack of plate voltage, which must be high for the large output tubes. Where D.C. is supplied to the premises and a large amplifier, whose tubes require 400 or 500 volts for the plates, is to be installed—a rotary converter or motor-generator set must be figured on. The purpose of these machines is to transform 110-120 volts D.C. to 115 volts A.C. and their power output (in watts) should be approximately fifty per cent. higher than the total power to be consumed by the amplifier, speakers, and auxiliary equipment.

Amplifiers made to operate from a D.C. power supply have a limited output—generally five to six watts maximum—and can be used only for a relatively small public-address system.

For rental service or portable work, A.C. amplifiers of medium power output, between 10 and 15 watts, are suggested. By employing two storage batteries to operate a mechanical converter (12 volts D.C. to 110 A.C.) such as shown in Fig. 21, the amplifier may be operated in any location, independent of power supply.

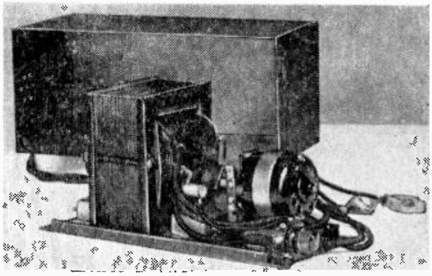


Fig. 21
(Courtesy Universal Microphone Co., Ltd.)
A Mechanical Converter. 6V or 12V. DC to 110 AC.

The output of this device is 150 watts, at 110 volts A.C. No additional filters, other than that already incorporated in the filtering unit of the rectifier supply within the amplifier, are necessary. For smaller amplifier work (between 5 and 10 watts output) a similar converter operating from a single storage battery may be used. Its output is rated at 60 watts, 110 volts A.C.

For small P.A. work on sound trucks, this converter will be found excellent. However, present practice in this type of installation is to employ an amplifier whose tube filaments (or heaters) are so wired as to operate from the storage battery of the car—or a separate battery, for convenience in recharging. The plate supply is obtained from a small dynamotor or motor-generator which operates also from 6 volts. In larger sound-truck systems gasoline-driven generators are recommended because of the power required to operate very large amplifying equipment. Or, a 12-volt D.C. rotary converter (operating from two storage batteries in series or four in series-parallel) may be substituted. Both of the latter suggested methods for large sound trucks will also operate synchronous type turntables—providing the frequency of the output is constant and the total load does not exceed the power output of these devices.

CHAPTER II

PUBLIC ADDRESS AMPLIFIERS

Four and one-half Watt, Seven Watt, Ten Watt, Fifteen Watt, Twenty-five Watt, Forty Watt and Fifty Watt Amplifiers. Also Special and Portable Equipment.

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 as 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.

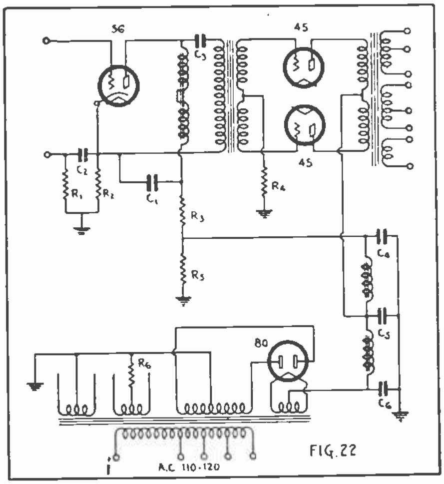
And, since the output of the driver stages in itself is often suitable for smaller requirements the efficiency and simplicity of this type of construction and description can be readily acknowledged. (See data on installation, instruction—Chapter III—giving electrical reasons for separate construction.)

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.

Four and One-Half Watt Amplifier

Fig. 22. This is a small amplifier comprising a 56 input stage operating into two 245 power tubes in push-pull arrangement. Parallel plate feed is employed, coupling the 56 into the -45's. As a result improved frequency response is obtained, although a stand-



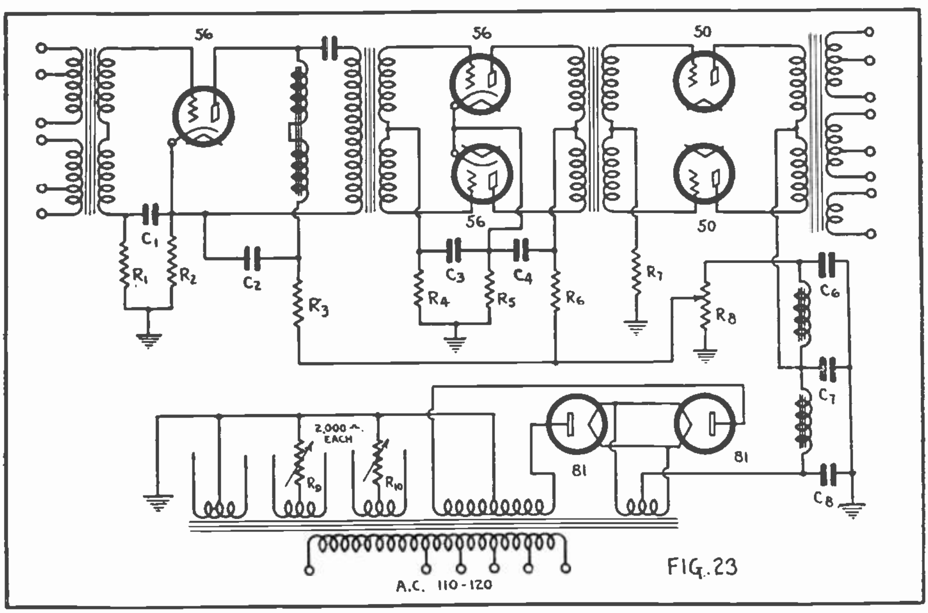
Schematic wiring diagram of a 4.5-watt "Class A" amplifier.

ard input push-pull transformer can be employed, thereby eliminating the plate choke and C3.

This amplifier is suitable only for small P.A. coverage outdoors or for an approximate audience of 100 people indoors and where the auditorium is not too large; it is excellent for small sales meetings, announcing systems, auction rooms, etc. It will operate one large loud speaker, or two medium sized speakers—dynamic type. It is a "Class A" amplifier, with good quality if speaker and microphone are properly matched to amplifier. However, this amplifier is most suitable for phonograph use, or close microphone P.A. work, since the gain is not high enough for sensitive microphone pickup.

Seven-Watt Amplifier

In Fig. 23 is shown an amplifier of slightly higher output. A single '56 works into a pair of '56's in push-pull, parallel plate feed, feeding a pair of 250 power tubes push-pull. At 400 volts per plate, R.C.A. tube data sheets rate a 250 tube as having an undistorted power output of 3.4 watts. In push-pull the output is slightly over 7 watts at this plate voltage, but at 450 volts per plate the output would be approximately 9½ watts. (Thus it can be seen that not all 250 push-pull amplifiers are capable of delivering 15 watts, as is sometimes assumed.) This also is a "Class A" type amplifier. It is excellent for outdoor use if A.C. is ob-

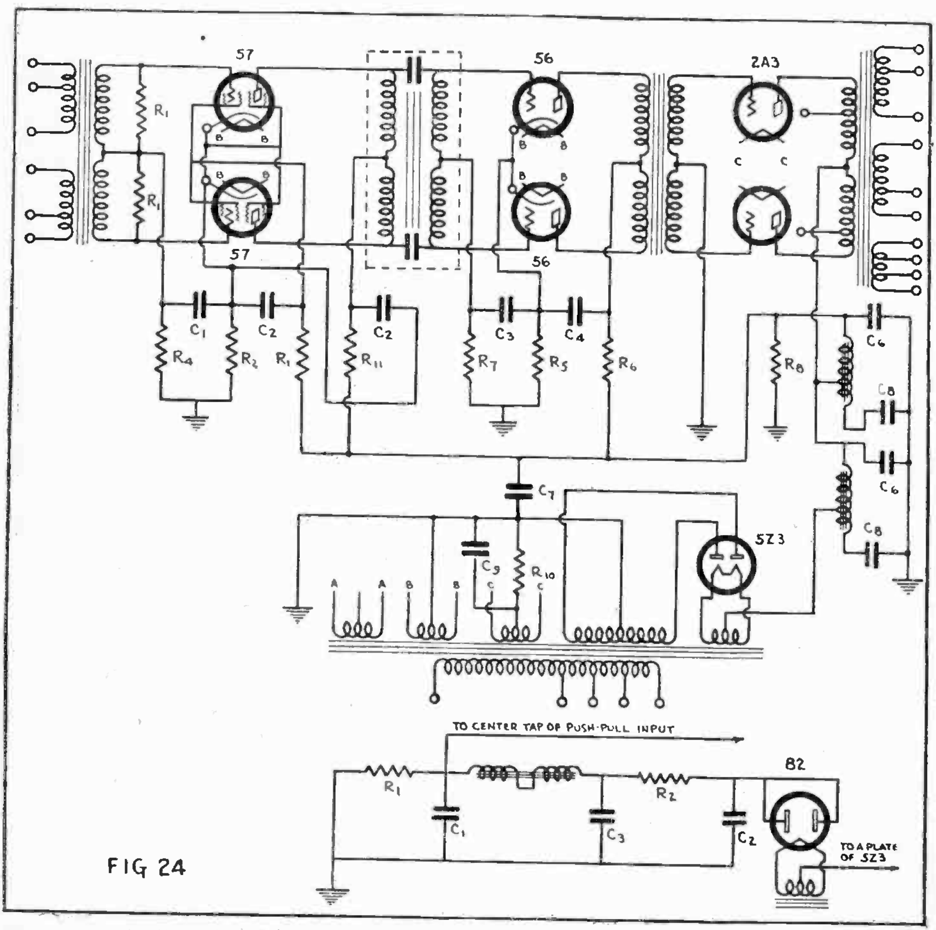


Wiring diagram of a 7-watt amplifier. (If 450 volts is used on the plate, the power is increased to approximately 9.5 watts.) This is a "Class A" amplifier. For values, see end of chapter.

tainable, or if a converter such as is described under Power Supply Requirements is used. For indoor use, it will satisfactorily cover an audience of from 250 to 500 people. It will drive two large dynamics or four medium-sized speakers. Tapped input and output impedances are shown for microphone and phonograph pickup use on input side, and for matching high- or low-impedance speaker lines.

Ten-Watt "Class A" Amplifier

The schematic for this amplifier is shown in Fig. 24. The power stage is push-pull "Class A," using two 2A3 tubes with self-biasing arrangement. A pair of '57's in push-pull operate into two '56's push-pull, which drive the two 2A3 tubes. This all results in an excellent amplifier of laboratory standards—since, as has been explained previously, with this method of amplification all "even" harmonic distortion is balanced out in the output of each stage. Tapped input impedances for microphone and phono use are shown. Also tapped output impedances are suggested, with impedance taps varying from 12 to 500 ohms; in addition to a tapped voice-coil line (Kenyon transformer type KPP2A3). The numerous possible uses of these impedances are evident. As a typical example:



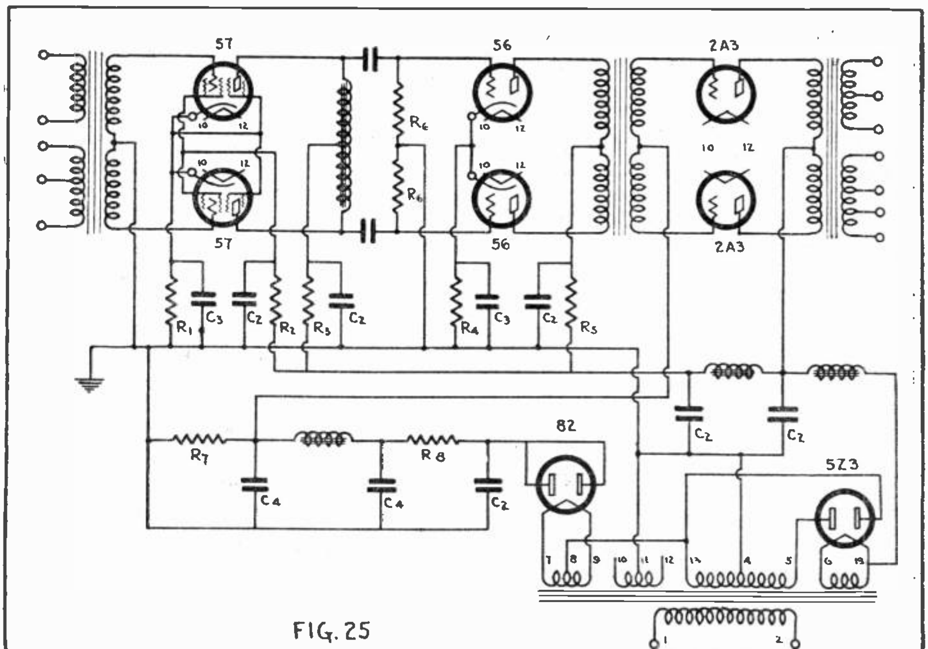
"Class A" 10-watt amplifier of excellent design and high quality output. Self-biasing arrangement is used. For values of parts see end of chapter.

assume a transformer to which a varying number of 500-ohm lines are to be connected. If one line is used, it connects to 500 ohms; two in parallel to 250 ohms; three in parallel to approximately 200 ohms, four in parallel to 125 ohms; six in series-parallel to 333 ohms; eight in series-parallel to 250 ohms; nine in series parallel to 500 ohms; ten in parallel to 50 ohms. Where required, five in parallel or seven in series-parallel can be connected with a small impedance mismatch. Five in parallel connect to 125 ohms. Seven in series-parallel connect to 333 ohms. A "Tapped Voice Coil" line is a terminal arrangement designed to take care of one or a number of voice coil lines. Various impedances can be obtained with a negligible difference in frequency discrimination. The impedances available are 1.3, 3, 4.5, 7.5, and 15 ohms. The numerous possible uses of these terminations are illustrated in an instance where it is desired to connect a number of 15-ohm voice coils to the transformer output. If one speaker is used, it is connected to 15 ohms—two in parallel to 7½ ohms—three in parallel to 4½ ohms—four in series-parallel to 15 ohms—five in parallel to 3 ohms—eight in series-parallel to 7½ ohms—nine in series parallel to 15 ohms—ten in parallel to 1.3 ohms. Where required, six in parallel and seven in series-parallel also can be connected with low impedance mismatch. Six in parallel connect to 3 ohms—seven in series parallel connect to 7½ ohms.

This amplifier can well be used for small theatre sound-installation work, recording-studio installation, or for audition tests in connection with testing of possible broadcast talent.

Fifteen-Watt Amplifier

This amplifier is similar to the one described previously, with a few exceptions. Its increase in power output is obtained through the use of fixed bias instead of a self-biasing arrangement. This permits higher plate potentials to be applied to the power tubes—which is the reason for the increase in power. The schematic wiring diagram is illustrated in Fig. 25. This amount of amplification is satisfactory for indoor



"Class A" 15-watt amplifier, employing a tube arrangement similar to Fig. 24, but with fixed bias. For values see end of chapter.

coverage of an audience of 1000. For outdoor use, it can be heard for several city blocks—depending on the noise level.

Twenty-five Watt "Class B"

This is generally considered the largest output practically obtainable from a single-unit construction amplifier. All amplifiers having an output in excess of this value should be termed super-power amplifiers, and constructed in separate driver stages and power stages. The reasons for this have been outlined previously.

Because of special features in design, this amplifier is rated somewhat higher in power output than tube specifications indicate, but, as previously outlined, is still within safe and conservative limits. Refer to Fig. 26 for the schematic wiring diagram; a 57 is resistance coupled to a 59 ("Class A") into a "Class B" push-pull arrangement of two 59 tubes. The coupling condenser in the resistance-coupled stage is a .02-mf. mica

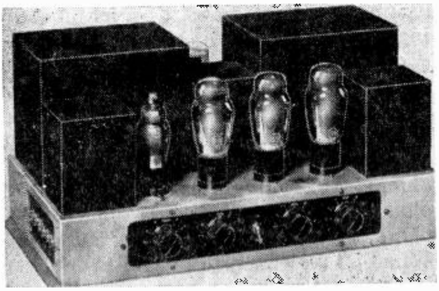
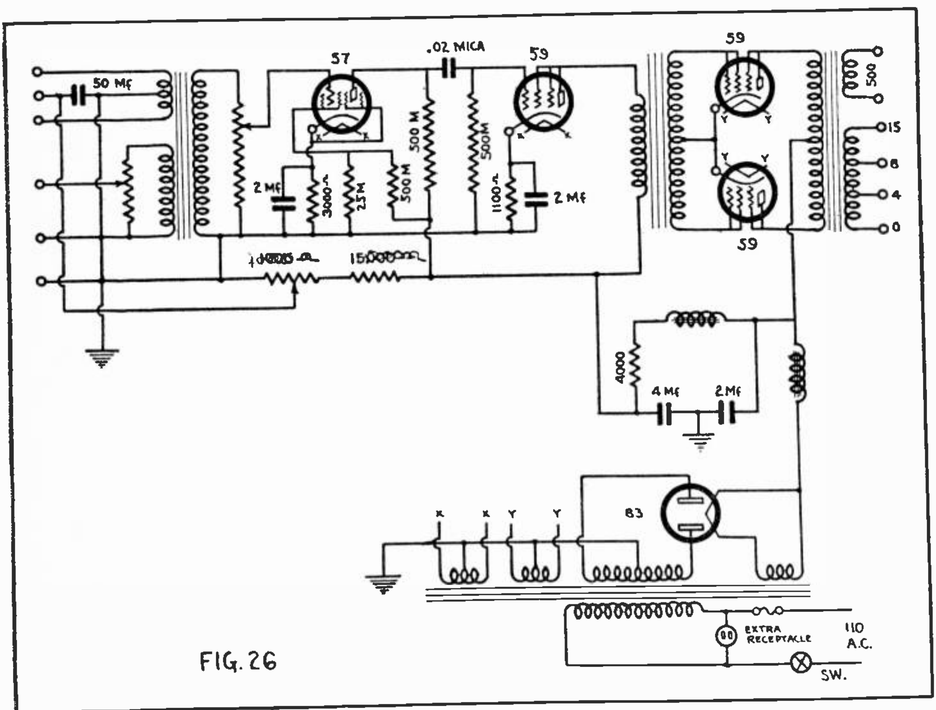


Fig. 27
(Courtesy Simplex Electric Co.)
Photograph illustrating construction, layout, and controls of the "Class B" 25-watt amplifier.

condenser, instead of the paper type. By using mica-type coupling condensers, the losses due to paper dielectric are materially decreased. Provision is made for microphone current—eliminating the necessity of dry cells for this purpose.

The rated gain of this amplifier is 86 D.B.; it has an input tapped for standard single- or two-button microphone, or a condenser microphone's head



Wiring diagram of a "Class B" 25-watt amplifier. It has numerous features which are indicative of excellent engineering foresight.

amplifier output; or for a high-impedance or low-impedance phono pickup or a triode-detector output for radio pickup. Individual microphone and phonograph volume controls are included to allow mixing, and a master gain control, as well as tone control for modification of high-frequency response.

A photograph illustrating these various controls, tube layout, location of impedance taps, etc. is shown in Fig. 27.

This amplifier is well-suited for large requirements, such as ball parks, extremely large auditoriums with a seating capacity of over 2000, sound-truck use, or for very large outdoor meetings.

Forty-Watt "Class A"

Two amplifiers are used for this power output, the driver illustrated in Fig. 28 consisting of two '57's in push-pull feeding into resistance-coupled push-pull '59's. The driver has a gain of 65 D.B. at 1000 cycles per second and an output of 3.2 watts.

When connected to the power stage

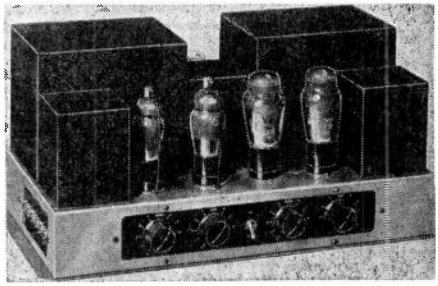


Fig. 29
(Courtesy Simplex Electric Co.)
Photograph of amplifier diagramed in Fig. 28. Note the neatness, compactness, and convenience of its construction.

(schematic is Fig. 28A) it provides a three-stage triple push-pull 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.

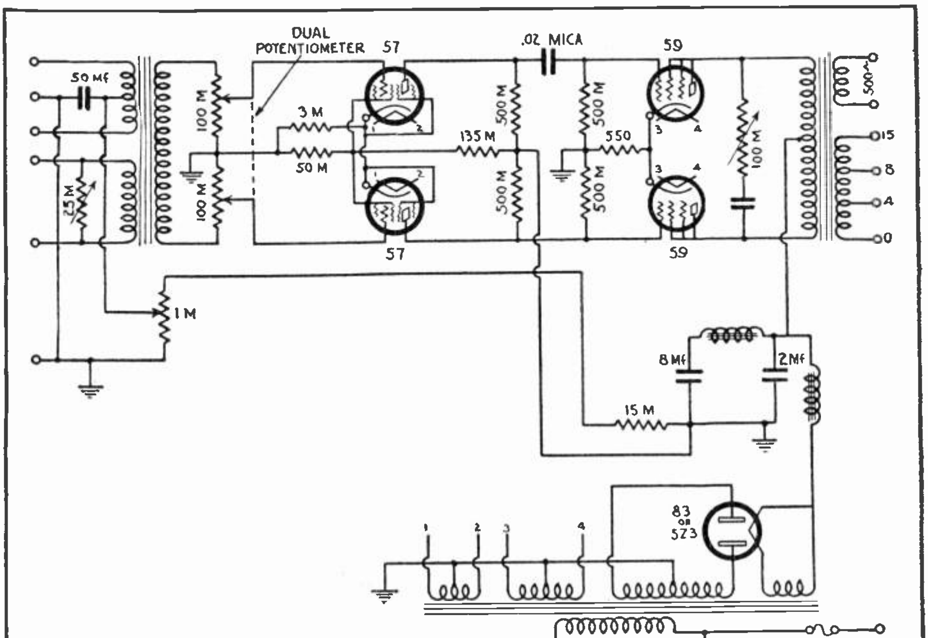


FIG. 28

A "Class A" 3.2 watt amplifier, having a rated gain of 65 D.B. at 1,000 c.p.s. Used as a driver for power stages, whether Class "A" or "B", requiring a high input. Includes microphone current supply.

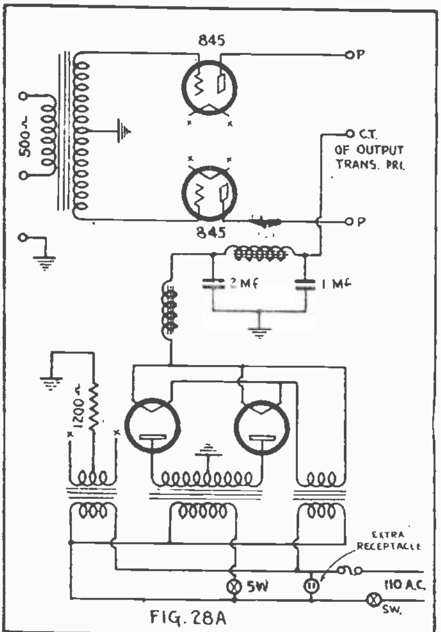


Diagram of a "Class A" 40 watt power stage. The amplifier in Fig. 28 is designed to drive this stage.

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 29A respectively.

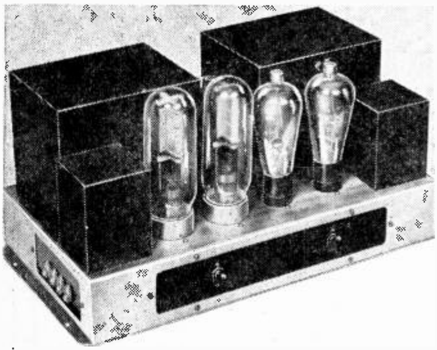


Fig. 29A
(Courtesy Simplex Electric Co.)
Photograph of power stage diagramed in Fig. 28A. Rectifier tubes and power supply for this stage are included.

Fifty-Watt "Class B"

The unit illustrated in Figs. 30 and 30A is a 50 watt Class "B" power stage. A driver, such as shown in Fig. 28, 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

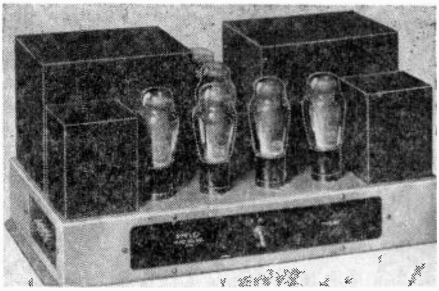


Fig. 30A
(Courtesy Simplex Electric Co.)
Photograph of the "Class B" 50--watt amplifier. This power output is obtained from four '59 "Class B" tubes in push-pull parallel.

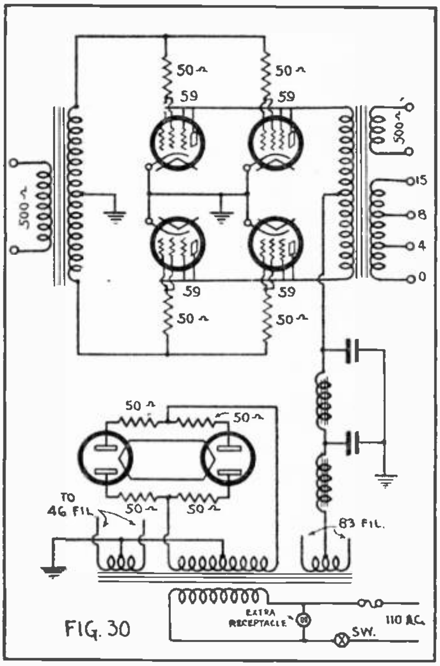


Fig. 30
A "Class B" 50-watt power stage. Input and output transformers are included. Special consideration must be given to the design of the output transformer, especially the primary winding which must be capable of carrying the very high plate current required by the two tubes.

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.

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.

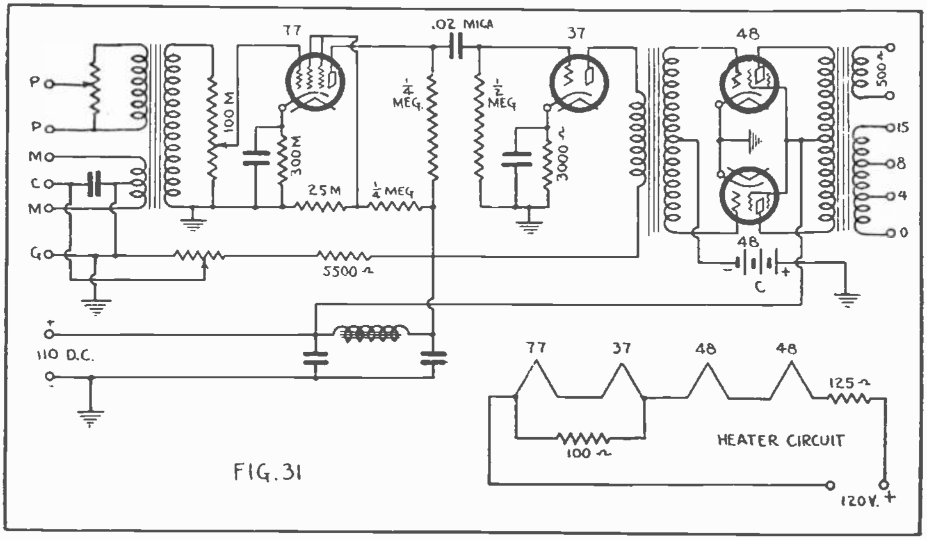
If the installation requirements call for a small amplifier, for small audiences or for indoor work, then it is recommended that a D.C. amplifier illustrated in Fig. 31 (schematic wiring diagram) be employed. By using separate bias (C batteries) a power output of six watts is obtained. The tubes are 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.

Six-Volt Portable

One of the neatest, most impressive, and highly efficient portable amplifiers the writer has ever seen is shown in Fig. 32. Everything is self-contained (excepting speaker) within the carrying case. It is ideal for rental, or for demonstration purposes. Two "Class B" '79 twin amplifier tubes are employed in a push-pull parallel arrangement, delivering a power output of 12 watts. This is sufficient for most rental or demonstration purposes. It can also be used for sound truck, sales meetings, conventions, etc.; the feature of this arrangement being that, when it's all over, the amplifier can be easily and quickly packed up and removed.

A 6-volt dynamotor, operating from either one or two (in parallel) storage batteries, supplies the required high voltage for the plates of the tubes. The storage battery also furnishes the power for the heaters of the tubes.

Provision is made for phonograph and microphone mixing on the input side. The output has impedance taps ranging from 4 to 500 ohms. Microphone



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

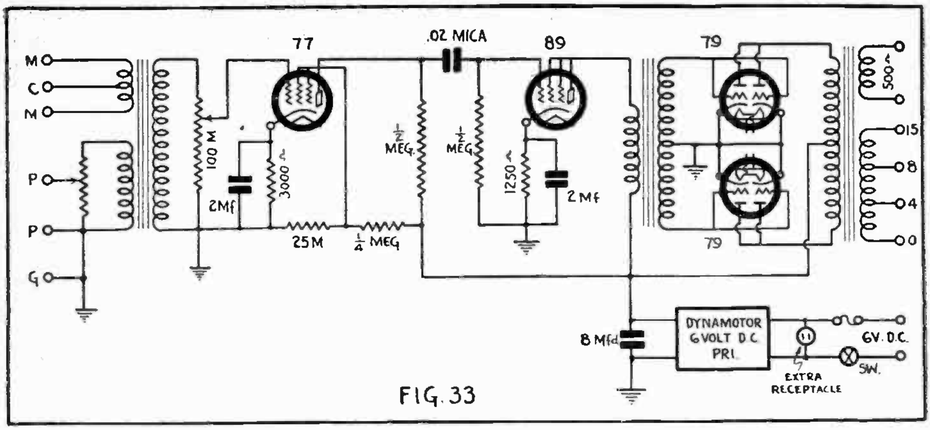


FIG. 33

Schematic wiring diagram of the portable system illustrated in Fig. 33A. It is a "Class B" job of 12 watts output—sufficient for medium sized requirements.

batteries, dynamotor, and all necessary cables are stored in compartments located in the bottom of the cabinet. A master volume control in addition to mixer control (for phono use) is located on the panel front. A schematic wiring diagram of this unit is shown in Fig. 33.

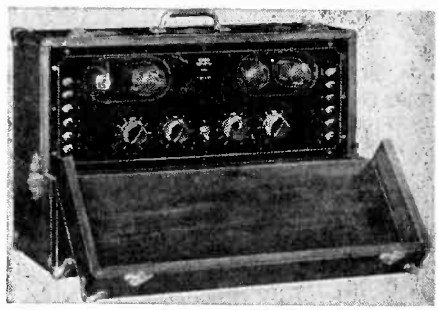


Fig. 33A (Right)
(Courtesy Simplex Electric Co.)

An ideal neat portable for rental or demonstrating service. No external power connection is necessary, since the microphone batteries and dynamotor are mounted within the case. A 6-volt storage battery operates the complete unit.

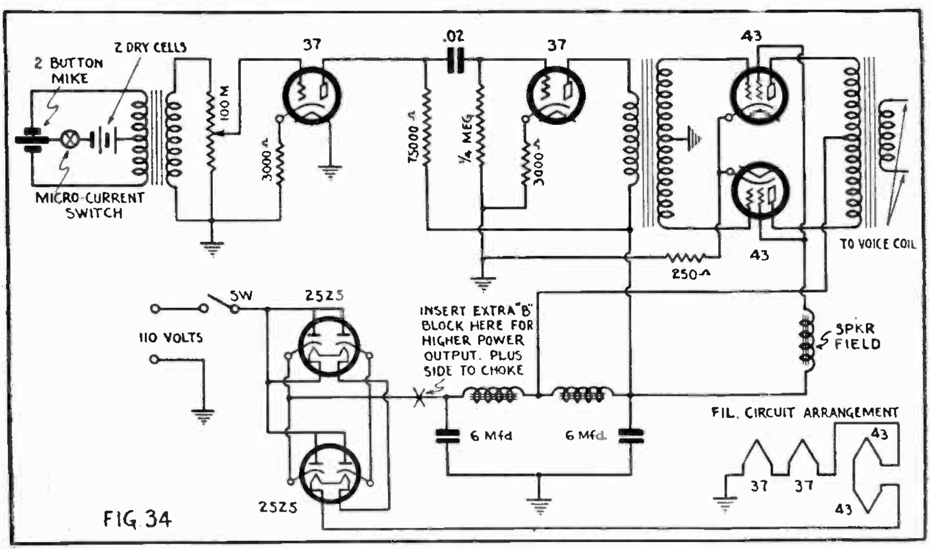


FIG 34

An A.C.-D.C. "Class A" amplifier of approximately 5 watts output. Recommended for portable service for small requirements where power-supply encountered is not definitely known.

A.C.—D.C. Amplifier

Small amplifiers are used by a good many demonstrating or window salesmen. Their procedure is generally to set up a portable, with microphone, in a store window and to fasten the speaker outside above the window or door entrance. Then, as they demonstrate the efficiency of their corn plaster, razor sharpener, or what have you, they make their "spiel" into the microphone; it is conveyed to the speaker and thus to the crowd outside.

Since these men travel from one location to another, they have no means of anticipating the types of power supply they will encounter. The amplifier most adaptable for this type of installation is illustrated in Fig. 34. It operates from either A.C. or D.C., is simple to operate and set up, and can cover fairly well where the outdoor noise level is not too high. It has a power output of approximately 3 watts with normal line voltage. By inserting a 45-volt B block at point marked "X" in the diagram, "plus" side towards choke, the output will be increased to approximately 5 watts.

PART VALUES FOR FIGS. 22, 23, 24, 25

—LEGEND—

Figure 22

R1—	50,000	Ohm	1	Watt	Resistor
R2—	2,700	"	2	"	"
R3—	10,000	"	2	"	"
R4—	50,000	"	1	"	"
R5—	10,000	"	40	"	"
R6—	800	"	20	"	"
C1—	2	Mfd.	400	Volt	Condenser
C2—	2	"	200	"	"
C3—	.25	"	400	"	"
C4—	16	"	500	"	Electro. Cond.
C5—	8	"	"	"	" "
C6—	2	"	"	"	" "
C7—	.25	"	400	"	Condenser
C8—	2	"	"	"	"

—LEGEND—

Figure 23

R1—	50,000	Ohm	1	Watt	Resistor
R2—	2,700	"			"
R3—	10,000	"	2	"	"
R4—	50,000	"	1	"	"
R5—	1,350	"	2	"	"
R6—	5,000	"	2	"	"
R7—	50,000	"	1	"	"
R8—	25,000	"	75	"	"
C1—	2	Mfd.	400	Volt	Condenser
C2—	2	"	400	"	"
C3—	2	"	200	"	"
C4—	2	"	400	"	"
C5—	.25	"	400	"	"
C6—	4	"	600	"	"
C7—	4	"	600	"	"
C8—	2	"	800	"	"
C9—	25	"	400	"	"
C10—	2	"	400	"	"

—LEGEND—

Figure 25

R1—	1,500	Ohm	1	Watt	Resistor
R2—	250,000	"	1	"	"
R3—	20,000	"	2	"	"
R4—	1,300	"	1	"	"
R5—	5,000	"	2	"	"
R6—	100,000	"	1	"	"
R7—	15,000	"	2	"	"
R8—	70,000	"	2	"	"
C1—	.1	Mfd.	400	Volt	Paper Condenser
C2—	1	"	1000		Electrolytic Cond.
C3—	2	"	50		" "
C4—	10	"	200		" "

—LEGEND—

Figure 24

R1—	10,000		2	Watt	Resistor
R2—	60,000		5	"	"
C1—	50	Mfd.	100	Volt	Electro Cond.
C2—	1	"	1000	"	" "
C3—	10	"	200	"	" "

CHAPTER III

INSTALLATION AND INSTRUCTION

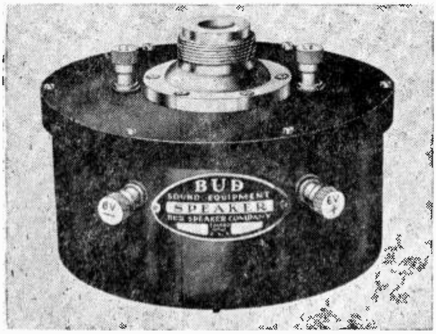
Figuring Requirements

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 (which must first be amplified to the required power and level) 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 any veterans in this field.

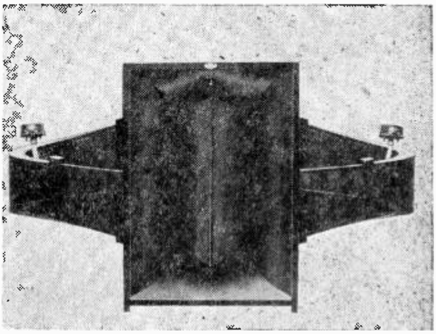
Location and coverage are always the primary considerations in determining size and type of amplifier. An installation made outdoors naturally requires a great deal more of amplified sound than one indoors. If a large stadium must be covered—then the amplifier must of necessity be large. The Power output 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 also would do if a wide-flare theatre type horn was used (see Fig. 38). This is permissible only if the acoustics of the auditorium are good (see Chapter IV 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.



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



(Courtesy Bud Speaker Co.)
A wide flare—double unit horn.

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—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 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 imperfections, 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.

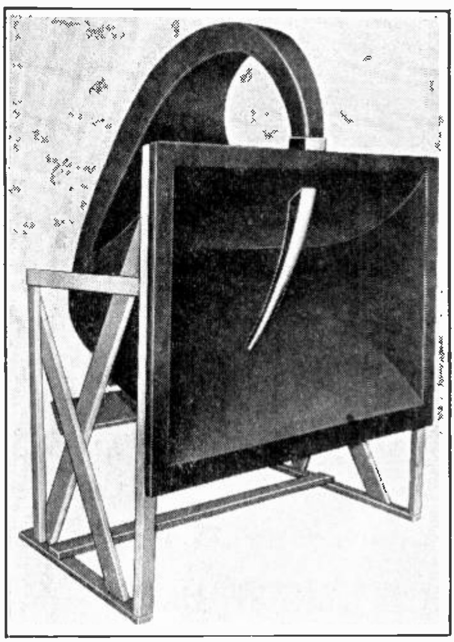


Fig. 35
(Courtesy Racon Electric Co.)

A horn with directional characteristics, for projecting sound in auditoriums or theatres. Length of air column is 6 feet.

A horn which meets the above conditions, providing there is space and a means of disguising it, is shown in Fig. 35. 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. 36, when taken apart consists of three pieces, the largest one of which only totals 37 inches. The total length is six feet.

Fig. 36
(Courtesy Racon Electric Co.)

A demountable six foot trumpet. Meets with requirements of a portable installation or for rental PA work—where quick set-up is necessary.

Getting back to amplifier power outputs, we shall now take a large installation into consideration to illustrate how to determine the equipment to b 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, race track, or outdoor meeting place.

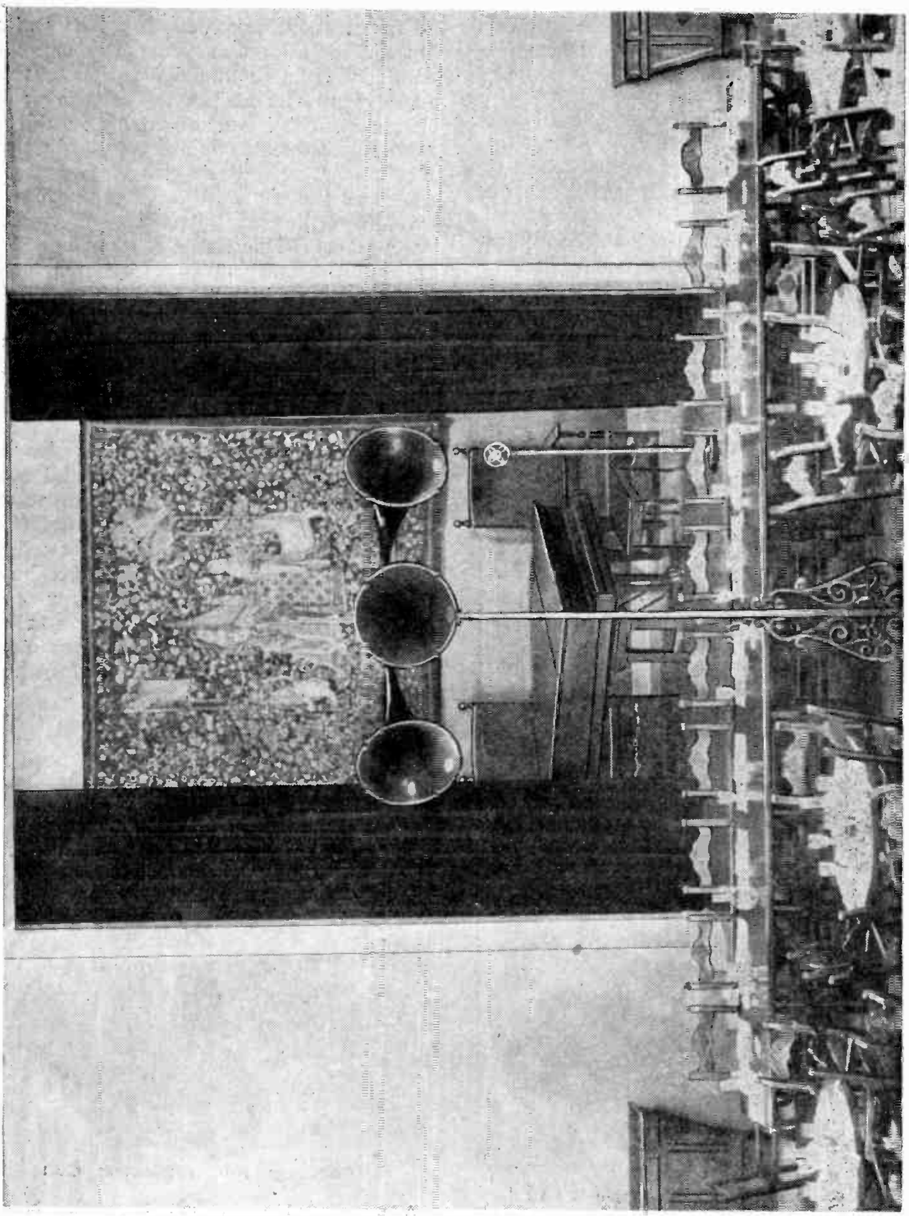


Fig. 37
An indoor P.A. installation. Note location of trumpet type speakers, near speaker's table and projecting out into audience for best coverage.

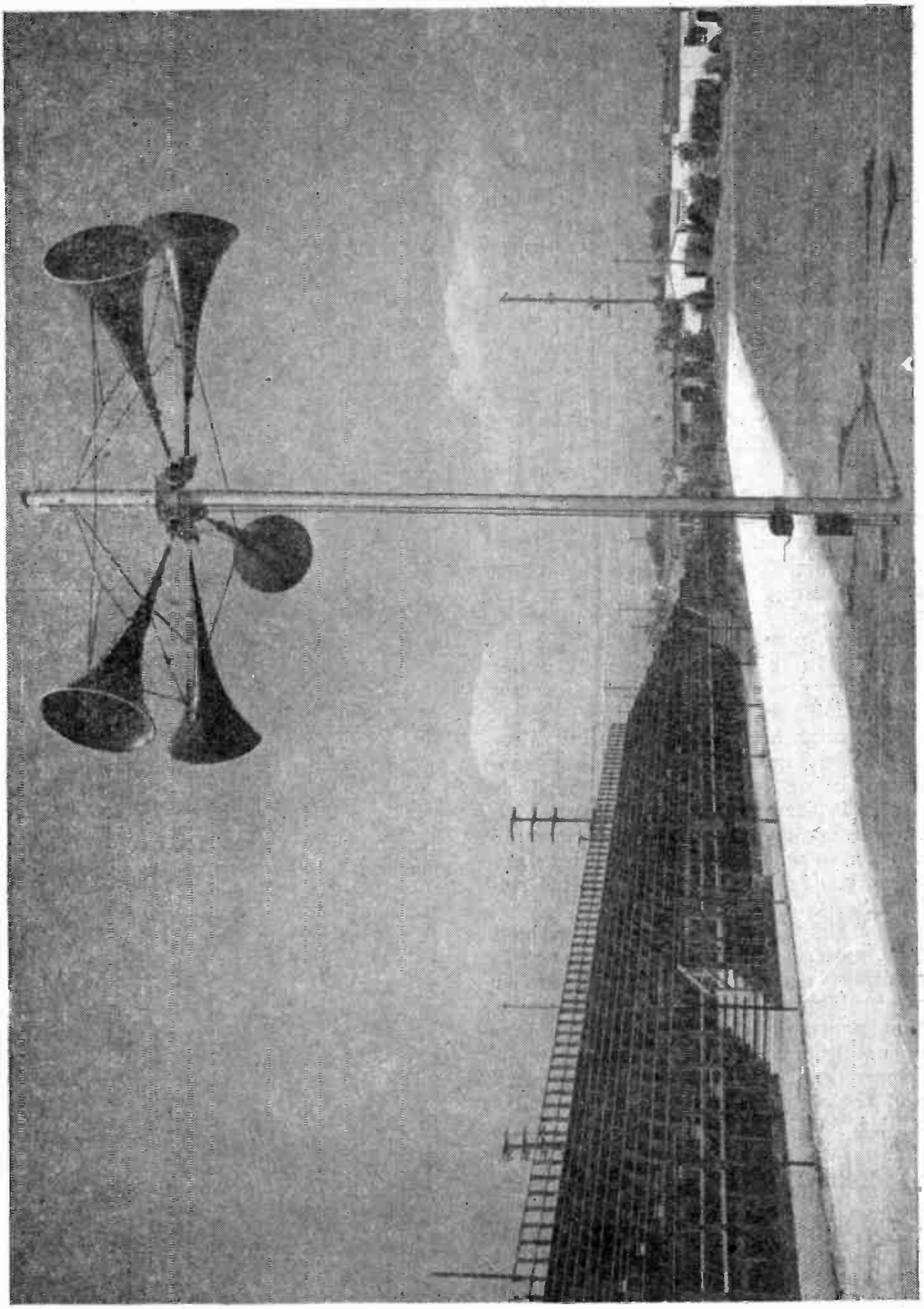


Fig. 38

An outdoor installation, typical for race tracks, ball parks, or stadiums. The amplifier (not shown) is installed in either a special weather-proof booth in the stands or other convenient and satisfactory location.

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. 38 is desired, the distance between poles with five 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 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.

A radial horn, such as that illustrated in Fig. 39, can be ideally substituted for individual trumpets as shown in the previous photograph. This reproducer also is excellent for sound truck use, where sound emanations are to be projected uniformly in all directions.

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 Two. 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

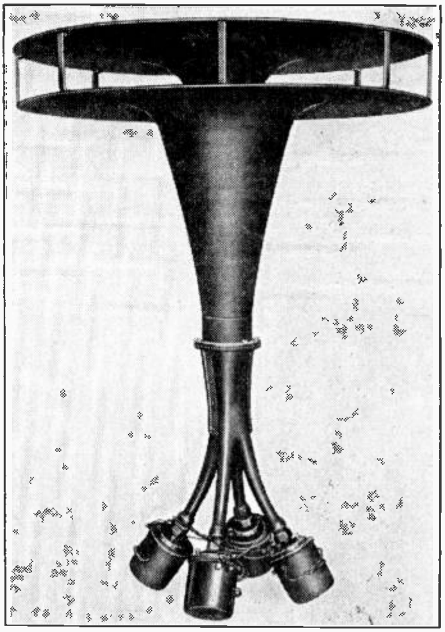


Fig. 39

(Courtesy Racon Electric Co.)

A radial horn for projecting sound equally over 360 degrees. Particularly adapted for sound-truck use, tower, amusement park, or where complete circumferential coverage is desired.

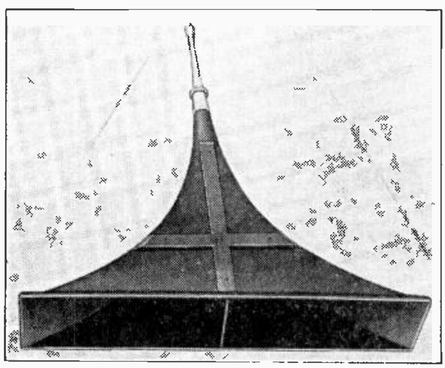


Fig. 39A

(Courtesy Racon Electric Co.)

A trumpet designed to meet special conditions where space is limited. Excellent for sound-truck use, where height limitations are imposed.

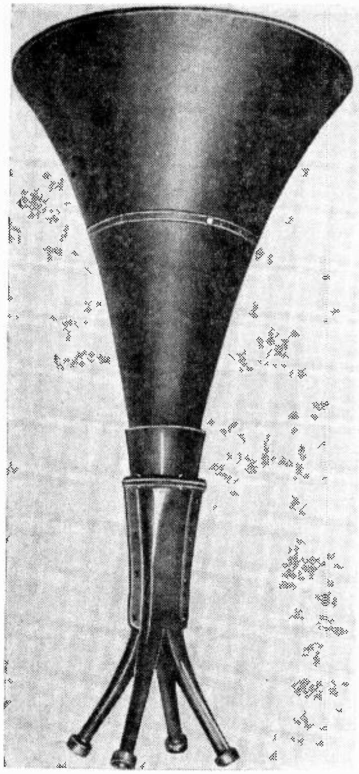


Fig. 39B
(Courtesy Racon Electric Co.)
Four-unit airplane horn for long-range projection.

flare horns for best frequency response. The reason for this is best illustrated by referring to Fig. 40. 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 affect a compromise 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. 41.

For horn or trumpet use, units are constructed as shown in Fig. 42. They are available in three sizes for oper-

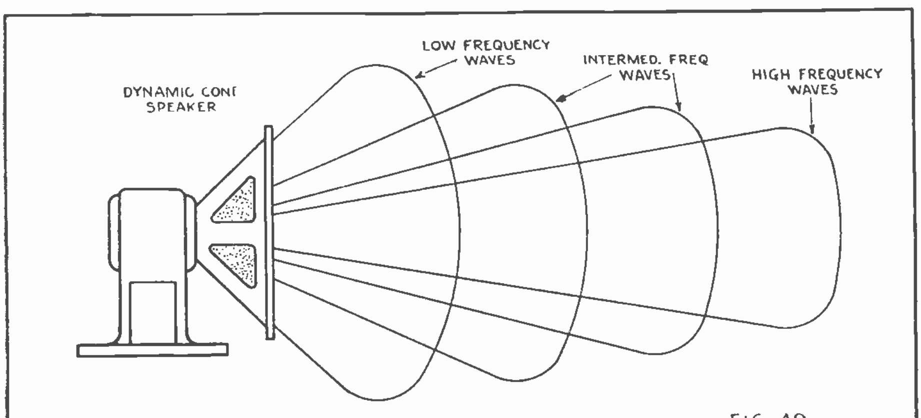


FIG. 40

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.

ation with various size P.A. or theatre amplifying equipment. All are rated at a peak-load capacity of 50 watts,

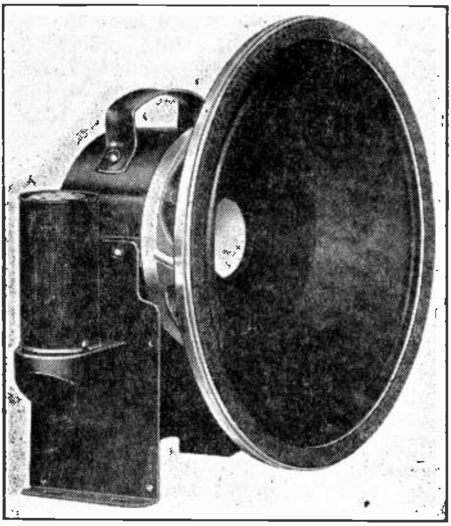


Fig. 41

(Courtesy Jensen Radio Mfg. Co.)

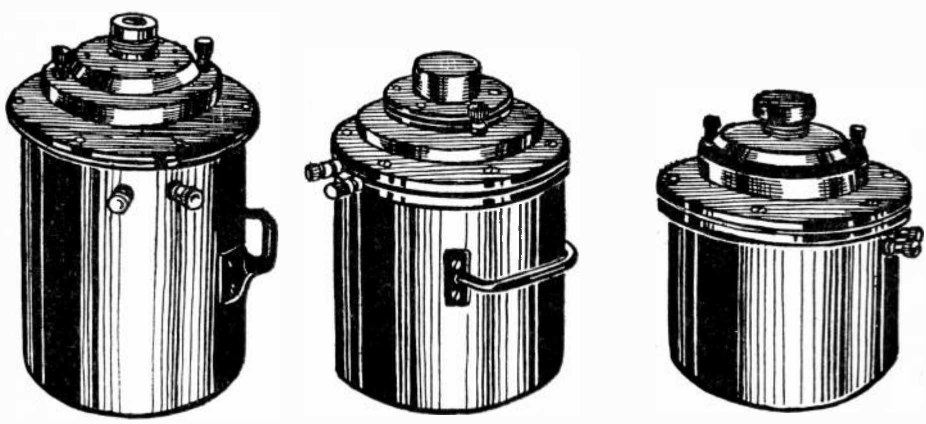
Specially designed cone-dynamic speaker for public-address work. Note the sturdier construction of this unit, as compared to ordinary radio cone dynamics. Power supply, with rectifier, for field excitation is included.

Fig. 41A

(Courtesy Jensen Radio Mfg. Co.)

A dynamic cone speaker, properly baffled and housed in a beautiful cabinet. Ideal for dance halls, hotel lobbies, or auditoriums, where quality reproduction is preferred to long-range projection of sound.

but range in continuous operating capacity from 20 to 25 watts. The voice coils in all three models have an impedance of 15 ohms (1000 c.p.s.) and the field coil excitation is 6-8 volts.



SUPER-GIANT GIANT MASTER

Fig. 42

(Courtesy Racon Electric Co.) Three sizes of trumpet dynamic units, the Master, Giant, and Super-Giant. The latter is designed for very large power outputs.

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 harmonious and overtones in musical reproduction. A suitable filter should be used which provides a low-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. 43. The power input to this unit (Model A) is limited to five watts. It is of dynamic principle and construction, and no baffle is required for it.

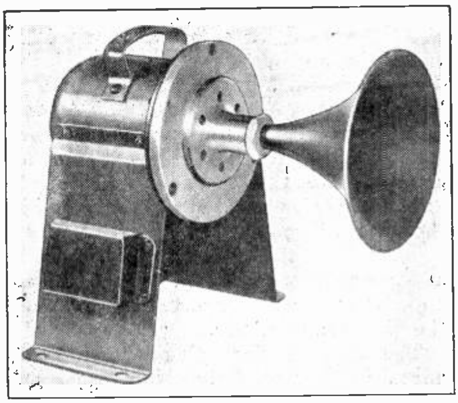


Fig. 43
(Courtesy Jensen Radio Mfg. Co.)
A high-frequency response speaker (dynamic type) which, when used with a suitable filter network and in combination with flat-response speakers, will give excellent results in reproduction.

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. 42 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

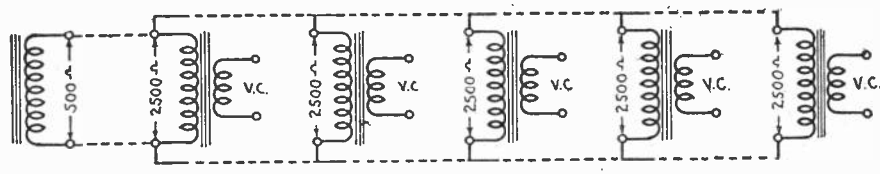


FIG 44

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

to Fig. 44 illustrating voice coil connections, parallel, or series and parallel arrangements. With the field voltages turned "on" (turn amplifier "on" if field excitation 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.

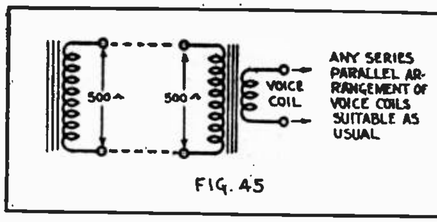
(4) Where long speaker lines are necessary, because of their remote location from amplifier, use the 500-ohm tap on the output transformer. Transmission impedance of output should be between 200 and 600 ohms, and the reason for this is that the characteristics of impedance at low values (around 8 to 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

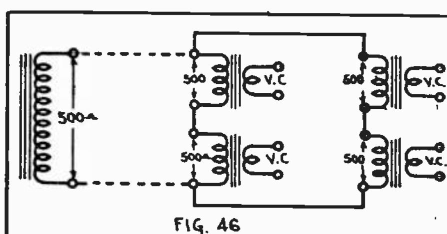


Single speaker installation using 500-ohm transmission level, eliminating long-line defects.

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 effectively matches the secondary of the line matching transformer. Where a single speaker is concerned, employ the circuit in Fig. 45. Where five voice coils are employed, use speaker transformers and the arrangement shown in Fig. 44. 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. 46. 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.

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



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

for resistances in parallel:

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

For other combinations see Chapter Two—information dealing with the tapped-output transformer employed in the 10-watt "Class A" amplifier.

(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 mean, on all other installations, follow the local fire underwriters' 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.

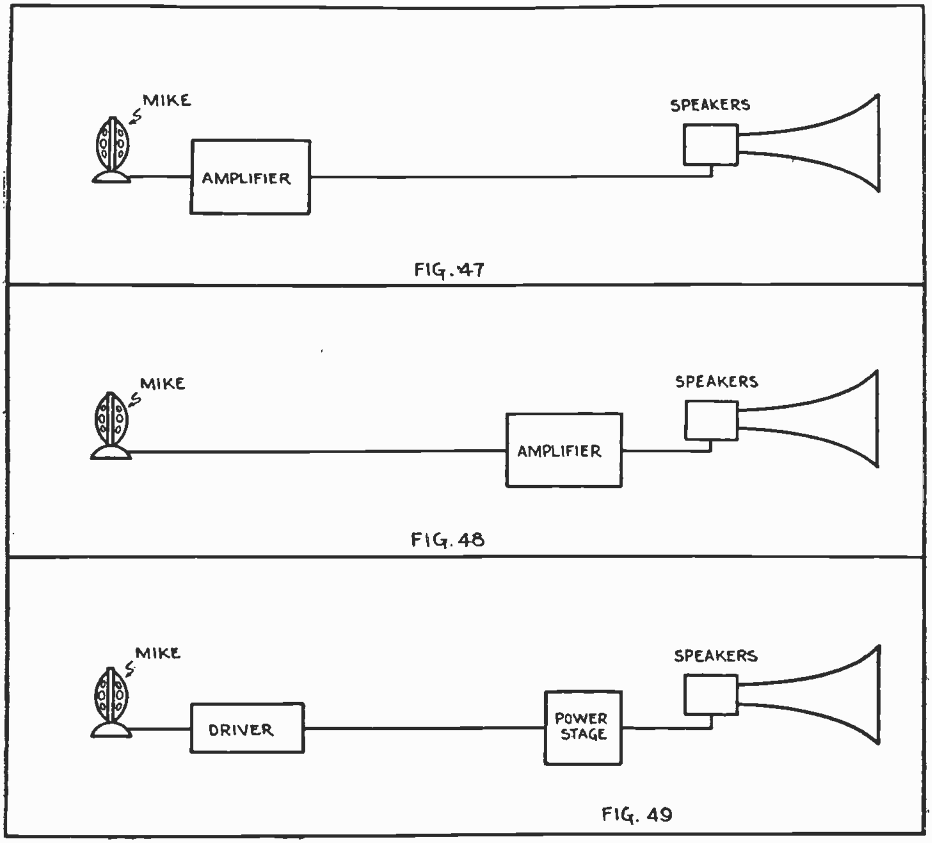


Fig. 47—One method of installing the amplifier where the speaker is at remote point. Controls are convenient but location is poor. See text for reasons.
Fig. 48—A better method, locating the amplifier near the speaker and remote from microphone input.
Fig. 49—Best method of installing—where long lines are concerned. Driver stages at mike, power stage at speaker end. Refer to text for explanation.

(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 sheathing.

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

(a) Where the complete amplifier is placed at microphone end with controls for mixing or regulating volume. See Fig. 47—illustrating this method which is convenient for controlling the gain but is poor from the angle of transmission level.

(b) Placing amplifier at speaker location. This method is better, but the control of the amplifier is limited and inconvenient; also, the transmission level may be so low that line noise may be appreciable. However the transmission is more efficient than in case (a), since it is at low level. See Fig. 48.

(c) The best method, for the same reason assigned for constructing super power amplifiers in unit form (driver stages in one unit and power stage in another) consists of placing the driver stage with all necessary controls for regulating volume, tone, etc at the microphone end; then installing the power stage at the speaker end. See Fig. 49. 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

This is generally caused by acoustic feedback, contrary to the general impression that it is always audio oscillation. However, 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 microphones, when placed thus, will pick up the sound emitted from the speakers which it has just transferred into electrical energy — the result being the howl, ringing or whistling noise generally encountered. The remedies for this type of trouble are thoroughly gone into in the first chapter dealing with carbon microphones.

CHAPTER IV

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.

Even those who are completely unfamiliar with the subject of acoustics can recall the difference that exists in sounds when heard in an empty room or auditorium. 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 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. .... .18
Upholstered Church pews, per linear ft. .... up to 1.6
Plain Plywood auditorium chairs, each .... .24
Part upholstered chairs ... 1.6
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

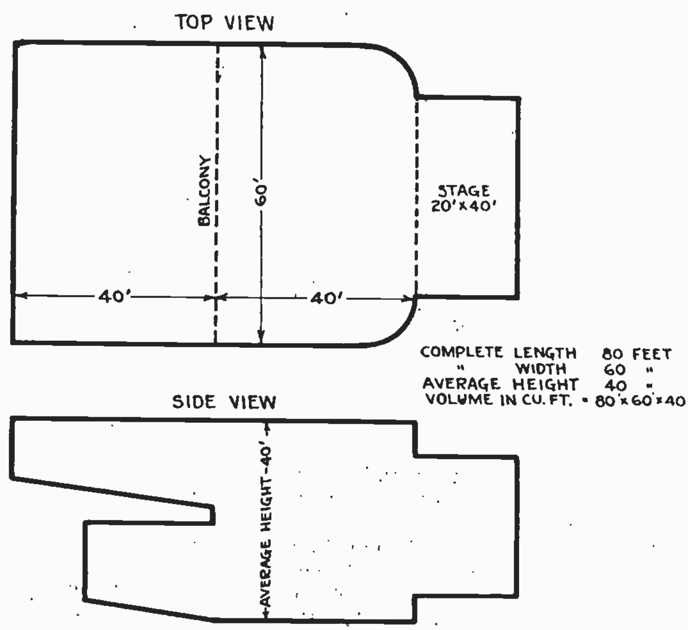


FIG. 50

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

for carpet (Table One) we have 330 additional units.

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 330,000	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

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

1/3 audience

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

2/3 audience

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

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 ⅔ audience which is 3.8 seconds—we find that the excessive time is 2.3 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 of ceiling. Stage walls should also be treated, to eliminate the reverberation at those points which would reflect back to the microphone and create 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 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 measurement was taken, and in that manner "the average time period of reverberation" is obtained.

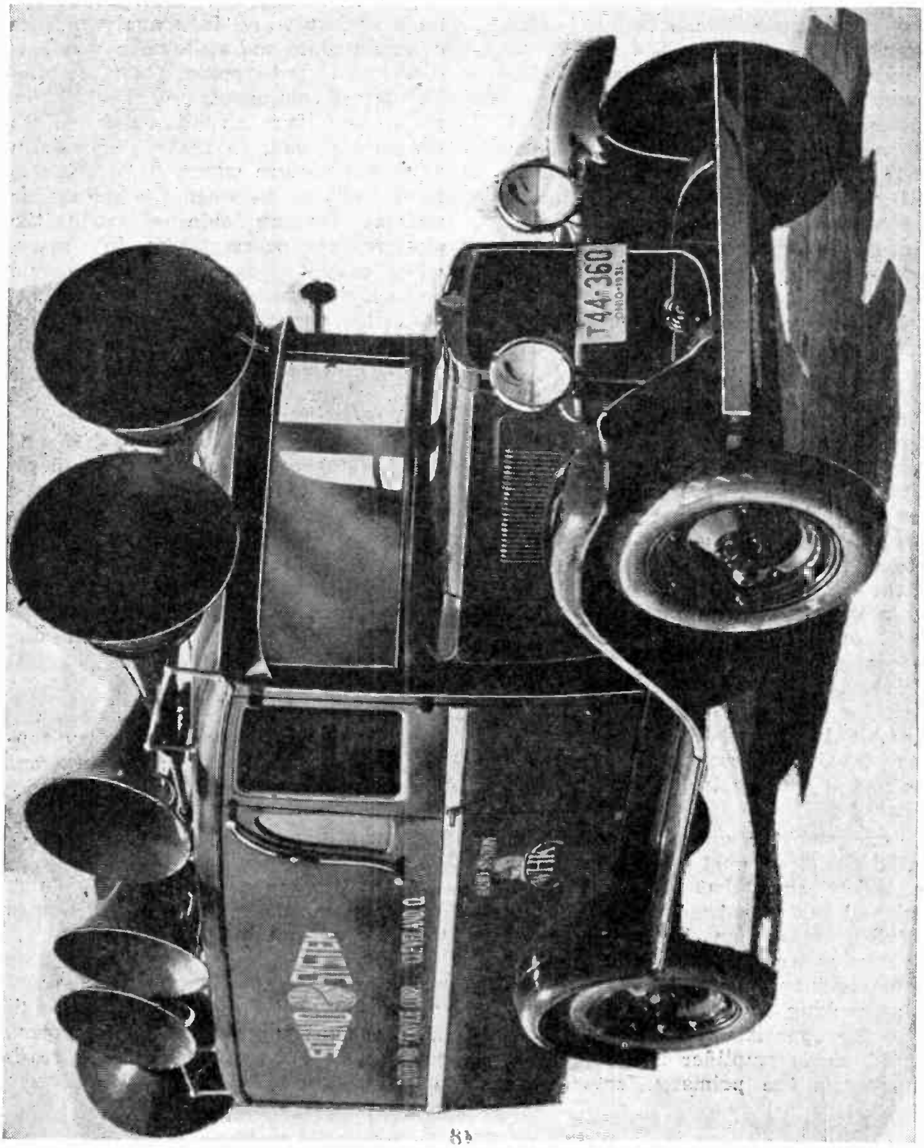
By subtracting this time from the optimum time specified in Table Two (for the particular auditorium being figured on) then employing the formula $A = \frac{.05V}{T}$, the amount of absorption necessary for treatment is obtained. After which, the desired material can be selected and the auditorium then properly "decorated" with it.

Always treat the rear wall of an auditorium in preference to 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 reverberaton. Where the expense of complete treatment is too great for the building owners, this type of speaker is to be recommended and used.

A Sound-Truck Installation, excellent for advertising, ballyhoos, or for addressing outdoor gatherings. The installation can be improved upon in many ways, particularly in the number and type of trumpet speakers employed.



Part of the amplifier equipment can be seen through the side door.

CHAPTER V

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 phono motors (i.e. two-speed 78 and 33⅓ RPM), 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 case is exactly the opposite where a poorly designed, cheap amplifier is used. Since economy is the primary factor in a cheap amplifier, the units in the construction of the amplifier and power supply must be of an inferior quality, with little or no safety margin allowed for line-voltage surges, overload and constant operation over a long period of time.

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. Then to check the system to see if it is faulty, as complained.

A summary of various troubles and remedies generally encountered is herewith given, properly catalogued and classified so that the information can be easily obtained if desired in an emergency. It is assumed that the P.A. equipment was satisfactory prior to the time of trouble, *i.e.*, gain of amplifier was sufficient, speaker distribution satisfactory.

Low Volume

(1) Weak Microphone battery supply, materially reducing the current throughout 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, buth tubes must have approx. 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 tubes for emission, especially 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. Can be definitely determined by checking for grid and cathode bias. "Class B" stages, however, in most cases employ no grid bias.

(5) Speaker overloaded; 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 O.K. 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 or grid or plate resistors, defective—not in the sense that they have "open-circuited", but because some fault has changed their characteristics or value. Check resistance of windings 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 . These rules should be followed explicitly.

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 positions 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 determine if filament-supply winding is O.K. Be sure line plug makes good contact within receptacle.

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 applies 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 cooperation, poor price for installation 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 sportsmanlike manner.

Formulas and Data

For newcomers 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.

To find Reactance of a Condenser:

$$X = \frac{1{,}000{,}000 \text{ ohms}}{6.3 x f x C}$$

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:

$X = 6.3 x f x L$

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 $X = 6.3 \times 60 \times 1$, 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 formulae 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:

(X1) (Xc)

225 — 100 = 125 (resultant reactance)

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

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

= 160 ohms impedance

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 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 currents 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 = .30 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:

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

The Decibel

Prior to the advent of the vacuum tube, losses in transmission lines were measured in terms of "miles loss". If a circuit was said to have a loss of "20 miles", it would have a loss equal to that introduced if we were to connect 20 miles of standard No. 19 gauge telephone wire to its input, and measure the output power at a frequency of 796 cycles.

With the introduction of the vacuum tube in telephone repeater circuits, the term "miles gain" and "miles loss" were adopted, which served to denote a gain or loss standard.

Since the gain in power is directly proportional to the gain in miles, the result obtained from the ratio of input power to output power produced the "miles gain" of that particular amplifier. Since the square root of the power amplification ratio is approximately equal to the current and voltage ratios, (in the case of a good amplifier excluding mechanical defects of the reproducing apparatus), it was convenient to use the current ratio as a measure of "miles gain", sound intensity being directly proportional to current.

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.)

Definition

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 logarithmic 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 noted by the ear.

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:

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

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.

$$P = \text{Power ratio}$$
$$10 \times Log \ P = 60$$
$$Log \ P = 60/10 = 6$$
$$P = 10^6 = 1{,}000{,}000$$

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 Decibels:

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 $10 \times Log \ 700 = 28.4$ D.B.; of the new amplifier, $10 \times Log \ 1000 = 30$ D.B.

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

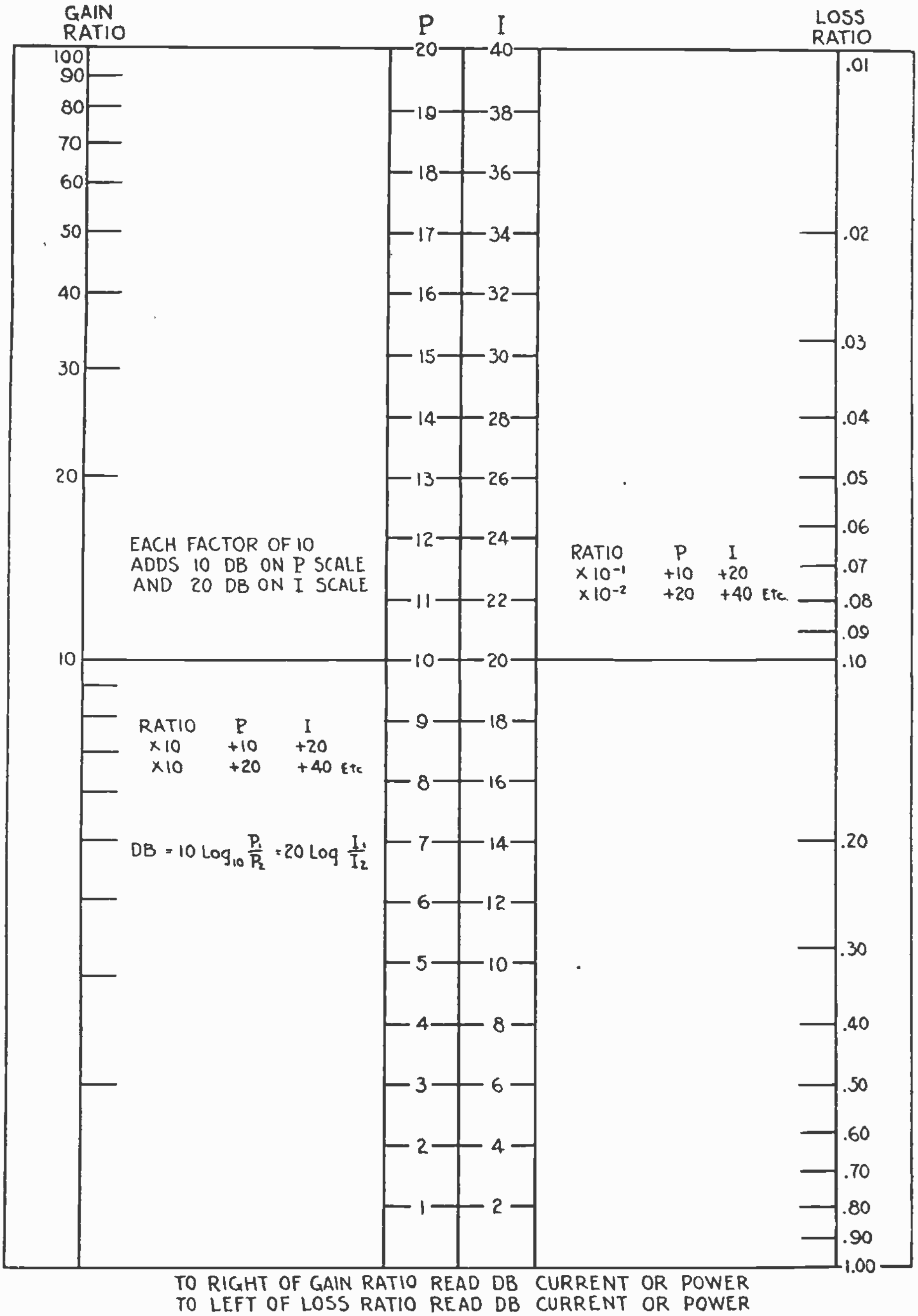


FIG. 51

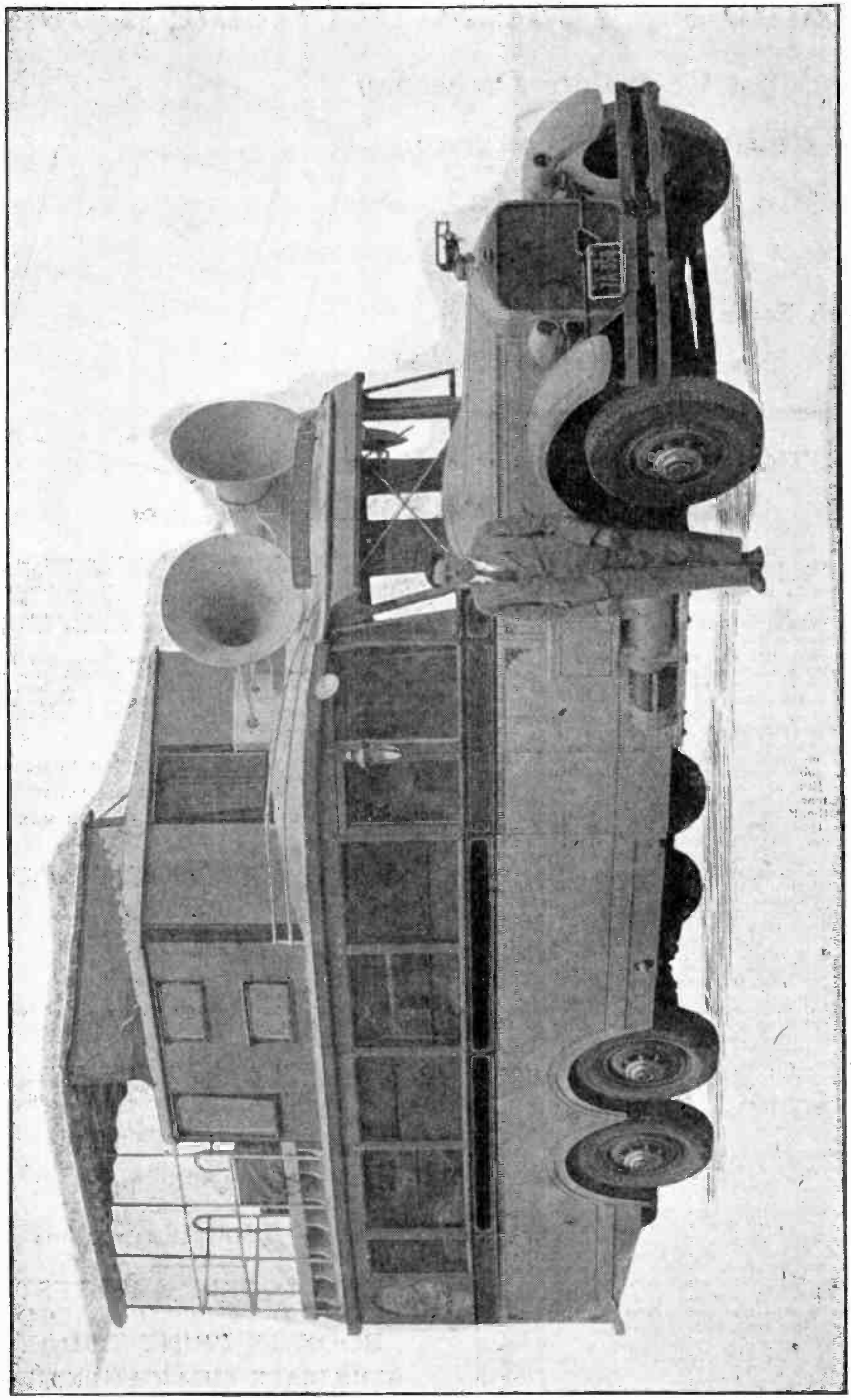
Chart for determining directly the gain or loss in D.B., which will be found directly to the right of the gain-ratio scale. The loss in D.B. can be measured at the left of the loss scale.

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. Constructional data on amplifiers has been purposely avoided, since this type of information has been consistently given in Radio Craft magazine.

For more advanced information on amplifiers or acoustics, reference can be made to contemporary literature. Perhaps, if the demand is great enough, another book dealing essentially with advanced engineering data on P.A. and sound systems will be published.

Meanwhile, comments, criticism, or suggestions for future improvement of this book are solicited. Please address the author in care of the publisher.



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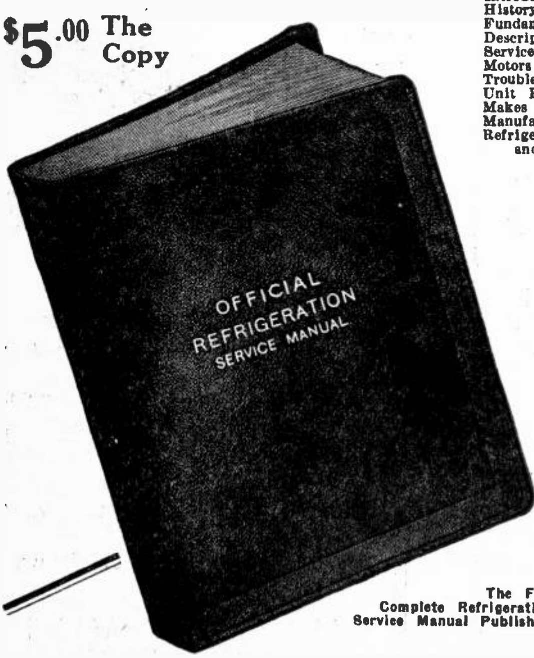

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