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HOME RECORDING AND ALL ABOUT IT

A Complete Treatise on Instantaneous Recording,
Microphones, Recorders, Amplifiers,
Commercial Machines, Servicing, Etc.

by *George J. Saliba*



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RADIO-CRAFT MAGAZINE

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New York, N. Y.

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CHAPTER 1

Introduction

The theory of sound was first perceived scientifically by the ancient Greeks. They were the first to analyze the origin of sound and come to the conclusion that sound as heard by the ear was the result of disturbances in the air. They knew that vibratory objects were the source of sound, but it was not until 1857, only 75 years ago, that Leon Scott patented in France an instrument which he called the phonautograph. Scott's machine utilized a piece of smoked paper attached to the cylindrical surface of a drum, so mounted that when rotated by hand it moved forward at the same time. A stylus was attached to the center of a diaphragm through a system of levers in such a manner that it moved laterally along the surface of the cylinder when the diaphragm vibrated. Over the diaphragm was placed a barrel shaped mouthpiece. When the drum was rotated, words spoken into the mouthpiece caused the stylus to trace a wavy line upon the smoked paper. This wavy line was the first known record of sound vibrations. Unfortunately, Scott did not go any further in his experiments. He was unable to reproduce his sound, and as a result his machine had no practical value. It was Thomas Edison in 1877, or 20 years later, who came out with his famous phonograph. His machine was very similar to Scott's phonautograph, except that it differed in two very important details. The first was that the smoked paper was replaced by a sheet of tinfoil, and second, the stylus was attached directly to the diaphragm so that it traced an impression of variable depth as the diaphragm vibrated, instead of a wavy line as with the phonautograph. After such a record had been made, the drum was returned to the starting point, and, with the stylus in place, again rotated as before. The record-

ed sound was then intelligibly reproduced. Thus, Edison gave us the first phonograph and also the first instantaneous record.

In subsequent models the tin foil was replaced by a wax cylinder. For many years the wax record, either in cylinder or disc form was used almost exclusively for the recording and reproducing of sound. As a matter of fact, the first phonographs by Edison were instantaneous recording machines. The owner had his own choice of either playing back commercial records or making his own.

The records used were of cylindrical wax, and the machine was provided with a shaving device so that the records could be shaved and new ones made. The present day dictating machine is nothing more than the old Edison phonograph, with a few improvements.

At the present, there are four methods of sound recording. The first two are very similar, in that both use a flat disc for the sound record. The hill and dale method, as developed by Edison, utilizes a constant width groove. The depth is varied according to the sound impressions. The reproducer is then varied in a vertical motion as the needle point moves up and down, within the sound track.

The lateral cut method utilizes a groove constant in depth, but variable in width; that is, the needle moves from side to side according to the sound impressions. This method has been in wide commercial use for years, and it seemed, for a while, that the hill and dale method was to become obsolete. Lately, however, vast progress has been made in adapting the variable depth method to electrical recording. This method possesses many advantages over the variable width. In the first place, more sound can be put on a record of given dia-

meter. Since the grooves are of a constant width, up to 150 lines per inch can be put on the disc as against 96 or 100 that are the limits with the variable width. The other advantage is the frequency response is much better. Deeper bass notes can be recorded without any danger of over cutting. As it is now, with the variable width, if very low bass notes are to be recorded, the grooves must be cut further apart and consequently they are of shorter duration. The higher frequencies can be recorded and reproduced more easily, because the reproducer is more sensitive to the finer modulations. Unfortunately for the home recordist, this method has not been developed, up to the present time, for instantaneous recording, so until this development takes place, the amateur must content himself with the variable width method which has proved to be very satisfactory.

The third method of recording is the photographic one which is used in the talking movie field. The simplest system is where a flashing lamp is used. The output of the amplifier is fed to this lamp, and the glow is alternately increased and decreased following the modulating current in frequency and depending in degree upon its strength. This light shines through a slit and optical system that brings it to focus on the film as a fine line running cross-wise of the sound track. There is then produced in the developed film a series of alternate light and dark lines whose spacing and contrast depend on the frequency and intensity of the modulated current applied to the lamp. A low note corresponds to a slow frequency of sound vibration and results in a wide spacing of lines on the film. A high note, corresponding to rapid frequency sound vibrations, results in a close spacing of the lines.

In reproduction, the positive film is run through a standard projector which is modified by the addition of an attachment for reproducing the sound known as the sound head which is located below the mechanism of the head.

The beam from a small, high intensity electric light is concentrated

by an optical system containing a slit and brought to focus as a fine line across the sound track of the film as it passes through a sound gate. See fig. 1. The film at this point moves uniformly, and at the same speed as used in recording. On the side of the sound gate opposite the light is a photoelectric cell, which responds to variation in the amount of light striking it by letting pass a varying electric current. The more

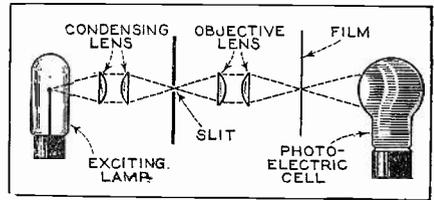


Fig. 1. Optical system for sound on film reproduction.

light, the more current, and it responds practically without lag to the fluctuations of the light received. The density of each particular line of the sound record as it passes through the beam in the sound gate, determines the amount of light passing through the film into the light sensitive cell, and the current through the cell is therefore modulated according to the sound record. There is 14½ ins. of film between the picture gate and sound gate, but since the sound record is displaced on the film the same distance in advance of the picture the two reach their respective gates at the same time. The sound and picture are always in this same relation, and they are therefore always properly synchronized without attention.

The output of the photo-cell is strengthened by a small amplifier built into the sound attachment and is then fed to the regular amplifiers.

Needless to say, such a recording system is out of question for instantaneous recording. The cost of the apparatus would be prohibitive to the amateur, even if the theory was practicable, and unfortunately, at the present time he has no means whereby he can make his own home talkies on film. Some day such a system will be developed and until that day

arrives, we must be content with the reliable disc method.

The fourth method of recording is known as magnetic recording. A steel wire is passed between the pole pieces of a magnet which is energized by a solenoid, which, in turn, is energized by the conventional microphone and amplifier. The steel wire then retains a magnetic record which is reproduced when the wire is passed again through the pole pieces. These pole pieces have coils of wire on them. The output of these coils is then fed through an amplifying system.

On the surface this method of recording seems ideally suited for the amateur. The first difficulty is that this apparatus has never been developed for commercial use. All of the work has been done in the laboratory, and the results have never been any too satisfactory. The main objection is that the magnetic impressions begin to spread, especially the higher frequencies. In a short time the record is practically useless. The high frequencies are practically gone and, only the lows are present.

From the foregoing apparently, the only practical method available to the layman is the disc method of variable width. The apparatus for this has been so highly developed, that the amateur has hardly any more work to do than in operating the kodak camera.

The uses to which this instantaneous recording can be put are varied and many; and the profits to be realized therefrom will be proportional to the foresight and ability of the salesman who puts across the idea and makes the installation. Every home that has a radio receiver, every music school, music store, amusement park, department store, club, and broadcast station is a good live prospect. In short, the field of application for this method of making records is unlimited; and it remains only for the energetic salesman to familiarize himself with the technique of obtaining good results, then to go out and demonstrate. The idea sells itself.

Orchestras and bands are now being recorded, so that their technique

may be studied carefully and improved upon. Singers, instrumental artists and music students everywhere are making this recording a regular part of their course; since they can thus watch their progress and note their improvement. Students of elocution can record their talks and study their delivery. Records of broadcasts can be made, and, if necessary, encore programs can then be broadcast. Likewise, anyone who broadcasts can have his selections recorded for his personal file.

Vaudeville singers or musical acts will find this new art very much to their advantage; for they can use these records for advertising purposes and auditions at distant points. Another novel application of this instantaneous recording is in the making of "sound effects" for amateur theatricals. The ambitious producer can, after patient experimenting with the recording of different sounds, electrically reproduce them whenever desired; thus giving his presentation the realism of the professional theatre.

PORTABLE RECORDING

One of the most common uses of the portable recording machine is to take it into the home to record the voices of the different members of the family and to form a voice album similar to the picture album. If the family has young ones, then periodic visits can be made so that the voices of the children at different stages of their growth are preserved. Some might argue that the studio can easily render this service, but it must not be forgotten that the photographer who takes his photographs in the home has always been successful and always will be, so why can't the professional recordist do the same thing? Individuals are much more at ease in their own homes with familiar surroundings than in the studio, and this in itself is a tremendous factor in overcoming microphone fright with the result that better records are made. The potential possibilities in this field are quite apparent when it is observed that every single family is a good live prospect, not for just one call but for repeated calls.

At parties, portable recording has proved itself to be a great source of entertainment and, at the same time, a big money-maker for the person making the recordings. In the past, it has been the custom for the host or hostess to buy souvenirs to give their guests as mementos of the occasion, but now portable recording steps in to give the guests the thrill of hearing their voices as others hear them and at the same time gives them a living record of the occasion. Appropriate labels for the records can be made for the party souvenirs, which will give them a sort of exclusiveness so that the host will feel that he is giving his guests something personal rather than just a disc.

At banquets, speeches can be recorded for the speakers themselves, or for the guests, while at church fairs and bazaars, recording booths can be set up and business solicited in much the same manner as at studios. Students of music, who in the past have been reluctant to go to the studio for recording on account of the inconvenience of carrying their instruments, are excellent prospects because the studio can now be easily brought right into their own homes with no inconvenience to them. It is readily seen that visits of this nature can become a regular part of the student's courses.

One of the most unique applications of the portable service is the recording of wedding ceremonies. By the use of a double turntable, the complete ceremony can be easily recorded and the writer has been informed by one firm that is doing this sort of work, that not one single bridal couple approached has refused to have their ceremony recorded.

RECORDING SYSTEMS

Whether the recording equipment is utilized in commercial enterprises or for home use, the apparatus in either case is substantially the same. For home use the audio amplifier of the radio receiver, used in conjunction with an ordinary magnetic phonograph pickup and a microphone makes a simple but efficient and prac-

tical recording system (See Fig. 2).

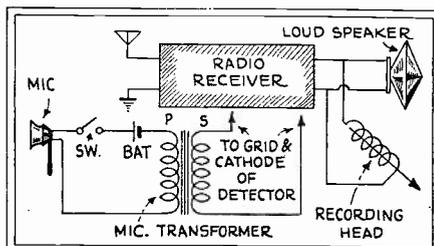


Fig. 2. The general arrangement of the standard voice and radio recording reproducing equipment.

This system makes use of pre-grooved records, which are now available at all music and radio stores. The pre-grooved record, which is made up on either a metal or celluloid disc, has a blank groove already cut into the surface; and this groove serves the same purpose as the feed screw used in recording on blank uncut discs; namely, to guide the recording head across the face of the record. The microphone transformer, being of the step-up type, amplifies the audio frequency voltages; and this gain, combined with the μ or amplification factor of the detector tube, really adds a transformer-coupled stage to the audio amplifier.

A weight (about 10 oz.) should be attached to the recording head to prevent the needle from jumping the groove, as it tends to do when modulated. The weight also serves the purpose of pushing the needle deep into the groove, thus making available more mass to work against; with the subsequent result of more volume in the produced record.

Only home-recording needles should be used for recording and playback. These needles, which have a relatively dull point, with a red shank to differentiate them from regular phonograph needles can be obtained at all radio and music stores.

In recording from the microphone, the switch "Sw." is closed, and the volume control of the radio set is turned away down; and vice versa when records are to be made from the air. With a little patience and experimenting the home recordist can achieve results that will be almost on a par with commercially-pressed records.

CHAPTER 2

Microphones

CHOICE OF MICROPHONES

In the selection of the microphone, one has a choice of several types. The single-button carbon, the two-button carbon, the condenser microphone, and the dynamic microphone are all readily adaptable to home recording.

An average single-button carbon microphone has the characteristic shown in Fig. 3. It is noted that this characteristic rises rapidly from 100 to 500 cycles, then flattens out up to about 2800 cycles, and from that point falls off very sharply. In other words, there is a variation of 8 DB between 100 and 2800 cycles. In any electro-acoustical device, the maximum allowable difference in level over the entire range is between 2 and 3 DB, and it is readily seen that this type of microphone is not suitable for recording if good results are desired.

While voice may be recognizable through this instrument, the sharp cut-off around 2800 cycles makes it absolutely useless for any musical work. The carbon hiss is another objectionable characteristic—because it makes the letter “s” very hard to reproduce, giving the effect that everybody talking through it has a lisp.

The double-button carbon microphone is the type best suited for home recording. Fig. 5 shows a simple circuit using this instrument. It is easily seen that, as the diaphragm is actuated by the voice waves making it move in either direction, the current through one side of the transformer will increase while the current through the reverse side will decrease.

This effect contributes to the elimination of the microphone hiss caused by the normal current flowing through the carbon granules, as well as eliminating distortion caused by even harmonics. It also eliminates any effect of the microphone current upon the trans-

former, since the battery current flowing through the microphone transformer creates opposing magnetic fields, and therefore is balanced out. (This is similar to the action taking place in the primary of the output transformer in a push-pull amplifier.)

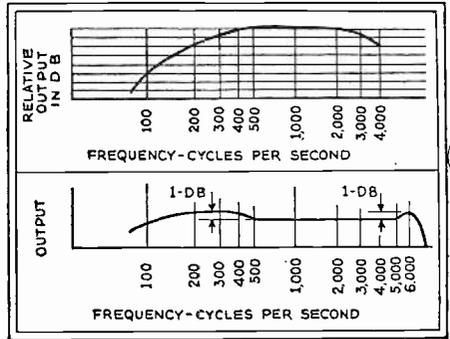


Fig. 3. Above. Single button microphone response curve.
Fig. 4. Below. Two button microphone response curve.

A well constructed two-button microphone has a characteristic as shown in Fig. 4. The curve is flat, within 3DB, from 30 to 6000 cycles, and this is more than enough to reproduce all of the frequencies necessary for good recording. No frequency above 6000 cycles is ever put on the air from a broadcast studio.

The condenser type of microphone, no doubt, is the instrument for perfect recordings, but its high cost and the extreme care required in its use make it impractical for the average home-recording enthusiast. Its characteristic is very flat from the lowest audio frequency to well above 7000 cycles. It has no internal noise, and there is no danger of any trouble, such as packing, developing during recording.

The microphone consists in its essentials of nothing but two metal plates. One is a flat brass disc, called the “back plate,” and the other is an extremely thin, tightly stretched circular sheet of duralumin, called the

diaphragm. This diaphragm is spaced .001 to .002-in. from the back plate and well insulated from it. These plates together form a small condenser, from which the microphone derives its name. Sound waves striking the diaphragm cause it to move slightly toward or away from the back plate, and thus vary slightly the capacity of the condenser.

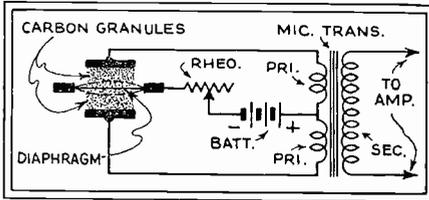


Fig. 5. Connections of a two button microphone.

Fig. 6 shows a circuit of this microphone with its associated amplifier. Since the capacity of the condenser transmitter is very small, the capacity between the leads from it to the grid of the first amplifying tube must also be kept very small, and that is the reason that the amplifier and transmitter are always built as a unit.

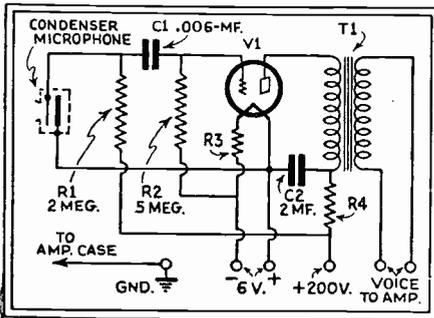


Fig. 6. Connections of a condenser microphone to its associated amplifier.

A more recent development in microphones is the dynamic microphone. It is a well known fact that ordinary loudspeakers and headphones can be used as microphones.

The dynamic speaker owes its high efficiency to the dynamic principle, in that a moving coil actuated by voice frequencies is arranged to float in a magnetic field. This magnetic field may take the form of an electro-

magnet or a permanent magnet. The dynamic microphone operates on the same principle as the dynamic speaker.

Essentially it is composed of a diaphragm D supporting a voice-coil of fine aluminum ribbon, wound edge-wise in the field of a permanent magnet M, as shown in the cross-section view. Fig. 7. When sound waves impinge on the diaphragm, the coil (to which it is rigidly attached) vibrates with a plunger-like motion, cutting the lines of force, and thus generating across two terminals a potential which is substantially constant from about 35 to 10,000 cycles. The use of the permanent magnet obviates the necessity of utilizing any exciting batteries; and since the impedance of the voice coil is only 25 ohms, that of the line load also is low. These factors combine to eliminate the batteries and the local amplifier.

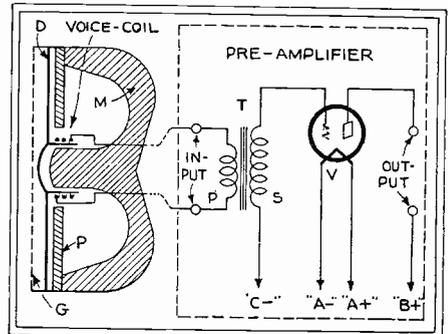


Fig. 7. Connections of a dynamic microphone and remote pre-amplifier.

The diaphragm is made of duralumin .0011 in. thick, and has a dome-shaped center portion which extends to the inner edge of the moving coil. This type of construction stiffens the center so that the diaphragm has a plunger action throughout the entire audio-frequency range.

The advantages of the dynamic microphone are as follows:

It may be placed at a considerable distance from the pre-amplifier;

It is adapted to use in localities indoors or out, where there exists wind or other extraneous noises;

Simple and rugged in design;

Frequency response graph practically uniform;

Unaffected by atmospheric conditions;

Conveniently located and mounted, and does not require spring mountings;

High sensitivity, occasionally precluding the need of a pre-amplifier;

Does not require an exciter battery;

Is insensitive to ordinary vibration

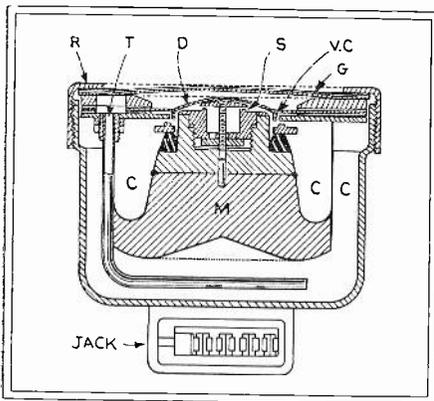


Fig. 8. Cross section of the dynamic microphone, in which the letters have the following meaning. R, clamping ring; T, pressure equalizing tube; D, diaphragm; S, air gap; VC, voice coil; G, protective grille; M, permanent magnet; C, cavities.

There is no doubt that this type of microphone is the ideal for instantaneous recording, but again its high cost makes it prohibitive to the average amateur. It must be borne in mind that the output impedance of the "mike" is 25 ohms, and consequently the conventional 200 ohm input transformer is useless.

MICROPHONE TECHNIQUE

Too many records are spoiled by incorrect use of the microphone. Fig. 9 is the schematic diagram of a single-button microphone circuit, and fig. 10 that of a two-button microphone hook-up. In fig. 9 the milliammeter is placed in series with one leg, and the microphone current is

varied by means of the potentiometer "P"; the values of this current is determined by the type of microphone used, and this information is usually supplied with the instrument.

If a two-button microphone is used, jacks in each button leg, as shown in fig. 10 will be necessary. Some people connect the meter permanently in the center leg, to read the sum of the two currents, but this is a risky procedure. If the microphone is rated at 20 mils per button, the middle leg will carry 40 mils. With the meter in the center leg reading 40 mils, one button may be packed and carrying 30 mils, while the other carries only 10 mils. The result will be that the button carrying the 30 mils will pit and burn out. For the same reason it is inadvisable that the meter should be placed permanently in either leg. The ideal way of keeping close watch on the current is to have a meter in each leg, but this means added cost.

If the speaker, or singer, stands too close to the microphone the reproduced record will be loud and pos-

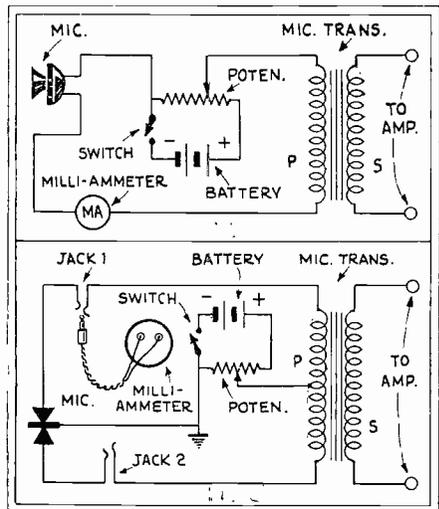


Fig. 9. Above, Connections for the adjustment of current in a single button microphone.

Fig. 10. Below. Connections for the adjustment of current in a two button microphone. The current in each leg of the latter should be checked separately.

sibly distorted; even if there is no distortion, the quality will be poor. The effect will be "tubby" and stifled, as when talking into a partly filled barrel. On the other hand, if the distance from the microphone is too great, the volume of the record will be low. It is best to stand about 10 inches from the microphone, and the voice directed into it. If it is necessary to stand closer to the microphone, the person should face the instrument and direct his voice past it. At no time during the recording should the current be changed by the operator; otherwise a crackling noise will be registered.

If the current should suddenly rise, it is an indication that the microphone is packed; this usually happens on particularly loud notes. The pressure causes consequent lowering of the resistance. The microphone should then be tapped lightly, to spread the granules.

When starting to record, the full microphone voltage should never be applied suddenly, but should be brought up gradually until the milliammeter reads the normal current. A little time may elapse, while the microphone is warming up, before the button current readings stabilize.

It will be found that the use of a two-button microphone will result in much better recordings than by the use of a single button type. At best, the single-button will not pass frequencies higher than 2500 cycles; while the two button will easily pass 5000—6000 cycles. If the recording system is to be used for voice only, then a single-

button microphone will be sufficient.

The carbon microphone while the least expensive of all the types is nevertheless a very delicate instrument and extreme care should be used in handling it. The microphone should be used always in a vertical position and should be preferably mounted in a ring from which it is suspended by springs. Some people use rubber bands, but these are unreliable because the rubber deteriorates. The purpose of the springs or rubber is to prevent any vibrations from being transmitted to the instrument and as a result being recorded. One disadvantage of using springs is that they have a natural frequency of their own, and if the vibrations are of this frequency the springs will emphasize this particular vibration to the extent that it will be recorded. Rubber bands do not have this disadvantage.

Carbon microphones should never be exposed to moisture, but should always be stored in a dry place. Moisture causes the buttons to pack. A heavy note or shouting also causes the buttons to pack. In either case the microphone should be tapped lightly with the hand to loosen the granules. Revolving the unit might also help considerably. Do not hit the microphone with any instrument as damage might result. Under no condition should the microphone be tapped or shaken when the current is turned on. Batteries are recommended for the microphone supply, but a well filtered low voltage power supply is quite suitable.

CHAPTER 3

Amplifiers

The advisability of using high gain, quality audio amplifiers is absolutely necessary for the insurance of good records.

The recording level required for instantaneous or "home" recording is much higher than that required for commercial wax recording; the cutting stylus in the latter case having very little mechanical work to do against the wax disc and, consequently the required level is only about +3DB. In making instantaneous records, however, the cutting stylus, besides modulating the track, must compress the material of which the record is made. This compression must be effected by weighting the cutting head with a fairly heavy weight, and naturally the modulating action of the stylus is retarded considerably. As a result, the gain of the amplifier feeding the cutting stylus has to be quite high if a loud record is desired.

Aluminum records are made at a level of between +15 to +20 DB, and since the output level of a carbon microphone is about -36 DB, the gain of the recording amplifier must be at least +51 DB. Ungrooved celluloid records, due to their greater hardness, require a higher recording volume level than aluminum records, or about +25 to +30 DB. It is obvious, therefore, that the amplifier gain should be at least +61 DB. The recording level for pre-grooved celluloid or aluminum records is the same.

It is desirable for two reasons that the amplifier have more gain than is really needed. First, high gain affords extreme freedom of position about the microphone: that is, the person or persons being recorded may be located at a greater distance from the microphone than ordinarily, and still obtain a good recording. Secondly, high gain makes it unnecessary that the microphone, in order to increase its sensitivity, be operated at the high current value, which

results in strong background noise.

The "direct-coupled" amplifier is considered one of the most faithful from the point of view of frequency response, and it makes an excellent amplifier for use with pre-grooved celluloid or aluminum records.

The disadvantage is that the gain with respect to the microphone is comparatively low. There is very little mobility allowed around the microphone, and since the latter thus has to be operated at full current value, to increase its sensitivity, the chances of microphone noise are increased.

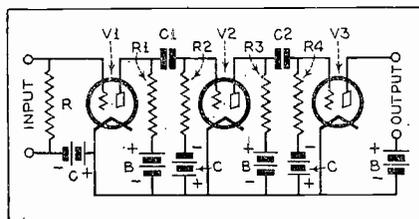


Fig. 11. Three stage resistance coupled amplifier.

Fig. 11 shows a schematic of a resistance coupled amplifier. The variation of the plate current in the resistance R1 produces across it a varying voltage drop which actuates the grid of the next tube V2. The blocking condenser C1 is for the purpose of preventing the plate voltage from being impressed on the grid of the tube. This blocking condenser must be small in order that rapid voice variations may be reproduced. A large capacity may result in blocking. When a signal is impressed on the input the condenser becomes charged, and it requires a certain amount of time to discharge. This time required depends on the time constant of the condenser, and this is equal to the product of the grid leak resistance and the condenser capacity. It is therefore obvious that these two factors must be properly proportioned to each other to keep this time constant small.

Resistance coupling does not give as much amplification as other types because the only amplification is that due to the μ of the tube, and at best only 75% of this is available. The high μ tube can be used to bring up the amplification per stage so that it is about equal to that of a transformer stage.

The main advantages of resistance coupled amplifiers are (a) flat frequency characteristics over the entire audible range, (b) absence of all resonance peaks, and (c) compactness and low cost of amplifier units.

One of the most important objections to this system is the excessive plate battery voltages that are necessary. The plate voltage on the tube is not the plate voltage at the supply,

this method of coupling, as in the preceding, the amplification in one stage cannot be greater than that of the vacuum tube itself. It has the advantage that the d. c. resistance of the choke is very small and as a result the voltage drop is reduced. This means that the plate supply is low, and the apparatus is more compact and lighter than the resistance coupled supply. High μ tubes can be used to increase the gain per stage, but this involves more care in design. At low frequencies the impedance of the choke is very low as compared to the high internal resistance of the tube and this results in a loss of amplification at the lower frequencies. This type of tube has a high effective input capacity and this is the

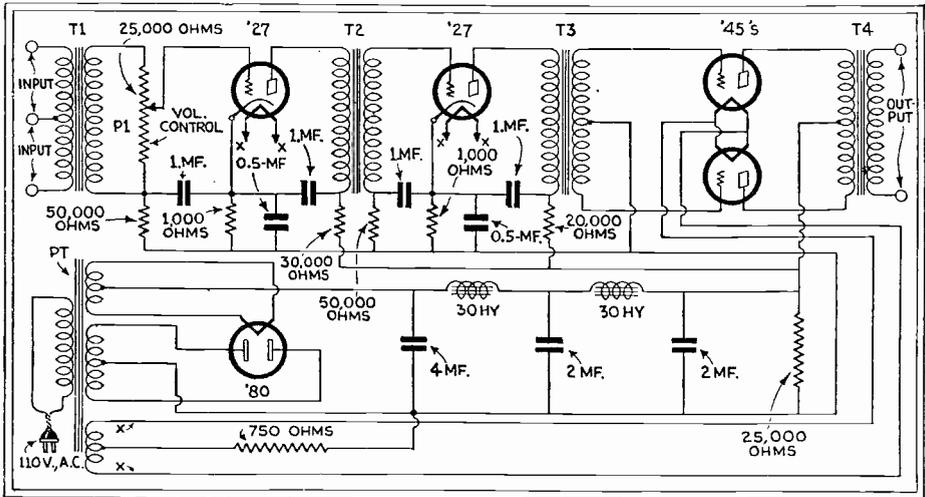


Fig. 12. Three stage transformer coupled amplifier suitable for recording. The very thorough bypassing makes for extreme stability of operation.

but this voltage minus the voltage drop in the plate resistor. The latter is usually very high from 50,000 to 100,000 ohms, and as a result the voltage drop is very high. These excessive plate voltages require a bulky and heavy power supply and some times this is quite an objection especially where space requirements are a determining factor. The voltages are high enough to be dangerous and great care must be exercised in handling the supply.

The impedance coupled amplifier is very similar to the resistance coupled one of Fig. 11. Instead of the plate, and grid resistors, chokes are used. In

case of resonant points and even oscillations, at frequencies lower than 400 cycles. The high capacity also causes a pronounced drop in response at the higher frequencies. For best results the high- μ tube is recommended only with resistance coupled amplifiers.

In fig. 12, is shown a circuit of a transformer coupled amplifier. For a given investment this style of coupling gives the most amplification per stage. Besides the μ of the tube being utilized, the transformer ratio also adds to the gain. The B supply requirements are comparatively small and the amplifier is much more stable. The only real ob-

jection offered to this method of amplification is that the frequency response is not very flat. There is usually a resonant peak around 5000 cycles. This is due to the distributed capacity of the transformer combined with the input capacity of the tube, connected across the secondary terminals. To avoid this resonant condition the secondary winding is usually divided into two sections with a space between the sections.

Another way of flattening out the frequency characteristic is by using a resistance across its secondary winding. This resistance should be variable from 5000 to 1,000,000 ohms. When the resistance is decreased the amplification is lessened, and the quality improved. In this way it is possible to approach the characteristic of the impedance coupled amplifier.

In some transformer coupled amplifiers where more than two stages of amplification are used, the transformers are so chosen that resonant peaks occur at different frequencies over the entire range. This gives an approximation of the ideal equal amplification.

In the past year and a half the screen grid has come into use in amplifiers. The screen-grid tube, due to its high amplification factor is particularly advantageous where a great deal of voltage amplification is necessary. If the ordinary 3 element tubes are used in this case many stages in cascade would have to be used, and this is cumbersome and costly.

In Fig. 13, the tube is shown in its simplest circuit. This is the familiar direct coupled amplifier as developed by Loftin White.

Fig. 14, shows the circuit of a more elaborate amplifier using the screen grid tube. This circuit is a good exam-

ple of how the different types of amplifying systems are utilized. The first and second stages are resistance coupled while the last stage is transformer coupled. When the screen-grid tube is coupled by the conventional resistor-condenser combination to the power

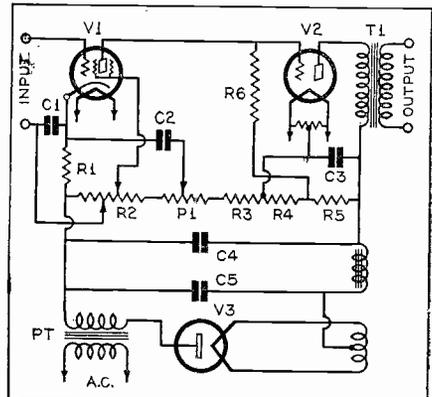


Fig. 13. Directly coupled screen-grid amplifier.

stage, it should be remembered that because of the high internal impedance of the tube, high impedance coupling units must be used to obtain sufficient voltage amplification.

It is well to remember that the gain of this amplifier will vary considerably for different screen-grid tubes of the same type. This is due to the wide variation in the screen currents which, materially affects their operating characteristics. In order to obtain uniform gain, it is necessary that the screen grid potential be adjusted for different tubes.

The ordinary conventional types of audio amplifiers, while entirely suitable for recording are not of much use if fidelity of reproduction is desired. The reason for this is two fold. Present day amplifiers are designed to have

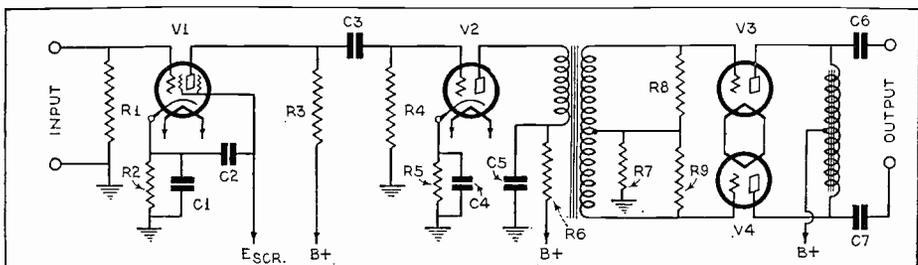


Fig. 14. Three stage amplifier utilizing screen-grid tube in first stage.

a nearly flat frequency characteristic over the entire audible range. While this is very desirable from the standpoint of commercial application requirements, it is undesirable from the recording standpoint. In the first place, the high frequencies are dampened out to a certain extent by the weight of the cutting head, and in the second place these frequencies are attenuated by the use of the fibre needle, if aluminium records are used. Fig. 15, shows the frequency characteristics of the fibre needle against that of the average steel phonograph needle. The loss in the reproduction of the high notes is tremendous, above 1000 cycles. To compensate for this, the amplifier must be so constructed that its frequency characteristic is that shown in Fig. 16 curve "A". When this curve is combined or added to the curve "B" the resultant characteristic is that shown

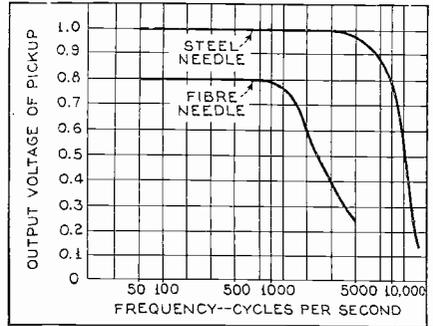


Fig. 15. Frequency characteristic of fibre needle against steel needle.

factors enter into the design, so that any kind of a prediction is entirely worthless. The only honest conclusion that can be reached is after a frequency run is made on the amplifier. For example a curve of a transformer coupled amplifier might show a decided peak at a certain frequency, which was entirely unexpected. This may be due to one of the transformers which may be poorly designed, and then it may be due to a circuit condition. The only thing to do in that case would be to make frequency runs for all the transformers to determine their characteristics. A common method employed to make the curve rise at the high end in transformer amplifiers is to introduce an air gap in the core of the transformer. This reduces the impedance of the primary, with a consequent loss of the low notes. As a result the amplifier appears to be rich in high notes. In resistance coupled amplifiers, the high register can be emphasized by using high value resistors in the grid circuits.

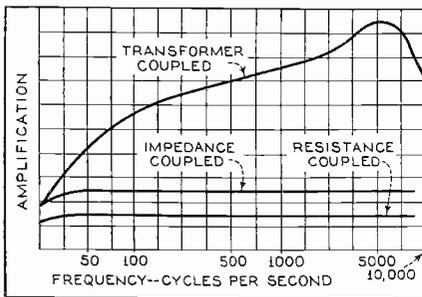


Fig. 14A. Characteristics of the basic circuits for amplifiers.

by curve "C". An amplifier having this characteristic will emphasise the high frequency notes considerably, and will not be very satisfactory for commercial records using the regular steel needles. It will be the ideal for instantaneous recording. Unfortunately, such an amplifier has a very limited field of application, and until more suitable recording material is developed, the efficient reproduction of the high frequencies will have to depend on the use of such an amplifier.

To attempt to enumerate any specific method whereby the characteristic of an amplifier may be made to rise, would be out of the question. This will depend entirely on the circuit of the amplifier and the constants of this circuit. It cannot be said that any particular type of amplifier will have such and such a characteristic. Too many

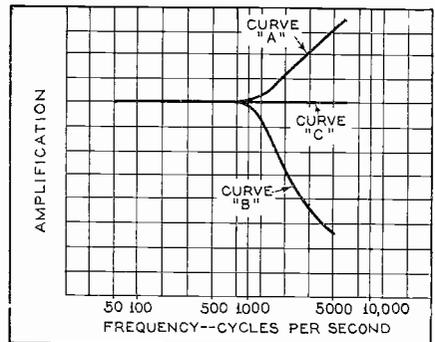


Fig. 16. Frequency characteristic of amplifier compensated for recording.

CHAPTER 4

Pickups and Cutting Heads

The present day electro magnetic pickup is nothing more than the application of a principle as old as the telephone. In 1890, F. L. Capps obtained a patent on a telephone receiver, which utilized the four pole electro magnetic system using a diaphragm. This principle is the basis of all the present day pickups. In 1925, the General Electric engineers took the Capps receiver, pivoted the armature in rubber bearings, provided the free end of the armature with rubber buffers, and inserted a set screw for a needle. Thus was born the first electro-magnetic reproducer. All the modern pickups are fundamentally the same in principle as this old timer with very few changes. The most important change is in the damping. The frequency characteristic of a pickup is dependent on the character of the vibrating system, which is made up of the armature and needle. This vibrating system, like all others, naturally has a certain resonant frequency which is usually between 3000 and 4000 cycles. In order to prevent excessive response at these frequencies, it is necessary to dampen the system, and this is done by rubber buffers applied to the free end of the armature. These buffers serve also to center the armature in the magnetic air gap. The trouble with the old type pickup was that they were very hard. They were dampened too heavily to eliminate the resonant peaks. This heavy damping caused the records to wear very rapidly, and difficulty was experienced in reproducing the low notes. As the result of this excessive wear it was necessary to reduce materially the amount of damping, until today, pickups have rather free swinging armatures, with the result that there is more faithful reproduction of low notes. The problem of resonance peaks, on the other hand has not been solved, and as a result, the quality is not so good on the upper scale. The only improvement

that might be claimed for pickups in the past seven years, might be said to be the reduction of wear on the records.

In Fig. 17 is shown the details of a simple pickup.

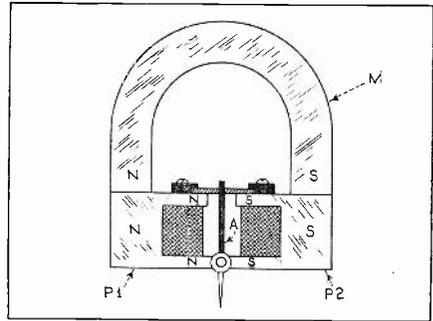


Fig. 17. Electro-magnetic pickup showing location of permanent magnet pole pieces, coils, armature, and damping.

The pickup is nothing more than a miniature electrical generator. The needle following the sound modulations on the record is caused to vibrate from side to side. The needle is fastened rigidly, by means of a set screw, to the armature "A" which is balanced in a magnetic field. This field is set up by the permanent magnet "M" which is placed against the "U" shaped pole pieces "P1" and "P2". In the "U"s are placed two coils of very fine wire usually No. 40 B. and S. When the armature is in the central position the lines of flux travel across from the north pole piece to the south pole piece. When the needle is caused to swing to the right, the armature swings to the left and the lines of flux are cut thus, generating a voltage. The path of the flux lines is now from the north pole piece through the armature and to the lower south pole piece as shown in Fig. 18. The flow of lines, when the needle goes to the left of the path is also shown in Fig. 18. The voltage that is generated is then fed either directly

to the grid and cathode of the first amplifier tube, or through a transformer whose secondary is connected to the grid of the tube. This voltage generated is usually in the neighborhood of one volt. Since the grid to cathode impedance of a vacuum tube is very high, around 500,000 ohms, it is very difficult to wind a pick-up to approach that impedance. While it is entirely practical to have a pickup of 25,000 or 30,000 ohms, it is not practical because of the difficulties introduced. Such windings tend to pick up hum and cause regeneration in the amplifier. Careful shielding will usually overcome this, but, the question of manufacturing must then be taken into account. The pickups of today are usually wound around 2000 ohms to give a 1 volt output. A very strong magnetic field is required to accomplish this, and as a result the armature must be made heavy enough so as not to be saturated.

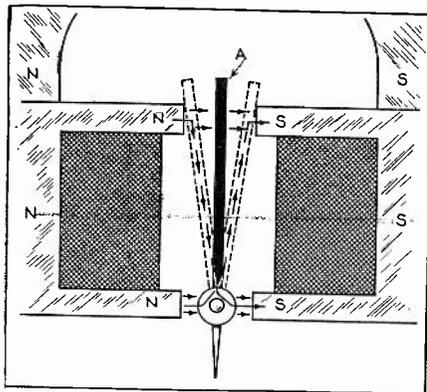


Fig. 18. Path of current in electro-magnetic pickup when needle is modulated.

Many pickups are wound around 200 ohms, but their output voltage is very small. The oil damped model shown in fig. 19 is an example of the low impedance, low output voltage type. Here the armature takes the form of an oil damped diaphragm attached to one of the poles of a permanent magnet. The other pole carries two pole pieces and two coils. The needle is so attached to the center of the diaphragm that the latter is caused to shift the flux from one pole piece to the other. The oil damping has the advantage that it fairly completely eliminates diaphragm resonance without greatly

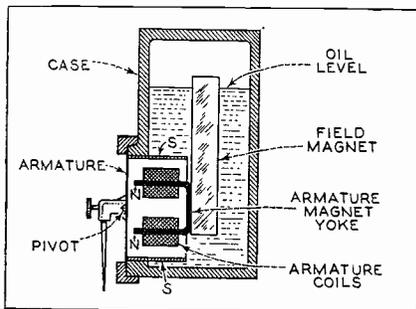


Fig. 19. Cross sectional view of oil damped pickup.

stiffening the system against low frequency vibrations.

In quality reproduction, it is necessary that as little weight as possible be applied to the record. If the head is too heavy, excessive record wear will result and the scratch will be increased considerably. A certain amount of weight may be taken off the record by counterbalancing. In Fig. 20 is shown a method of counterbalancing with weights, while in Fig. 21 is shown a method using a spring. Of course the latter is the cheaper of the two and while it is just as effective, the change in spring tension (which is very probable) will destroy any effect of counter balancing. It must not be forgotten that a certain amount of weight is necessary in order to secure proper tracking. It is customary to apply a

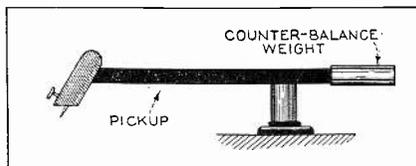


Fig. 20. Pickup using weight for counter balance.

pressure of four or five ounces to the needle point so that it will ride in the bottom of the record groove and not be thrown out by the large amplitudes associated with the bass notes.

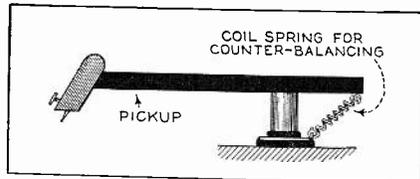


Fig. 21. Pickup using spring for counter balance.

CUTTING HEADS

In instantaneous recording, the electro magnetic pickup serves two purposes. First it is instrumental in making the record, and then it reproduces it. In recording the cutting head is nothing more than the pickup with slight changes, used as an electric motor, instead of a generator. The chief function of the recording head is to receive power from the amplifier, and with it drive a mechanical recording stylus. A good recording head operates in a linear fashion over the range of amplitudes involved in speech and music. In Fig. 22 curve "A" is the characteristic of a cutter. It is noticed that the response falls off about 250 cycles. It is necessary to have this falling characteristic in order that maximum loudness be obtained from a record for a given spacing between grooves without cutting over from groove to groove. A characteristic of the pickup is that the voltage induced in its winding is proportional to the velocity with which the armature moves. In order, therefore, that a lateral oscillation of the needle point may furnish constant output voltage, it is necessary that the lateral velocity of the needle point be constant. For a sine wave, velocity is proportional to the product of amplitude and frequency, so that as frequency increases, the amplitude decreases proportionately. In curve "A" Fig. 22 constant velocity is obtained from about 250 cycles to about 4500 cycles, while below 250 cycles constant amplitude is obtained. It is readily seen, that if this attenuation of the low frequencies is not done, there will be a tendency of the needle to cut over from groove to groove.

In order to compensate in the reproduction for this falling characteristic, pickups are designed with the rising characteristic shown by curve "B" Fig. 22.

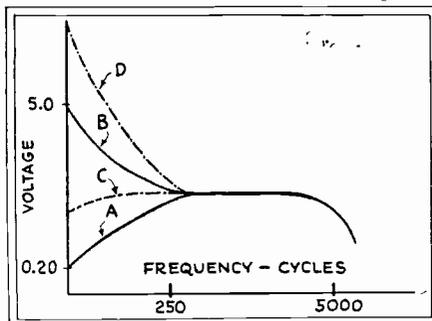


Fig. 22. In the above graph, lines A and B represent respectively the voltage characteristics of commercial recording heads, and playback pickups. At C, is indicated the use of a pickup for recording; and at D, the resulting distortion when using the same pickup for play back.

Let us consider the use of a regular phonograph pickup, hooked up backward to recording, instead of a commercial recording head, compensated for the mechanical limitations of the disc, as stated above. Then, the low frequency response would be, approximately, as shown dotted at C; and, with the pickup connected as a reproducer, this high volume level recorded at the lower registers would result in accentuated bass reproduction, as indicated at D (providing, the record does not double track).

It is thus evident that the phonograph pickup is not the ideal instrument for home recording. The tendency to cut over from groove to groove at the lower frequencies is very great and, when using a phonograph pickup, for recording, volume must be sacrificed in order to prevent this cutting over. However, "cutting heads" are now available on the market at a slightly higher cost than pickups; these cutters are really like the regular phonograph pickup, but properly damped to simulate curve A.

CHAPTER 5

Control Boxes

For home recording the control box must be capable of performing the following functions, using only a single knob.

1. Switch in the microphone circuit for voice recording.
2. Change the circuit for playback;
3. Connect the equipment for radio recording;
4. "Normal" (Radio production at full efficiency.)

It is the purpose of the writer to describe in detail some of the control boxes now available, starting with one which can be built easily in the home.

Fig. 23 shows the circuit of such a box. The switch Sw. 1 shown in the diagram is of the "anti-capacity" type obtainable at radio stores for a small sum. The four moving contacts of the

switch can control many circuits; and therefore it lends itself very nicely to home recording circuits.

The microphone transformer "MT" is of the conventional type. The 200-ohm windings form the primary; while the secondary has an impedance of 200,000 ohms to match the grid-to-cathode impedance. The single-button microphone is shown as an example; however the use of a two-button microphone will improve the recordings.

The operation of this control box is extremely simple. If recording is desired, the switch is thrown to the "recording" position, and the toggle switch "SW-2" in the microphone circuit is closed. For microphone recording, the radio set is detuned, or the volume control is brought way down. If radio recording is desired, the microphone switch is thrown to "off" position, and the desired program is tuned in. Playback is accomplished by throwing the switch to the "phono" position and breaking the microphone circuit. It is important to remember that, when microphone recording is not desired, the microphone switch must be "off" otherwise the battery will run down rapidly.

It will be noticed that, in the "playback" position, the high-impedance pick-up is connected directly to the grid and cathode of the detector tube, without using a coupling transformer. A transformer is not really necessary; because the quality is not improved in the least, and it means added expense. As a matter of fact, the effect of the transformer would be to reduce the entire level of the higher frequencies; and this is detrimental to good quality.

In the writer's opinion the use of a coupling transformer is only permissible when the gain is low and warrants an increase; or when the leads are quite long. Lengthy high-impedance leads are the cause of feed-back

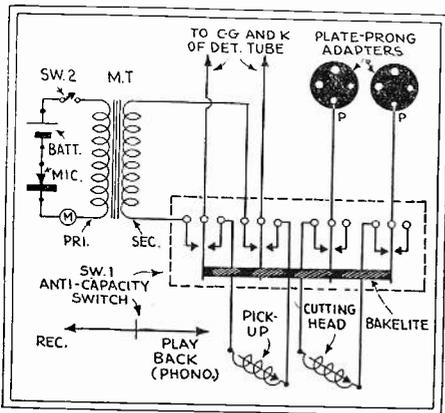


Fig. 23. A simple changeover unit for home recording, using a standard multiple double throw switch, SW-1; the adapters fit underneath the power tubes.

switch are all rigidly connected together by an insulating strip, as shown; so that when the handle is thrown to the right, contact is made between the four moving contacts and the four left-hand springs. When the handle is thrown to the left, the moving contacts make connection with all the right-hand springs. It is very evident, therefore,

and the picking up of noises. To prevent this, a "low-impedance" pickup usually 200 ohms, is used in conjunction with a suitable input transformer.

When the switch is thrown to the recording position, a slight decrease in volume at the speaker may be noticed. This is due to the fact that the impedance match between the output tubes and the load is destroyed. For maximum undistorted output, the plate circuit load impedance of a 3-element tube must equal twice the tube impedance; and, if an impedance equal to the normal load impedance is put in parallel with the latter, the output tubes will then "look into" an impedance only equal to their own. Maximum power transfer is now accomplished, though with a certain loss of quality and volume. However, this condition is not enough to have any noticeable effect on the finished record.

If single-prong adapters are not obtainable, the two wires are placed on the plate prongs of the output tubes.

The Presto control box shown in Fig. 24, comes complete ready to be wired to the radio receiver. This box has on it three positions, namely "Radio," "Mic," and "Radio-Rec."

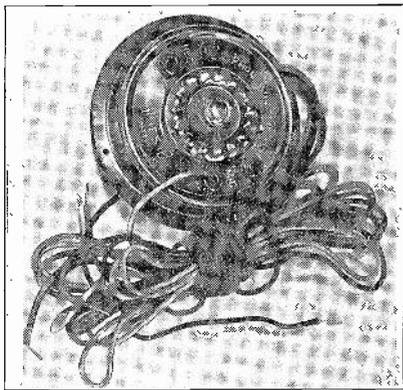


Fig. 24. A new, compact control box for selection of circuits to record, play back, or reproduce radio.

In Fig. 25 is shown the simplest way of utilizing this box. The selector switch is of very ingenious design and, from a close study of the diagram, the various operations will be evident. Seven contacts are distributed about the periphery of the circle; one stands alone while the remaining six are strap-

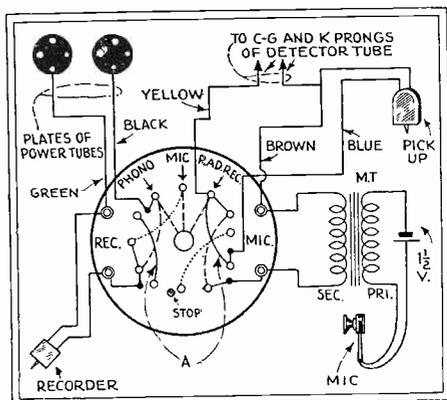


Fig. 25. A practical circuit incorporating the control box shown in Fig. 24; both pickup and recorder units are required. Arms A take three positions.

ped together to make 3 pairs. The arm of the switch is made up of two arched metal strips "A", which are insulated from each other.

On the top of the box are provided two pairs of phone receptacles; one for the microphones and one for the recorder or cutting head. Five wires from the box are connected permanently to the radio receiver; the black and green to the plates of the output tubes; the blue to the pickup; the yellow to the grid of the detector; and the brown serving as a common lead to both the cathode and the pickup.

A more elaborate use to which the

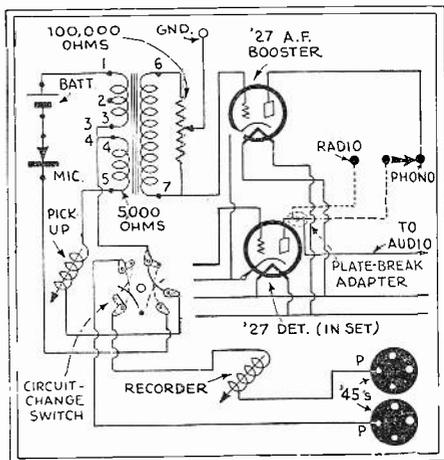


Fig. 26. Substantially, the circuit of Fig. 25, with a booster stage added to obtain better quality and volume, with less background noise.

box may be put is illustrated in Fig. 26. Here a microphone amplifier or booster is shown. This is for radio sets which do not have sufficient gain in the audio stages for good recording. The microphone transformer used is preferably, of special design, with a two section primary consisting of a 200 ohm winding for the microphone, and a 5000 ohm (impedance) winding to match the pickup. This hookup also provides a single-pole, double-throw toggle switch for radio, or phonograph, eliminating the necessity of detuning the radio set when microphone recording is desired.

From Figs. 25 and 26, it should be obvious how this control box operates. When the switch is in "phono" position, the pickup is connected directly to the grid and cathode. In "Mic." position, the microphone circuit and the recorder are cut in; the volume control of the set must then be turned way down, or the set detuned.

In "Rad-Rec" position, the microphone circuit is disconnected and radio recording is accomplished.

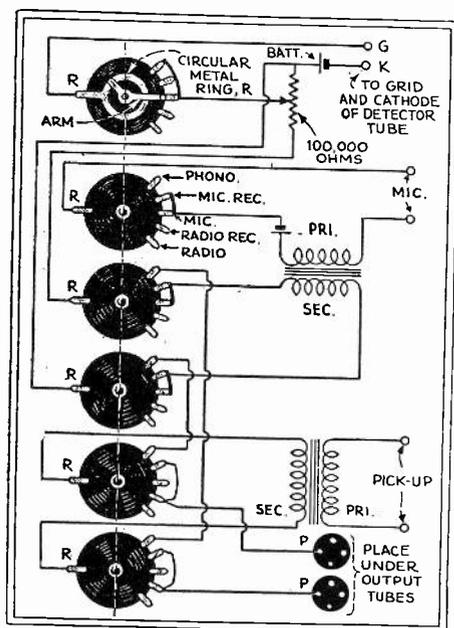


Fig. 27. Expanded circuit of the "Best" control box.

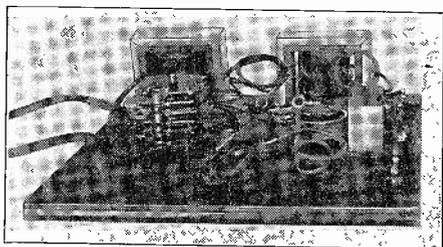


Fig. 28. Bottom view of panel in the "Best" control box.

Fig. 27 is a schematic of the Best control box. The selector switch used in this box is made up of six circular plates of fiber which have connector lugs evenly distributed around their rims, as clearly shown in the photograph, Fig. 28. Five of these lugs give selection; while the sixth, or common connection, is permanently attached to a circular metal ring which is fastened to the fiber disc. One end of the switch arm makes contact with any one of the five lugs, while the other end is always in contact with the circular ring.

There are six sets of these rotary switches. Each arm is individually insulated, but all are rigidly connected to the shaft; so that, when the control knob is turned, the arms move in unison. For example, when the arm is turned to "Radio", no connection changes are made and, consequently, the radio is free to be operated. When the knob is turned to "Rad-Rec" the circuit is as shown in Fig. 29, and radio programs can then be recorded.

A novel feature of this control box is the "Mic." position, see Fig. 30, which enables the operator to use the radio for announcements, etc. In other words, a very efficient public-address system is available.

When microphone recording is desired the knob is turned to "Mic-Rec" as in Fig. 31; which is similar to the circuit of Fig. 30, except that the cutting head is connected to the plates of the output tubes.

Playback is accomplished by turning the knob to "Phono", Fig. 32. This disconnects the microphone and cutting head and then connects the latter to the grid and cathode of the detector tube.

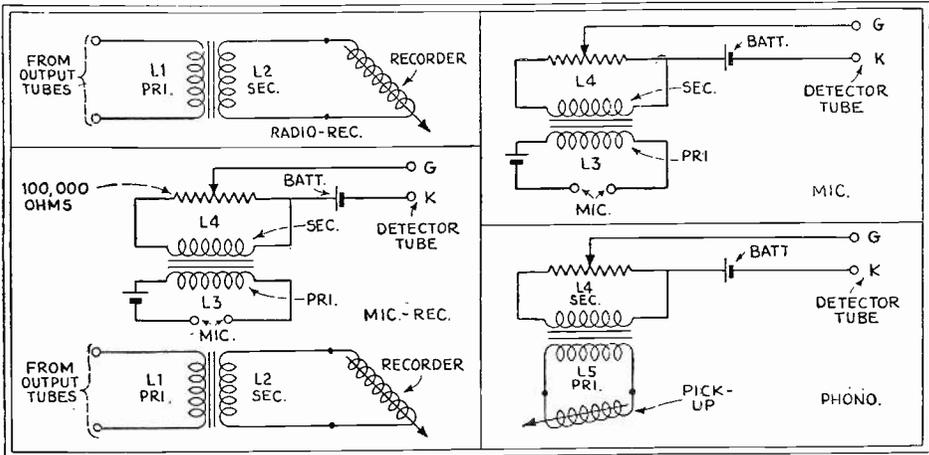


Fig. 29. Upper left. Radio-recording position.
 Fig. 30. Upper right. Public Address position.
 Fig. 31. Lower left. Microphone recording position.
 Fig. 32. Lower right. Playback position.

CHAPTER 6

Turntables and Filters

A powerful electric motor is absolutely essential if consistently good records are to be expected. The requirements of the motor are as follows:

1. It must furnish a definite maximum mechanical power output that is determined by the unbalanced weight of the recording head—coefficient of friction between the cutting needle and disc, size of record and speed.

2. It must have good speed regulation from zero to maximum power output to insure constancy of pitch throughout the entire record.

3. It must run true in its bearings and rotate the turntable in a single plane.

4. It must be thoroughly filtered so that any vibration in the motor is not transmitted to the turntable.

Filtering is much more important in recording than it is in reproducing. In playback, any vibration or oscillation in the motor speed is not audible because the needle is riding lightly in the groove and is not very sensitive to any slight vibration. On the other hand, in recording the needle is tight up against the record and is therefore very sensitive to any vibrations, and if any are present, they will be recorded.

A good test to determine how a turntable is behaving is to record a sustained note and then play it back on the same table. If the note warbles, that is, has sort of a tremolo effect, then it is a sure indication that the turntable is not thoroughly filtered. By filtering is meant that there must be no rigid connection between the motor and turntable.

The average phonograph motors that are on the market today are not very suitable for any recordings, especially on aluminum discs over 6 or 7 ins. in diameter. These motors are designed only to carry the weight of the pickup head and not the heavily weighted recording heads. The main disadvantage of these motors for recording purposes is

that their power is very small, usually about 20 watts and the torque developed is not enough to carry the recording head. If a 7½ in. record is used, the motor will pull the table, but at a slower speed than 78 R. P. M. As the cutting head approaches the center, the speed will gradually pick up until it becomes 78 R. P. M. when the record is nearly finished. On playback, the pitch of the record will be higher than the original at the beginning and gradually approach the normal pitch when it nears the end. Suffice to say, this is not good recording. Some people usually increase the motor speed before recording, so that when the head is placed on the record, the speed will be 78 R. P. M., but as has been stated before, the speed will increase as the recorder nears the end, and when the record is played back, the first part will be normal while the ending will be decidedly off-pitch.

The phonograph motor will not make 10 in. or 12 in. aluminum records at all and will have a hard time making 10 in. or 12 in. pre-grooved records. Unfortunately, the motor and turntable manufacturers have not deemed the home recording field large enough to warrant their producing a motor suitable for recording. As a result of this condition, one or two of the manufacturers of home recording apparatus have been forced to develop their own motors and turntables.

This apparatus is usually built as an integral part of the recording machine and is therefore not available as a separate independent unit, but this fact should not deter the recordist from making his own turntable outfit.

The motors used should be of 30 or 35 watts rating, and the armature should run in smooth running ball bearings that make for absolute quiet operation.

In Fig. 33, is shown a type table that is rim driven by a motor that is mounted vertically. The turntable is of cast

aluminum and mounts on a shaft that is set in a bronze casting at the bottom of which is a thrust bearing. The inside of the rim is carefully machined to a diameter that depends on the speed of the motor and the size of the rubber pulley. For example, let us assume

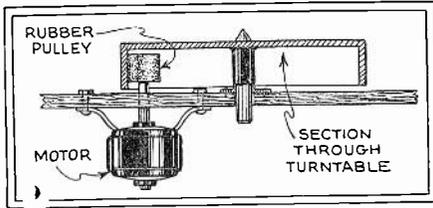


Fig. 33. Rim driven turntable for recording.

that the outside of the turntable is 12 ins., and that we have a motor whose speed is 1200 R. P. M. The table must run at 78 R. P. M. We first determine that the thickness of the rim must be $\frac{3}{16}$ ins. This leaves the inside diameter equal to $11\frac{1}{2}$ ins. The only unknown is the size of the rubber pulley. This is determined from the following equation.

$$\begin{array}{r} \text{Diameter of pulley} \quad \text{Speed of motor} \\ \hline \text{Inside dia. of table} \quad \text{Speed of turntable} \\ \text{Substituting for the above we get.} \\ \text{Diameter of pulley} \quad 1200 \\ \hline \quad 11.625'' \quad \quad \quad 78 \\ \text{Therefore:} \\ \quad \quad \quad (1200) \quad 11.625 \\ \text{Diameter of pulley} = \frac{\quad}{78} \\ \quad \quad \quad = 1.85'' \end{array}$$

If the pulley is made exactly 1.85 ins. and of non-resilient material the speed of the table will be 78 R. P. M. This pulley should be made of a soft rubber for two reasons. First, the rubber contact insures a positive drive between the table and pulley—and second a thorough filter action is obtained. This rubber should not be too soft or too hard. If it is too hard, slipping will be the result. If too soft, flat spots will develop when the motor is at rest. These flat spots will produce a period in the motor which will be quite noticeable in the recording. A fairly stiff—but sufficiently resilient rubber should be used. The motor is suspended from the board, as shown, in such a manner

that the tendency of the pulley would be to lean against the rim. The effective diameter of the pulley is thus reduced so if we had made this diameter exactly 1.85 ins. the speed of the table would have been less than 78 R. P. M. Therefore, the diameter would have to be slightly greater than 1.85 ins. How much greater will depend entirely on the type of rubber used. To prevent any vibration of motor being transmitted to the turntable, the mounting screws are insulated from the board by the rubber washers shown.

This type of drive is about the simplest and most efficient there is. No worms or worm gears are used, and it is therefore very quiet in operation. The cost of construction is comparatively small and while some of the mechanical work cannot be done by the amateur himself—it can be done by the neighborhood machinist.

Fig. 34, shows another type of drive that is very effective for driving a turntable. The motor comes equipped with a speed reducer so that the shaft driving the turntable rotates at exactly 78 R. P. M. The motor is rated at $\frac{1}{20}$ H. P. and is more than sufficient to drive the table with the cutting head on it at its normal speed. With this type of drive a little more care is required to obtain thorough filtering. As is seen in Fig. 34, the motor is fastened rigidly to a metal plate. This plate is then mounted on a rubber plate or a metal plate. This plate is then mounted on a rubber plate or gasket. The rubber is of the sponge type. The four machine screws which fasten the plate to the mounting board, are run through holes larger than their diameter. Rubber washers are then used before the nuts are put on. These precautions are necessary so that any vibration set up by the motor is not transmitted to the cabinet and turntable. The rotary motion to the table is transmitted by the vertical shaft through the flexible coupling shown. The motion is transmitted through the rubber washer, driving against the pins of the coupling. This coupling is necessary, so that any rapid speed variations in the speed of the motor or any back lash in the speed reducer is thoroughly filtered out.

In Fig. 35, is shown another form of

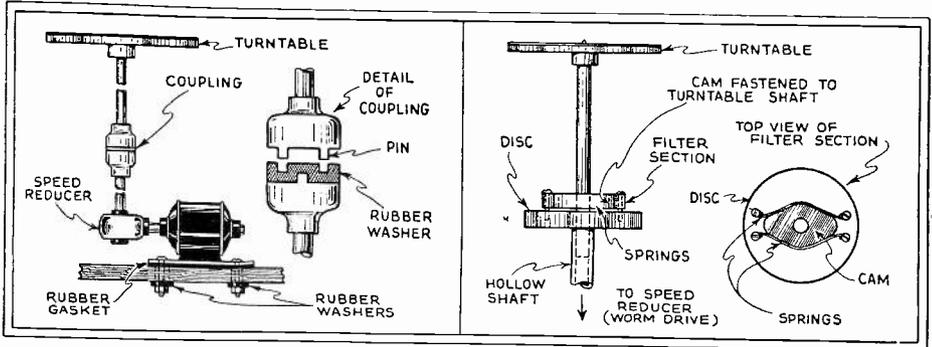


Fig. 34. Left. Turntable driven by motor incorporating speed reproducer and showing rubber coupling for filtering.

Fig. 35. Right. Same motor drive used as

filter that is also very effective. The motor used is the same as the one shown in Fig. 34. The difference comes in the filter.

A hollow tube is driven by the worm gear, and on the upper end of the tube is mounted a disk, which serves as a mounting for a steel spring. Between these two springs rests an egg-shaped cam which is fastened rigidly to the turntable shaft. The motor drives the disk on which are mounted the steel springs, and these springs in turn drive the cam. Any irregularity in the speed of the motor is instantly dampened out in the springs and not transmitted to the table.

The springs used must be made of spring steel. This steel must be heated before it is curled at the end to receive the screws. In curling the ends, care must be exercised in handling the hammer. The best way to do this is to set a shaft a little larger than the diameter of the screw in a vise—then—put the heated spring against it and hammer gently with the hammer. The spring might snap at the first few trials, but when the knack is mastered the operation becomes very simple. Be sure that only hardened steel springs are used. If a steel is used that bends easily, then the purpose of the filter is destroyed.

CHAPTER 7

Mixers

The use of mixers is very essential where the sound to be recorded is coming from more than one source. For example, if a talk is to be recorded with a musical background from the radio a mixer is indispensable. If a band or orchestra is to be recorded one microphone can not do the job efficiently; two or three are required, and this necessitates a mixer.

The mixer is a group of attenuators or volume controls arrayed in such a manner that the output of several microphones may be combined in order that it can be amplified and recorded on a single record.

A good mixer should possess the following qualifications:

1. It should have a constant impedance, regardless of its setting.
2. There should be no interaction between positions to cause a change of load on one, when another is varied.
3. It should have low loss.
4. It must be quiet in operation.
5. Its input and output impedances should match the circuits it is to work from and into.

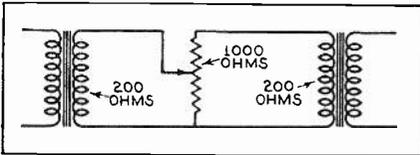


Fig. 36. "L" type volume control used in a line.

Before going into any discussion of the types of mixers to be used, the types of volume controls will be discussed briefly.

Fig. 36 shows a circuit of a volume control that is the most universally used of all types and which is probably the worst that can be used. This volume control is known as an "L" type attenuator and is connected across the load with the center arm connected to one side of the source. It is very apparent, therefore that for any given

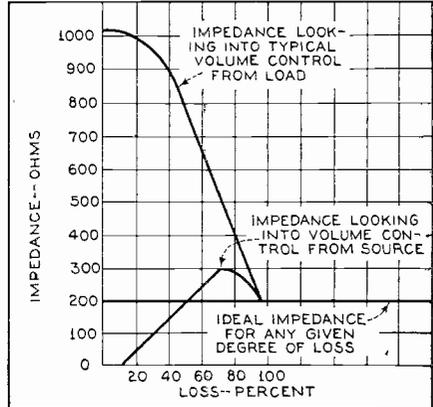


Fig. 37. Impedance characteristic of a mixer.

degree of attenuation, both the input and output impedances vary greatly, and it is impossible to design accurately equipment to work in and out of this type of volume control.

By referring to Fig. 37, it can be seen that the impedance looking into the volume control varies from 176 to 1000 ohms. This variation is instantaneous with any variation of the center arm feeding from the source. It is quite readily apparent that it is hard to decide what impedance should be used in determining the load impedance as any one impedance is almost as bad as another. As far as distortion is concerned in this particular leg, it can be ignored, due to the fact that the higher frequencies will not be greatly attenuated.

With the impedance looking into the mixer control from the source; it is noticed that it varies between 300 ohms and zero, depending on the setting of the attenuator. At the higher degrees of attenuation a considerable loss of higher frequencies is noticed and this alone would render this system very impracticable as a volume control. The ideal impedance drawn across the 200 ohm line is that of the "T" pad attenuator and is the most practical system of volume control.

In Fig. 38 is shown a three position mixer using ordinary type "L" volume controls connected in parallel. From the foregoing discussions it is readily seen that it would be impossible to calculate the impedance of these circuits,

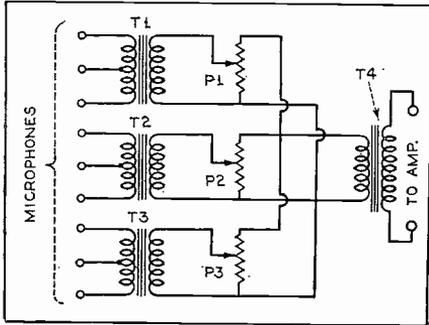


Fig. 38. Mixer using "L" pads in parallel.

as we have a variation taking place from each individual manipulation of the control. Therefore, it is practically impossible to pre-determine the best impedance match. In operating this mixer, if the gain of the circuit is raised, the two circuits will have a proportionate decrease in gain. This, makes the mixer very impractical for any kind of work.

Fig. 39 shows the same "L" type mixer except that the attenuators are connected in series instead of parallel. This arrangement has some advantages over the other in that there is very little chance of short circuit in any of the mixer positions, but the variation of impedance with each individual manipulation of the controls still makes it bad for any good work.

The modified "H" pad used in the

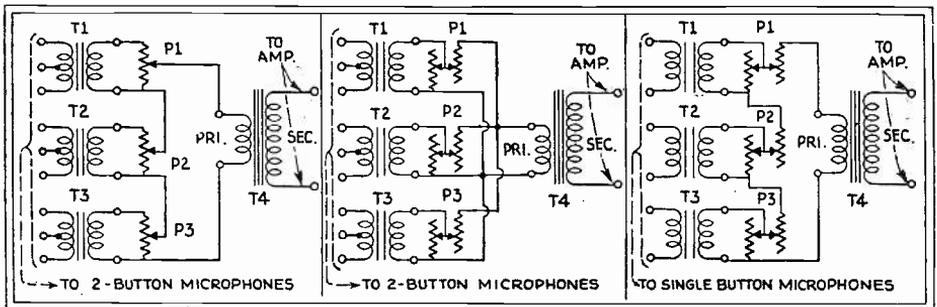


Fig. 39. Left. Mixer using "L" pads in series.

Fig. 40. Middle. The parallel constant output impedance type of mixer.

Fig. 41. Right. Series, type constant output impedance mixer.

mixer shown in Fig. 40, is more or less of the constant impedance type. It is very much superior to the types using the "L" pads. The compensating resistance is part of the pad, and operates simultaneously, thus maintaining the output impedance constant for any given setting. The input impedance, on the other hand, is not constant, and there is a variation from 0 to 200 ohms which is the cause of considerable distortion.

In Fig. 41 are shown the same type of "H" pads used in series instead of in parallel as shown in Fig. 40. The series system is much more preferable to the parallel type because the output impedance of the bank can be closely matched to the input impedance of the amplifier.

The best attenuator to use is the "T" type. A mixer using these pads in parallel is shown in Fig. 42. The impedance of the mixer control is constant despite any given variation of attenuation. Excellent impedance matching can be obtained with this system, any given variation in attenuation of individual volume control will not affect the setting of the others.

This circuit however, has one disadvantage. The image impedance of the load does not match that of the individual mixer circuits, and therefore, some distortion is caused by this effect. If these "T" pad volume controls are used in series as shown in Fig. 43, the ultimate in mixers will be obtained. The impedance is constant at all times as the manipulation of any individual volume control will not affect the level at which any other is operating, and since all the impedances

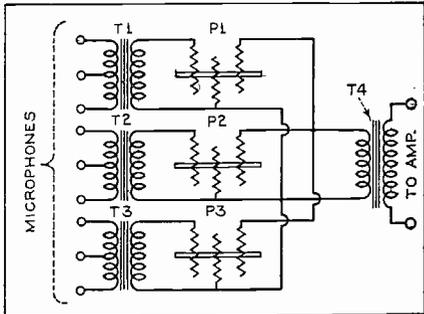


Fig. 42. Mixer using "T" pads in parallel.

are matched distortion is completely eliminated.

The cost of making a good mixer will be quite high if one is to use good transformers. For the home recordist, the simple resistance mixer shown in Fig. 44 is excellent for recording. The cost of the parts is very low, and the mixer can be built into a very small size. This in itself is a tremendous

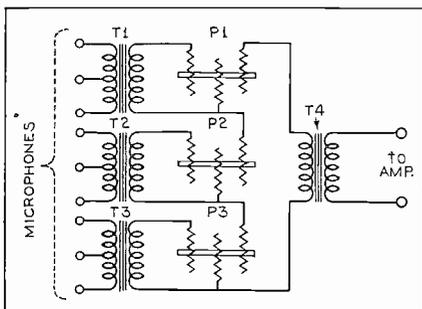


Fig. 43. Mixer using "T" pads in series. tremendous advantage especially in the home where space is a determining factor.

The uses to which a mixer can be put are many. First, let us take the recording of an orchestra. One microphone will have a difficult time picking up more than six pieces satisfactorily, and therefore 2 or 3 will have to be used.

The violins, having a very low output in comparison to the other instruments, naturally should have a microphone placed before them. If there are twenty or more violins, such as would be in a symphony band, the first violins should have a microphone and the second violins should have one also. The brass and the bass instruments should be placed in the rear away from the microphones. They produce heavy

notes which carry quite a distance. The piccolo, flute, etc. should have another "mike." If a singer is used then a microphone should be used for him also. The orchestra is recorded with their "mikes" turned way up, and the singer's turned way down. This is done at the mixer panel. When the singer sings, then his mike is turned way up and those of the orchestra turned down enough so that their music is a faint accompaniment. Naturally, the mixer monitor engineer should be in a sound proof room, where he can see the orchestra and singer, but can only hear them through his amplifiers. In this way, he can judge by ear, what each microphone level should be.

Using the mixer in the home affords the source of many novel records. Let us take a three position mixer which handles a microphone, radio and phonograph. In this way, the control box is done away with. In making a microphone recording, the phonograph and volume control are turned off. If desired, the radio may be thrown in and a musical background given to the record. On playback, the microphone and radio are turned off and the phonograph control used.

A novel record to make is to announce that some famous personage is to speak or sing and after the announcement, the radio is cut in. The many unique uses to which a mixer may be put are so great that lack of space will not permit their listing. Suffice to say, the enterprising recordist will find many.

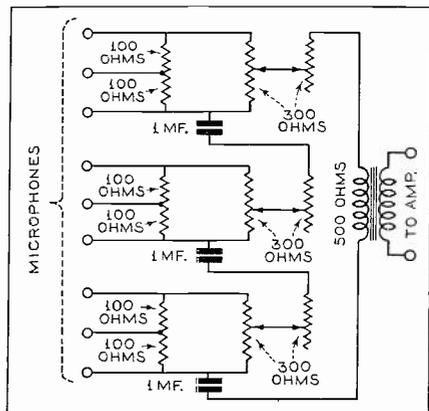


Fig. 44. Simple mixer using resistors instead of transformers.

CHAPTER 8

Level Indicators

Strange, as it may seem, the "level indicator", which is very essential for good recording, is in very little use. It is not hard to build; and, even if purchased, the slight cost is more than offset by the insurance of good records at all times.

Heretofore, it has been the custom to test the level at the cutting stylus by means of a "monitor" speaker; or, if the microphone happens to be in the same room with the machine, by means of feeling the stylus with the finger. At best, either of these methods is a guess.

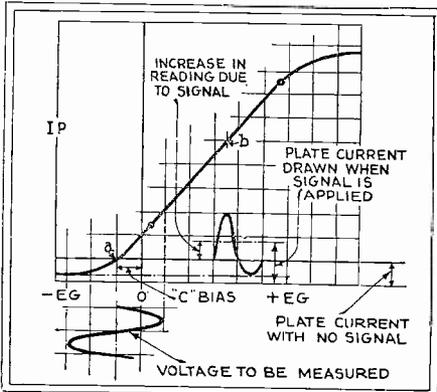


Fig. 45. Due to the non-linearity of the rigid voltage plate current curve, the average plate current is greater with a signal than without one.

The level indicator, in reality, is nothing more than an ordinary vacuum-tube or "V.T." voltmeter, which operates on the principle of the vacuum tube detector. In an amplifier, the vacuum tube must be worked on the "straight" portion of its characteristic (Point B, Fig. 45) so as to maintain the linear ratio of input voltage to output power, which is required for undistorted power output; while in the V.T. voltmeter the tube is worked on the curved "heel" of the characteristic (point A, Fig. 45) so as to obtain the distorted output shown in the figure.

The circuit of a commercial level in-

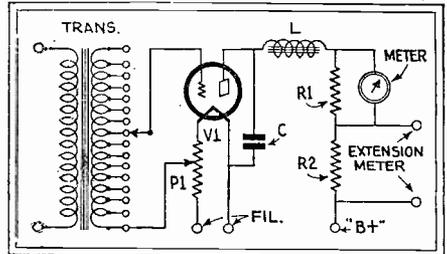


Fig. 46. A diagram of a commercial level indicator.

icator is shown in Fig. 46. An A.C. flowing through the primary of the input transformer will cause an alternating voltage drop across it; and by induction, an increased voltage drop will appear on the secondary side. A portion of this secondary voltage is applied between the grid and filament of the tube. This voltage alternately adds to, and subtracts from, the D.C. grid bias.

Since the tube is operated on the curved heel of its characteristic the plate-current change that corresponds to the grid voltage change will be distorted, and the average plate current drawn by the tube thus will be higher when an A.C. potential is applied to the grid, than if the grid had only D.C. bias.

In order to smooth out the fluctuations of current in the meter circuit, but still permit the meter to register most of the current peaks, a condenser C and an inductance L are connected in the circuit as shown in Fig. 46. Damping for the meter is provided by the resistance $R1$ shunted across it. It is evident, therefore, that the combined damping action of the tube and the plate circuit filter causes the current of the meter to deflect for groups of plate current fluctuations. If the needle was permitted to follow each individual plate current fluctuation it would be extremely difficult to follow the rapid, erratic movements of the needle.

Fig. 47 shows the circuit of a level indicator that can be easily built at home, and while not as elaborate as the commercial type, it is quite accurate enough for home recording. The meter used is an ordinary D.C. milliammeter with a 0-5 scale; damping is provided by the condenser C shunted across the meter. Since the battery will drop in voltage due to use, the 10,000 ohm potentiometer P2 is provided to afford control over this voltage, since it is very important that the filament and the plate voltages remain constant. From time to time the battery voltage should be checked.

The level that is necessary for good records of each type of record is best

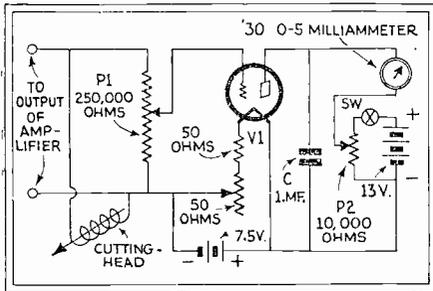


Fig. 47. A level indicator circuit for the home constructor.

determined by tests (of course, this figure was only roughly approximated in the values previously stated); that is, by making a record as the pointer fluctuates about a certain point in scale. If the record is too loud, the gain must be cut down and the test made over again.

The 250,000 ohm potentiometer P1 in the grid-circuit of VL is used for varying the voltage of the input signal to the tube, thus determining the maximum (three-quarter) swing of the needle of meter M.

The main advantages of the vacuum tube voltmeter is that it does not draw any appreciable current from the line, and the volume is maintained constant. Its biggest disadvantage is that every time the tube is replaced the instrument has to be re-calibrated. This is not a serious disadvantage for the home recordist who is using the instrument for determining his recording level. Since his scale does not have to be calibrated in decibels all he has to do

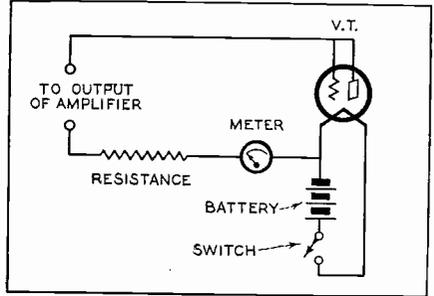


Fig. 48. Vacuum tube rectifier type level indicator.

is to re-locate his level mark as outlined above.

A simpler type of level indicator is where a rectifier is used with a D. C. milliammeter. The rectifier unit may be one of several types.

In Fig. 48, is shown the vacuum tube rectifier. The grid and plate and the tube are tied together. The principle upon which it operates is the same as the 280 rectifier. When an A.C. voltage is connected between the filament and the plate an electron current will flow to the plate when the latter is positive and not when it is negative. In other words current flows on the halves of the cycle when the plate is negative; the electrons return to the filament as fast as they escape. A D.C. meter in the plate circuit will read a certain amount of current which would be a value somewhere between the maximum current that flowed during each positive half cycle, and zero. The meter needle would not follow the rapid spurts of current and so would assume some average value.

Another type of level indicator is one where only a dry rectifier is used, with a D. C. milliammeter and resistor. In Fig. 49, is shown a circuit using a crystal rectifier. The crystal used is of the ordinary carborundum type, and while this system works quite satisfactorily, it has the disadvantage that the crystal is too unstable for

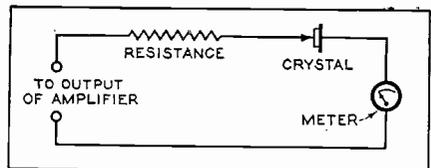


Fig. 49. Crystal used as rectifier.

operation and needs to be adjusted quite often. It is also subject to burn out at comparatively low current values.

Fig. 50, shows the dry copper oxide rectifier. This is the most desirable of the rectifier type of level indicators. It is very rugged and sensitive and needs little attention after it is set up. The rectifier may be used in either its full wave form as shown in Fig. 51, or in its half wave form as shown in Fig. 50. In the latter form the cost is very low and a very efficient indicator can be constructed which will more than fill the needs of the home recordist. These rectifier units may be obtained from old "B" eliminator power pack. The full wave rectifier unit can be obtained from dry "A" eliminators or from any radio supply store.

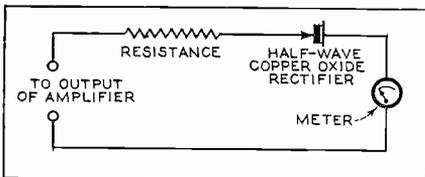


Fig. 50. Copper oxide disc used as a half wave rectifier.

There is now available on the market an 0-1 milliammeter which has built in it a copper oxide rectifier the size of a ten cent piece. With the addition of a suitable resistance to convert the meter to read volts a very compact V. I. may be made. Fig. 52, shows this type meter used in a commercial level indicator.

An "L" type attenuator pad is used between the meter and input terminals which serves as a multiplier for increasing the range while maintaining the input impedance constant. This indicator can be used in two ways. The pad can be set at zero and the level

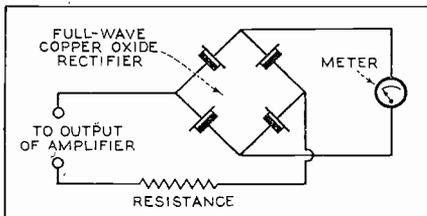


Fig. 51. Full wave copper oxide rectifier used in most level indicators.

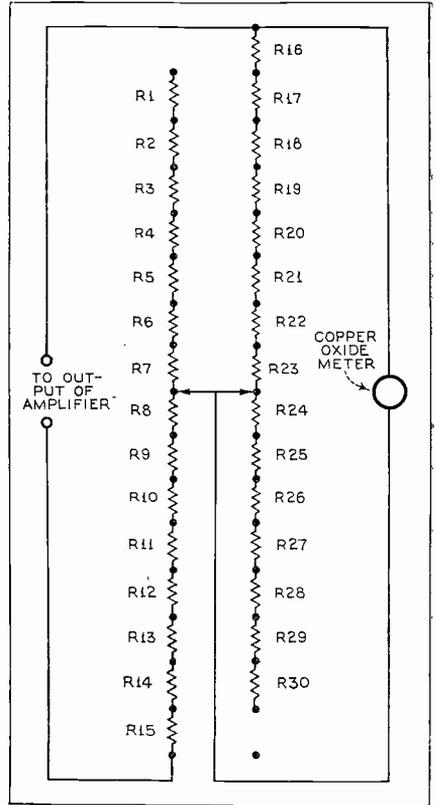


Fig. 52. Calibrated commercial volume indicator using copper oxide meter.

read directly from the meter, or the pad may be set at the number corresponding to the level desired and the gain brought up to the zero level mark on the meter.

The main disadvantage of the dry rectifier type of volume indicators is that they draw current from the line and this is not desirable in recording. The current drawn depends on the series resistor used and the size of this resistor will have to be determined by the recordist himself. The writer has used these half wave copper oxide rectifiers with an 0-1 milliammeter. Across a 4000 ohm cutting head a 3000 ohm resistor was found to give best results, but it was noticed that when the V. I. was in the circuit the recording level was decreased somewhat more than without the V. I. No such trouble was experienced when using a vacuum tube level indicator shown in Fig. 47.

The operation of a level indicator is very simple, but to the novice it might prove very annoying. The needle moves quite rapidly over the scale and it takes a little patience and experience to get used to being able to read the correct level. On loud notes, the needle will "kick" over the pre-determined mark, and while this is allowable, too many people take this as an indication that the volume is high and

consequently reduce the gain with the result that their record is ruined. A V. I. is an instrument that cannot be read like an ordinary meter with a non-oscillating needle. It is a very valuable necessity to any recording system and the little experimenting to be done before it is mastered is more than compensated for in the insurance of good records at all times.

CHAPTER 9

Recording Materials

At the present time there are several materials available for instantaneous recording, namely, gelatin, aluminum, celluloid and zinc.

Gelatin records are of the blank type requiring a feed screw for cutting. A special cutting stylus is used, and before recording, the surface is treated with a lubricant, such as vaseline, in order to preserve the keenness of the needle. After the record is made, reproduction without extraneous noises is attained by rubbing into the surface, gelatine, which serves to smooth out the sides of the sound grooves which had been laid bare by the cutting needle. Playback is affected by a steel needle whose point has been ground smooth and round. An excellent record can be made with this substance, but it has several disadvantages. The first one is that gelatin has a high water content, and before it is available for recording it must be aged, that is dried out until it is fairly stiff, so that when a groove is cut it will retain its shape. After the record is made, it must be kept away from a dry place. If this is not done, the water in the gelatine will continue to evaporate until the record becomes very stiff and brittle. The sound grooves will still be intact but the record will chip and break easily. Great care must therefore be exercised in placing and removing the record from the turntable. Another disadvantage that this disc possesses is that since it is made of gelatine, it readily dissolves in water. Therefore, it must not be handled with moist fingers or kept in a very damp place.

Aluminum records are either pre-prooved or blank. The blank record will be discussed in this section. Like gelatine, aluminum requires a feed screw for cutting, but the type of needle required is quite different. In gelatine a sharp flat bottom needle is used and material is removed. The weight required was the weight of the

cutting head itself. In aluminum recording, no material is removed. The needle, which is heavily weighted compresses the material, and at the same time makes the sound grooves. If material is removed, the surface noise on playback would be terrific, because of the non-homogeneous structure of aluminum. It must be borne in mind that not any kind of aluminum is suitable. In the first place, the blank disc is polished to a mirror like finish. This gives the surface a homogeneous structure. Next, this surface is waxed. The waxing can be applied with a piece of soft cloth which is first rubbed in wax. The surface of the disc is then rubbed with this cloth. The purpose of waxing is to fill the pores of the blank which the polishing was unable to do. At the same time it gives the needle a lubricated surface to work against. In the course of compressing, this wax is brought to the bottom of the groove and fills up any of the surfaces that might have been laid bare by the cutting needle. Oiling the surface will give practically the same results as waxing, but the latter has been found to be more satisfactory in that it is cleaner, and much more lasting.

In playback a steel needle cannot be used. The steel, being harder than the aluminum wears out the latter very rapidly. Even if the record did not wear out, the surface noise would be unbearable. Fibre or thorn needles must be used, and they must be kept very sharp. If dull needles are used, the reproduction becomes very poor. The needle is not able to follow the high frequency modulations and the surface noise increases, because the sides of the needle then scrape the walls of the grooves. An emery board or a finger nail file is used for re-pointing the needles.

Blank uncut celluloid records have proved to be excellent for recording. The needle used is a sharp pointed diamond needle, which is weighted with

about six pounds. The material possesses the disadvantage that it does not retain the high frequencies for any great length of time, due to its resilience. In one method of recording on this disc, the material is compressed, but unlike aluminum, the grooves have a tendency to close up after a few hours, thus obliterating the high frequency modulations. If the material is cut, the weight of the cutting head is sufficient, but then the surface noise increases. This noise can be reduced appreciably, by sharpening the needle to a very fine point. No hard and fast rule exists as to how to do this. Patience and experiments are the only solution.

Celluloid is obtainable in two forms, the acetate and the nitrate. The latter is inflammable and care should be exercised in handling it. Recording is much better on this kind than on the acetate which is the non-inflammable. Only clear celluloid should be used if good results are desired. In colored material the pigment used for coloring introduces resistance to the stylus and makes the material non-homogeneous. The result is that the record has a little more surface noise and is not as good in quality.

The pre-grooved record, which is now easily available anywhere, in the country is the simplest of the lot to use. No feed screw is required for cutting, and if necessary an ordinary pickup can be used with surprisingly good results. With these records, and as a matter of fact, with all celluloid records, the power needed for good results is greater than that for aluminum records. Too many people have condemned this type of disc, without first giving it a fair trial. A high powered amplifier is absolutely essential and no substitute can be used for it. In Chapter 1 is given the procedure to follow in using this record. For the present, the theory of the record will be discussed.

The record is pre-grooved simply for the purpose of abolishing the feed screw. This groove is very narrow, and it serves the purpose of guiding the cutting head across the face of the record. When the needle is placed in the groove and pressure is applied, the groove is spread to almost twice its original width. (See Fig. 53.)

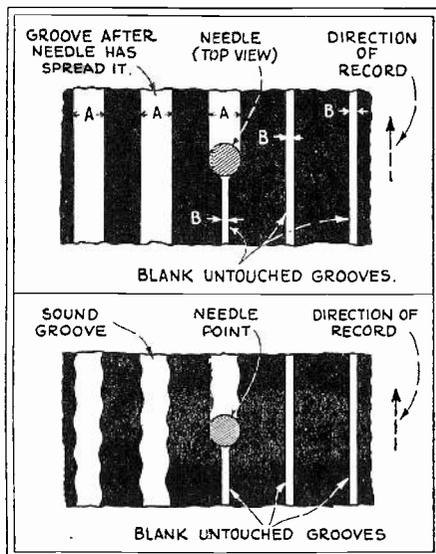


Fig. 53. Above. Manner in which the "pre-groove" is spread in the path of the needle.

Fig. 54. Below. Groove after being spread by modulated needle.

As Fig. 54 shows in more detail, when the needle is vibrated, a new, wider groove is made to correspond in its fluctuations to the tonal modulations impressed on the input of the amplifier. When the connections are changed over for reproduction, the playback needle follows this wider groove, and the vibrations are again converted, first into electricity and then into sound. It is quite evident that, if there is not ample space between grooves, a heavy bass note will cause the needle to "double track," or cut into the next groove, and spoil the record.

Some of these pre-grooved records have 78 lines to the inch, while others have 90 or more. It is the latter which are the source of a lot of trouble in cutting over from groove to groove on the heavy bass notes. If these latter records are used, the volume should be kept way down. This volume is best determined by trial.

The celluloid pre-grooved records are made by the processing method which is discussed in Chapter 16. The wax is first cut with a blank groove. Then it is plated, and a master is made. From this, a mother or matrix is made,

then the stampers are made. Unlike, commercial composition records, the celluloid is not rolled into a ball preparatory to putting it into the press. A piece of cardboard is placed in the press with a thin piece of celluloid on either side. The press is then brought down, and by a special mechanism, the ends are sealed together. A

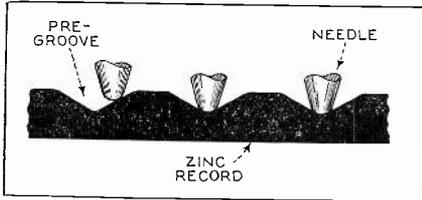


Fig. 55. Cross sectional view of pre-grooved zinc record.

record cannot be made with only one side covered with celluloid, because if the celluloid is lapped over the ends, the record will warp. If the celluloid is just laid flat with no overlap, then the record will peel. Solid celluloid with no paper backing, has not proved satisfactory.

Pre-grooved metal records are the oldest form of instantaneous records. Zinc was the material used for these records. The sound box of the old fashioned phonograph was the microphone

and the lungs were the amplifier. An ordinary steel needle was the cutting stylus. The person recording shouted or sang into the sound box and the sound waves were transmitted to the reproducer head, which modulated the needle. At best, the record was poor, but today fairly good results can be obtained by using the microphone, amplifier and cutting head.

The modulations were made near the bottom of the groove as shown in Fig. 55. When the needle was modulated it pushed the material from side to side. The steel needle being long and narrow, naturally did not have enough body to make any kind of deep groove. This fact, in combination with the small amount of power delivered to the needle was instrumental in producing poor records.

Pre-grooved aluminum records are now being made for recording, and they contain the same type of groove as the pre-grooved celluloid discs. The same precautions regarding the number of lines per inch etc., should be observed in the use of these records. They are not made by processing, but each one is grooved separately by a machine running at a speed faster than 78 R.P.M. The hardness of the aluminum is the reason that it cannot be pressed.

CHAPTER 10

How To Make Recordings

Instantaneous recording can be compared to making one's own picture with a kodak camera. The first few pictures might not be very good but the amateur knows that he can make good pictures with a little intelligent thought as to lighting, exposure, etc., and so by persevering he attains his objective. Strange as it may seem, the recording amateur is unwilling to even do any extensive experimenting, but after a few trials gives up with the conclusion that good home recordings cannot be made. Records can be made at home, with average apparatus, within the pocket book range, that are on a par with commercial records, if the would-be recordist would only take the trouble to analyze his equipment, method of recording, and the results he obtains and see where his trouble is and then correct it. Then, and only then, will he obtain results that he will be justly proud of.

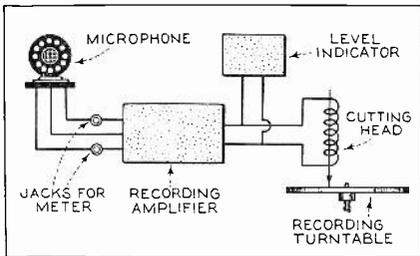


Fig. 56. Typical recording layout.

In Fig. 56, is shown a typical recording layout. The first thing to check is the microphone current. This should be near the value specified by the manufacturer. If the current is low the microphone will be less sensitive unless an extremely high gain amplifier is used. After checking the microphone, the amplifier should be turned on and allowed to warm up for a few minutes. The switch is then turned to the recording position, and a level test is made. If a level indicator is used, this

test is made with the subject standing at the microphone and saying a few words or singing. The volume is then brought up until the needle is kicking to the proper recording level. If a V.I. is not used, the level may be tested by the feel of the cutting stylus. This method, naturally requires experience, and if one is not able to own a level indicator, he should be willing to spend some time in acquiring this experience.

Another method of making a level test is to place the recording head on the record without starting the turntable and putting the ear to the record. The recording needle vibrating against the record, makes the latter a sound board. The sound is heard distinctly, and a little experimenting will usually determine how loud the sound should be.

At best either of these two methods is a guess. The disadvantage that they possess is, that, if for any reason, the person at the microphone backs up or gets closer or talks or sings louder the recordist has no method whereby to check his level. With the visual indicator, he knows instantly when his level is not what it should be.

The speed of the turntable motor should be tested with a stroboscope and the speed should be so adjusted that the table is running at 78 R. P. M. with the cutting head in position on the record. and cutting. When the lines on the stroboscope appear stationary, it is an indication that the table is running at the proper speed.

If the records are made with the motor at less than 78 R.P.M., the playback will be off the pitch until the turntable is adjusted to the same speed at which the record was made.

Do not entertain the idea that the motor is O. K. if it is strong enough to pull the record. It might, and will, reach normal speed when the record is

about half finished; but, on playback, the first part of the record will be off pitch, while the last part will be O. K. While six or seven inch records are used, the average commercial phonograph motors will be found satisfactory.

In reproducing, the needle should be sharp and clean if aluminum or blank celluloid records are used. If the record sounds distorted, it is an indication that the amplifier gain control was too high. If the sound was boomy and barrel like, the cause was that the person recording was too close to the microphone.

Standing too far away from the microphone results in the record having too much of an echo effect.

The amplifier used should have a fairly high gain, to minimize the needle scratch. If a low gain amplifier is used, the playback requires the volume control to be turned up quite a bit in order that the sound may be audible. It is obvious therefore, that if the gain is turned up, the sound increases, but the background and needle scratch are all increased proportionately, resulting in a noisy record. The high gain amplifier makes possible reproduction with the gain way down and hardly any noise.

When recording on one side of blank ungrooved records, it is found sometimes that the disc has warped slightly, and difficulty will be experienced in making the needle track. This can be avoided by either recording the other side or cutting a blank groove therein.

The inability to track, may also be due to several other reasons; if the tone arm is tilted a bit, or the turntable is wobbly, this will prevent the needle from following the groove. If the recording has been made at a high volume level, some of the grooves will cut into each other, and this also will prevent the needle from tracking.

Only two types of needles should be used to play back aluminum records, namely fibre and thorn. The use of any type of steel needle, aside from introducing considerable surface noise, will ruin the record.

Do not be too ready to condemn aluminum records until you have made sure that the needle with which you are playing back is sharpened to a fine

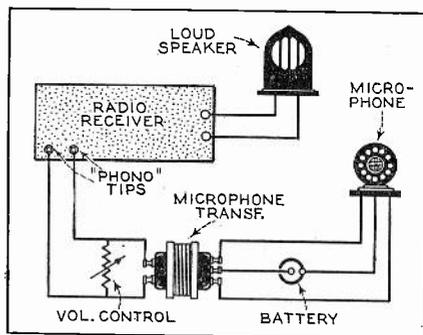


Fig. 57. Microphone connections if radio receiver has phono-tips.

point. The thorn and fibre needles should never be used more than once or twice before resharpening with a piece of emery board, that is, a finger-nail board.

The angle which the reproducer makes with the record has a great deal to do with the life of the needle point, and an over-heavy reproducer will very rapidly wear out needles. Therefore, it is very important that the needle be examined thoroughly before each playback.

The same troubles may be looked for in pre-grooved records. If the latter record is of celluloid, the needle may refuse to stay in the groove when recording. This means that either the weight was not enough or the gain was too high.

HOW TO USE THE RADIO AS A RECORDING AMPLIFIER

In using the audio amplifier of the radio set for recording, it is necessary to use an adapter under the detector tube. The cutting head can be placed in either of two places. If the head is of high impedance, it can be connected to two wafer sockets and these inserted under the power tubes. If a low impedance head is used, it may be connected across the secondary of the output transformer, whose leads are brought out to the voice coil of the loudspeaker. The voice coil leads are first disconnected. It is not recommended that low impedance cutting heads be used with radio sets, due to the fact that voice coil impedances of

commercial radio loudspeakers vary from 2 to 18 ohms, and if the cutter impedance is off a few ohms, the impedance match is way off in percentage. For consistently good results and for the prevention of needless expense, only the high impedance cutters should be used.

If the set has the output transformer mounted on the speaker, then the output terminals on the chassis are high impedance and the cutter is connected directly to them. Also, if the set has "phono" terminals the input connections are as shown in Fig. 57.

Some radio sets use a power detector into two power tubes, and the high gain of this power stage is not sufficient for recording, necessitating the use of a pre-amplifier such as shown in Fig. 58.

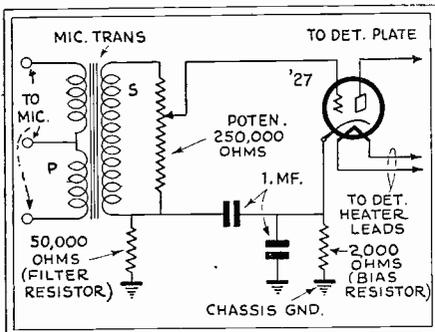


Fig. 58. Circuit of a one stage pre-amplifier for use with radio receiver.

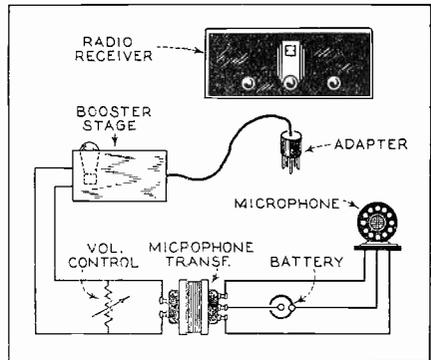


Fig. 59. Circuit of a booster stage used with a microphone and radio receiver.

The booster one stage amplifier, shown in Fig. 59, is manufactured by the Pacent Electric Co. of New York, and can be used for recording by the addition of a microphone transformer as shown. This adapter is provided with a toggle switch so that when it is in the "radio" position, records can be made from the radio. When it is in the "record" position the microphone is in use.

The booster is connected to the radio set in the following manner: The detector tube is removed from the set and inserted into the adapter at the end of the cable supplied as part of the "Booster Unit." The adapter with the tube in it is then placed in the detector "tube socket of the set.

CHAPTER 11

Recording Studios

Commercial studios for instantaneous recording can be divided into two separate types—first, studios devoted exclusively to voice recordings and individual instrument playing and, second, studios that have facilities for recording complete orchestras and bands.

In the first type of studio only one microphone is used and the recording machine, amplifier, etc., are all located in the same room with the microphone. This room usually contains about 42 square feet of floor space, and the over-all frequency characteristic of the system is not made very flat since it is rarely necessary to record any frequency above 4000 cycles. A moderately priced two-button carbon microphone, used in conjunction with a suitable amplifier whose gain is about 70 DB, and a made-over pickup is all that is necessary as equipment. For the recording machine an ordinary phonograph turntable is all that is necessary if pre-grooved records are to be used, but if blank uncut records are desired for recording, then it is absolutely essential that an excellent feed-screw device be used in order to insure a good even groove. As has been pointed out, if the recording machine makes a periodic groove—that is, the lines are unevenly spaced, when the record is played back, the results will be poor and if steps are not taken to prevent this, the finished product will only serve to cast reflection on the studio with a consequent loss of business.

A piano should be provided for accompaniment and it is usually a good policy to have a person who is a pianist run the studio. This will cut down labor costs and at the same time attract the singers who usually are very reticent about singing if accompaniment is not easily provided. For playback, the acoustic phonograph is best. The reason why this type of machine is recommended is that if the finished record plays back satisfactorily on it,

the customer is assured of success in his own home. Too many of these small studios that are rapidly springing up all over the country use inefficient apparatus and naturally their results are poor. To compensate for these poor results on playback, electrical reproduction is used and the record then sounds quite satisfactory in the studio, but when it is reproduced in the home on the old style phonograph (of which there are still many in existence) the results are very poor. The reproducer may be too heavy or the groove may not be deep enough with the result that there is double tracking. The customer is dissatisfied, and therefore any future business from him is lost. Instead of becoming a supporter, he turns "knocker". In the writer's opinion, the acid test for any instantaneous record is the acoustic phonograph. If the record sounds well on this, then it will sound much better on any other type of machine.

ACOUSTICAL TREATMENT OF STUDIOS

In most of the studios that the writer has had occasion to come in contact with the acoustic treatment of the studio has been simply to cover the walls and ceiling with heavy drapes and the floor with a heavy carpet. A studio that is so treated will prove unsatisfactory for recording from the standpoint of fidelity. The record will sound "tubby" and very unnatural. This is due to the absorption of all the high frequencies by the heavy drapes. For proper acoustics the studio should be so constructed that there is a certain amount of resonance present so that the high frequencies may be properly recorded. In the proper treatment of recording rooms two objects must be kept in view; first, the exclusion of all unwanted external noises, and second, the production of the right acoustic conditions for good recording.

The excluding of extraneous noises

is accomplished by building the room of double walls (See Fig. 60) with a dead air space between them. The dead air space is an excellent insulating medium against sound and is very effective in keeping out external noises. Great care must be taken to see that the walls and ceiling are all absolutely air tight. If this construction is carefully followed out, it will be observed that no sound originating in the studio will be heard outside, and vice versa, no sound originating on the outside will be heard inside the studio. As an added insurance against external noises the outside of the outer wall is covered with an insulating material such as Celotex

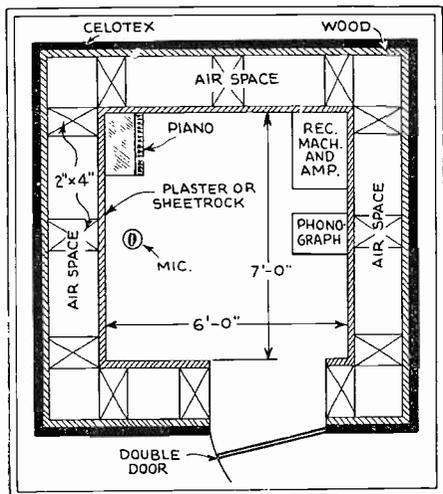


Fig. 60. Interior layout of a sound recording studio.

tex. The inside walls and ceiling should be partly covered with heavy drapes so as to lower the reverberation constant. The amount of drapery is best determined by experiment. The room should have a slight amount of resonance so that the faithful recording of the high notes is possible. By a slight amount of resonance is meant that the conditions must be such that a person talking at the microphone will sound the same as a person talking in an average dining room. It must be borne in mind that in commercial work the proper acoustical treatment of the recording room is just as important an item as the apparatus itself, and no effort should be spared to

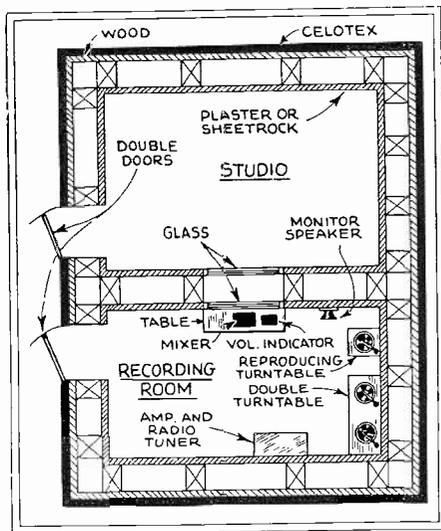


Fig. 61. A sound recording studio and control room design. Double walls furnish adequate sound insulation.

achieve these results. Good records mean "repeat business."

STUDIOS FOR ORCHESTRA AND BANDS

Studios that are to be used for orchestral recording are naturally more elaborately equipped than studios intended for vocal work only. In the first place, two or more rooms are required and more than one attendant is necessary. As is seen in Fig. 61, the recording room is adjacent to the studio and is separated from the latter by means of the double wall which is insulated against the transmission of sound from one room to the next. The advantages to be obtained in locating the two rooms adjacent to each other are two: first, the input leads from the microphone are kept as short as possible, thus minimizing the picking up of extraneous noises, and second the man at the mixer has a full view of the studio so that at times he may anticipate the action in the studio which in itself is a tremendous aid in obtaining a good recording.

Fig. 62 shows a black schematic of the apparatus to be used. It is recommended that at least two, if not three, microphones be used so that proper pick-up of the different pieces of an orchestra may be accomplished.

MIXER TECHNIQUE

Under ordinary conditions the mixer dial should be set at the beginning of a record and not touched thereafter. Of course there are exceptions to this rule; for example, when the mixer man sees that his level indicator is jumping past the danger mark on some particular notes, he is justified in cutting down his volume and then raising it when the danger is past.

Some operators are not very careful in the placing of the microphones for best pick-up, and as a result of this they have to resort to twisting the mixer dials to obtain the best results. This procedure is not recommended. The less manipulation of the controls during the recording the better chance there will be for a good record.

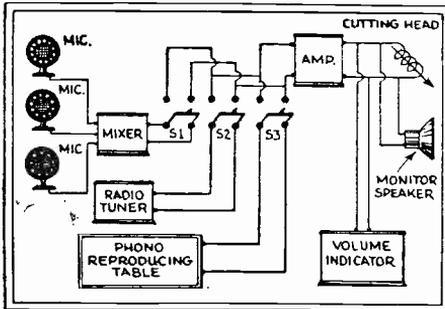


Fig. 62. Switching arrangement for connecting either alone, or in any combination the microphones, radio or phonograph to the recording amplifier.

The most common fault to be found among mixer men is their marked tendency to try and do the work of the orchestra leader. Some have their own particular ideas on how much high or low frequencies there should be recorded and as a result the record is usually an interpretation of the mixer man's idea of the piece rather than that of the leader, much to the chagrin of the latter. Some maestros now have the level indicator placed in front of them to enable them to control their volume more easily by signaling their band instead of leaving the interpretation of their piece to the mercy of the mixer man who is usually a better technician than musician.

DOUBLE TURNTABLE

The use of a double turntable is absolutely essential in that continuous recordings may be made. The turntables should be provided with a fader so that the cutting in of one record

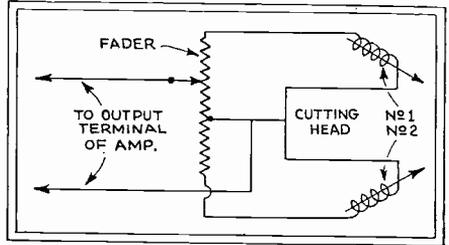


Fig. 63. Fader connections for continuous recording.

while the other is being cut out is accomplished without any loss of sound. This is indicated in Fig. 63. The tables should have a shift mechanism so that they may be run either at 78 R. P. M. or $33\frac{1}{3}$ R. P. M. The large 16" records ($33\frac{1}{3}$ R. P. M.) which run from 12 to 15 minutes continuously are especially suited for the recording of radio programs. A full quarter-hour program can be fully recorded on one disc. If the radio recordings are to be made for individual radio stars, then it is inadvisable to give them a $33\frac{1}{3}$ record because of their inability to obtain $33\frac{1}{3}$ R. P. M. reproducing tables. When the double turn-table is used the fading should be carefully done. Every attempt should be made to make the changeover when there is a lull in sound, for instance, when a chorus is ended or when a change of action is being denoted by music.

Aluminum should not be used for 16" slow speed records because the fibre or thorn needle that is used for playback wears its point out before the record is finished with the natural result of poor reproduction. Only materials that can be played back with steel needles should be used for the large records.

The method of connecting the radio receiver is shown in Fig. 62. It is noted that when switches S1 and S2 are closed, the outputs of both the radio set and the mixer are fed to the cutters. This hook-up allows the studio to make novel records, for example announcements can be made over the regular voice system to introduce any radio program, and talks in the studio may be recorded with a radio musical program.

The phonograph turntable provides the facilities for dubbing, or re-recording as it is more correctly known, and is connected into the circuit by switch S3 (Fig. 62).

CHAPTER 12

Commercial Machines

A MODERN RECORDING MACHINE

A particularly interesting recording machine (Fig. 64) is manufactured by G. J. Badgley & Co. While intended for use with blank ungrooved records, such as aluminum, it can be used also for blank pregrooved records simply by adding an ordinary phonograph pick-up equipped with the proper weights. The turntable motor M is of the commercial phonograph type: slightly modified in order to drive the cutting head CH across the face of the record.

The gear box GB contains two helical gears which transmit motion to the driving shaft D, which has a pulley mounted at one end of it. This pulley P1 drives, by means of the rubber belt B, the top pulley P2, which is mounted on the feed screw FS. This feed screw has 64 threads to the inch; but the feed-screw turntable gear ratio is such that 96 lines to the inch are cut on the record.

A threaded clamp C is used to prevent slippage of the record during recording. This clamp is purposely made with a left-hand thread to offset any tendency of the turntable, driven in the right hand direction by the motor, to loosen it.

The weight on the recording head can be varied by sliding along the weight-rod A, the weight B1. The rod also is movable so that the weight can be made to hang directly over the cuttinghead if necessary. This head is guided across the face of the disc, by means of a half-threaded coupling which is kept in mesh with the feed-screw by means of a spring contained in the spring housing SH. A very unique feature of the apparatus is the plunger P.

The motor, although it has enough torque to make a twelve-inch record, has a difficult time starting with the cutting head on the disc. Now, by the use of the plunger P the following pro-

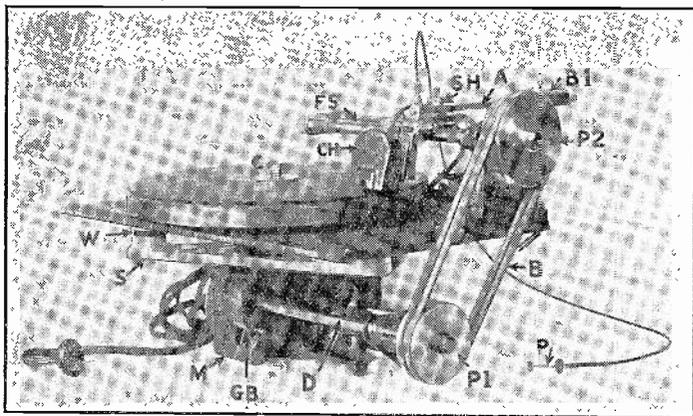


Fig. 64. Detail of the recorder shown in Fig. 65; it will operate on plain or grooved discs. A special recording head must be used to give great accuracy in raising and lowering the head. The components and their functions are described in the text.

To give rigidity to the motor, the spider S upon which the motor is mounted is made very long; and it is separated from the mounting plate by means of rubber cushions or washers W, to prevent motor vibrations being transmitted to the turntable.

cedure is carried out: While the motor is at rest, the cutting head is placed at the "start to record" point on the blank record. The plunger is then pushed, and the cutting head is raised from the record, after which the motor may be started. When it has reached

normal recording speed, the plunger is released, thus placing the recorder on the record.

This machine cuts a good, even groove with no apparent "line periodicity" (uneven space—not uncommon in some makes); and it is especially adaptable for studio work.

Fig. 65 shows the complete studio recording apparatus utilizing this machine. It must be remembered that excellent results are obtainable only when a good two-button microphone and a good three-stage transformer or resistance-coupled A. F. amplifier are

used. The standard impedance of the cutting head is in the neighborhood of 4000 ohms; however, it is obtainable with a unit of any standard impedance.

The cabinet contains, for recording and playback, a complete amplifier and current-supply system, consisting of two stages of A. F. using type '27 tubes, and a power third stage using push-pull '45's; the rectifier is an '80. An indication of the sound level at which the recorder is working is given by a dynamic reproducer contained in the cabinet. The microphone, of course, must be isolated in another room of the studio suite.

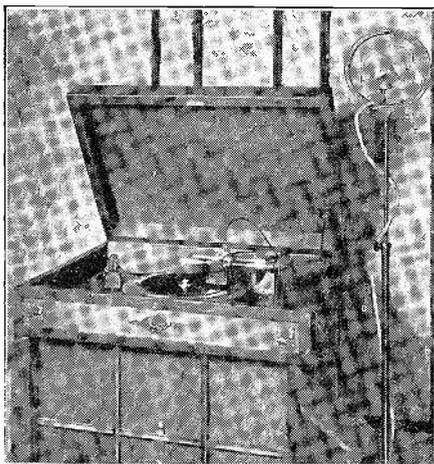


Fig. 65. A studio model recording machine.

THE RECORDOVOX

The Patent Model 171 "Recordovox" shown in Fig. 66, is made especially for home recording, to use only pre-grooved records; and once this apparatus is connected to the radio receiver, it need never be removed.

In order to use the "Recordovox" a radio set, turntable and microphone are needed. To use a single-button microphone, only two connections are made, one to the center post and the other to either one of the outside posts marked "microphone". A $4\frac{1}{2}$ -volt "C" battery is connected to the posts marked "Batt." If a two-button microphone is used, connections are made to the three microphone binding posts; and a 6 volt battery is required.

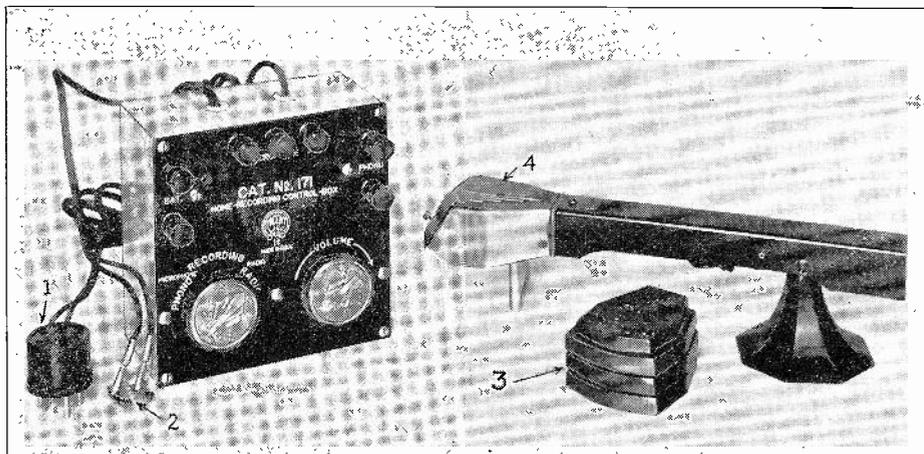


Fig. 66. This apparatus, with a microphone and its battery added is designed for a permanent attachment to a receiver, for recording and reproduction. Adapter 1 and lugs 2 connect, respectively, at the detector and power stages. The pick-up-recorder 4, is loaded with the weights 3 as required.

The recording head is connected to the terminals marked "phono". The five-prong adapter 1 (connected by a cord to the control box) is inserted in the detector socket of the radio set, and the detector tube is placed in the adapter. The single-prong adapters 2 (furnished with the instrument), are placed on the plate prongs of the two output tubes; which then are replaced in their sockets. The remaining cord from the control box plugs into the receptacles incorporated in these adapters. This completes the installation. For radio reception only, the selector switch is turned to "Radio" and the set tuned in the regular way; and to record a radio program the selector switch is set at the "Recording Radio" position.

phone recordings, the volume control of the radio set is turned to the position for minimum volume. (If a signal still is heard, the receiver must be detuned.) The selector switch on the control box is turned to "microphone recording," and (after the cutting head is set as described above), the apparatus is ready for the recording.

The microphone, if of the single button type, should be held in a true vertical position and about one inch from the lips of the speaker, who should use a tone slightly louder than ordinary conversation. If squealing is noticed, the microphone should be kept away from the loud speaker. In fact, for best results the microphone should be in a room separate from the radio set and with the intervening door closed.

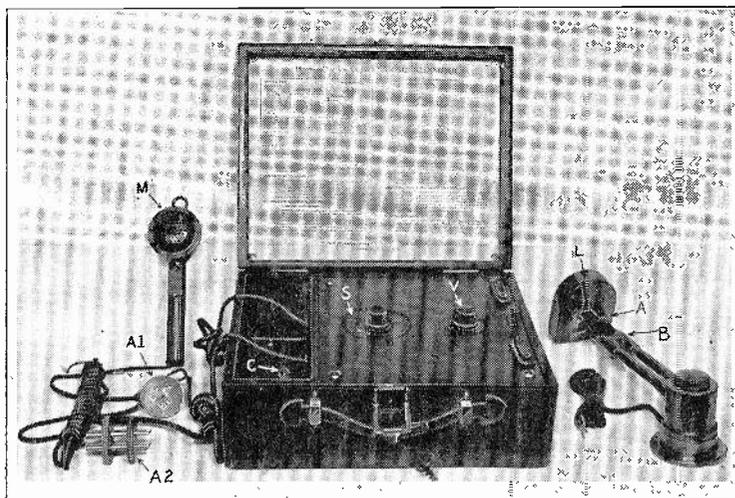


Fig. 67. The "Best" home recorder; left, microphone M, with adapters A1 for connection to the input, and A2 (two plugs) for the output of set; C is a cap for use with a screen-grid detector; S, switch; V, volume control.

The turntable motor is turned on, and a home recording needle is inserted into the recording head, the latter being weighted with one or more of the weights, 3, (supplied with the kit). The radio set is then tuned to the station whose program is desired for recording, making sure that the volume control is at a fairly high level. Best results, of course, will be obtained with all three of the weights; but, very often, the phonograph motors available do not have sufficient torque to pull the turntable around when the head is thus weighted, and a lesser number must be used.

When it is desired to make micro-

On playback, the previous instructions for detuning the radio receiver and setting the volume control at minimum volume are followed; and the selector switch is set to the "phono" position. The volume of the record reproduction is regulated by means of a knob on the control box.

NEW BEST APPARATUS

The Best Manufacturing Co.'s recording apparatus, shown in Fig. 67, is very similar to the "Recordovox" except for the method of weighting the recording head, which is very ingenious. No external weights are added to the record-

ing head. When the unit is to be used for recording, the lever L is pushed over to the side marked "R", locking the recording head and preventing it from swinging about at joint A. For reproduction, the lever is moved to position "P", and motion takes place at joints A and B. The balance of the recording head is such that, when its weight is fully applied to the record, it exerts enough pressure to make a good recording. This novel method of increasing the effective weight of the head possesses an advantage in that no weights are required, at the same time, it has the disadvantage that, should the

turntable motor develop insufficient torque to pull the record at a constant speed, because of the great weight of the head, a poor recording will result. Under this condition, the lever is dispensed with, and weights are substituted to mount on top of the recording head. The method of installation and operation are the same as described for the Pacent unit.

LATE MODEL UNGROOVED-DISC RECORDER

In Fig. 68 is shown the newest development in the way of home record-

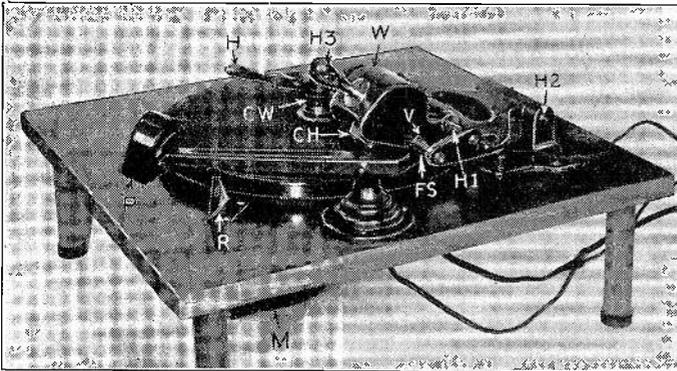


Fig. 68. Set up of the new "Presto" home recording kit, shown in recording position.

In this one kit are contained all the mechanical units necessary for recording on blank ungrooved discs. This entire mechanism is so constructed that it can be easily lifted from the table.

The cutting head is weighted with a W, the bottom of which is recessed and lined with leather at V.

Fig. 69. The "Presto" recorder in the "change record" position; note that the cutting head swings loosely on its bar H1, so that it may be folded back.

Installation is very simple. The only requirement is to fasten the plate to the motor-board, first making sure that the clamp-down CW will couple easily to the spindle of the turntable when the handle H is brought down. The clamp comprises a double-thread worm that is driven by the spindle of the turntable. This worm meshes with a pinion gear (PG

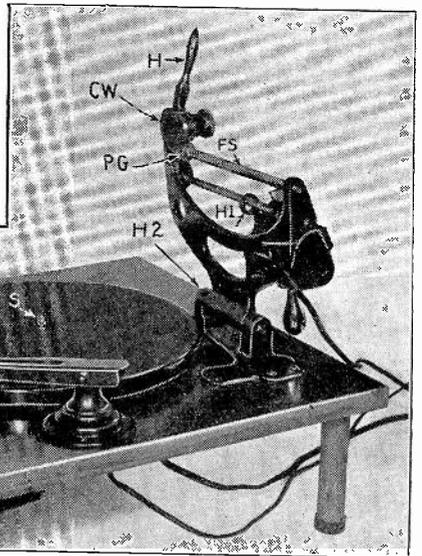


Fig. 69) mounted at one end of the feed-screw shaft FS. This screw has 12 threads to the inch; the threads being of the "buttress" type. Since the ratio between the worm and pinion gear is 8:1; and the feed-screw has 12 threads to the inch, the number of lines per inch that will be cut into the record will be 96.

ing equipment, of the Presto Machine Products, Inc. In this one kit are contained all the mechanical units (cutting head, feed screw, worm, worm gear, etc.), necessary for recording on blank ungrooved discs. This entire mechanism is so constructed that it can easily be lifted from the turntable, for changing records, by simply pulling upward a handle, H.

Installation is very simple. The only requirement is to fasten the plate to the motor-board, first making sure that the clamp-worm CW will couple easily to the spindle of the turntable when the handle H is brought down. The clamp comprises a double-thread worm that is driven by the spindle of the turntable. This worm meshes with a pinion gear (PG Fig. 69) mounted at one end of the feed-screw shaft FS. This screw has 12 threads to the inch; the threads being of the "buttress" type. Since the ratio between the worm and pinion gear is 8:1, and the feed-screw has 12 threads to the inch, the number of lines per inch that will be

cut into the record will be 96.

The cutting head is weighted with a 3-point weight, W, the bottom of which is recessed and lined with leather at V, so that it will mesh in a noiseless and proper manner with the buttress thread of the feed-screw.

The Presto recorder is supplied in kit form; and contains, besides the cutting unit, a control box, microphone, microphone pre-amplifier, using a type '27 tube, pickup and turntable. The operation of the control box is similar to the above mentioned control boxes, except that when the knob is turned to "Phono" the phonograph pickup is cut into the circuit.

The cutting mechanism can be used with either the Pacent "Recordovox" or the Best control box, by simply inserting the recording head leads into the receptacles marked "Phono". It must be borne in mind that this unit is not suitable for the playback; and, when the latter connection is desired, it is necessary to remove the recorder leads and substitute pick-up leads.

CHAPTER 13

Portable Recording

Portable recording machines while fundamentally the same as studio types have more intricate problems to be solved in their design. They must contain the same apparatus as the studio machine, but in less than half the space.

Portable machines may be either battery operated or A. C. operated. The choice of either type will depend entirely on the locality where the machine is to be used.

The A. C. job possesses the advantage that it is more compact, has fewer cases, and is much easier to carry around. At the same time, it has the disadvantage that it is not of any use where A. C. is not available. Of course one may take a motor generator set to the D. C. district, but when it is to be used where no type of current is available, it is of absolutely no value.

The battery operated job, on the other hand, can be used anywhere, out in the open, on expeditions, etc. The biggest disadvantage that this type has, lies, of course, in the batteries. They have to be replaced and charged, and this type is a little more complicated in setting up and the chances of mistakes are increased considerably in interconnecting.

Any portable recording apparatus should be made so compact that it is not bulky in carrying. It should be so light that whoever is to carry it, can do so without undue effort. It should be sufficiently rugged to withstand the many jars of transportation without any mechanical or electrical damage being done. Finally, the units should be so arranged that they can be connected together with certainty in a minimum of time. The equipment should be capable of picking up, amplifying, and recording a fairly wide band of frequencies.

In Fig. 70 is shown an A. C. operated portable recording machine built into two separate cases. One case contains the turntable, recording head, and level indicator, while the other contains the amplifier and control panel. A loudspeaker is not provided, but provisions are made for phone playback. The phones serve a dual purpose. In re-

ording they may be used for monitoring, while in playback they may be used for listening in. An attenuator pad is provided so that there is no danger of overloading them.

The three stage amplifier illustrated in Fig. 71 consists of three separate units, each built upon a separate panel with all the panels being the same in size. These units are supported one over the other by four threaded steel rods which pass through holes at the corners of the panels.

This construction has several important advantages. Any unit which becomes defective or out of date may be easily replaced. There is a minimum of unoccupied space because the parts of one panel may be arranged to fit down into the unoccupied space of the others. As examples of this, note the bypass condensers on the bottom of the middle unit and the switch on the upper unit, Fig. 71. The metal framework is used for the common ground connection in the system.

The lower unit is the power supply; the middle unit, the three stage amplifier; and the top unit, the switching panel which holds the microphone input transformer and current indicating meter. Two '27 type tubes are used in the first two stages, and two '45 type tubes are used in the push-pull power stage.

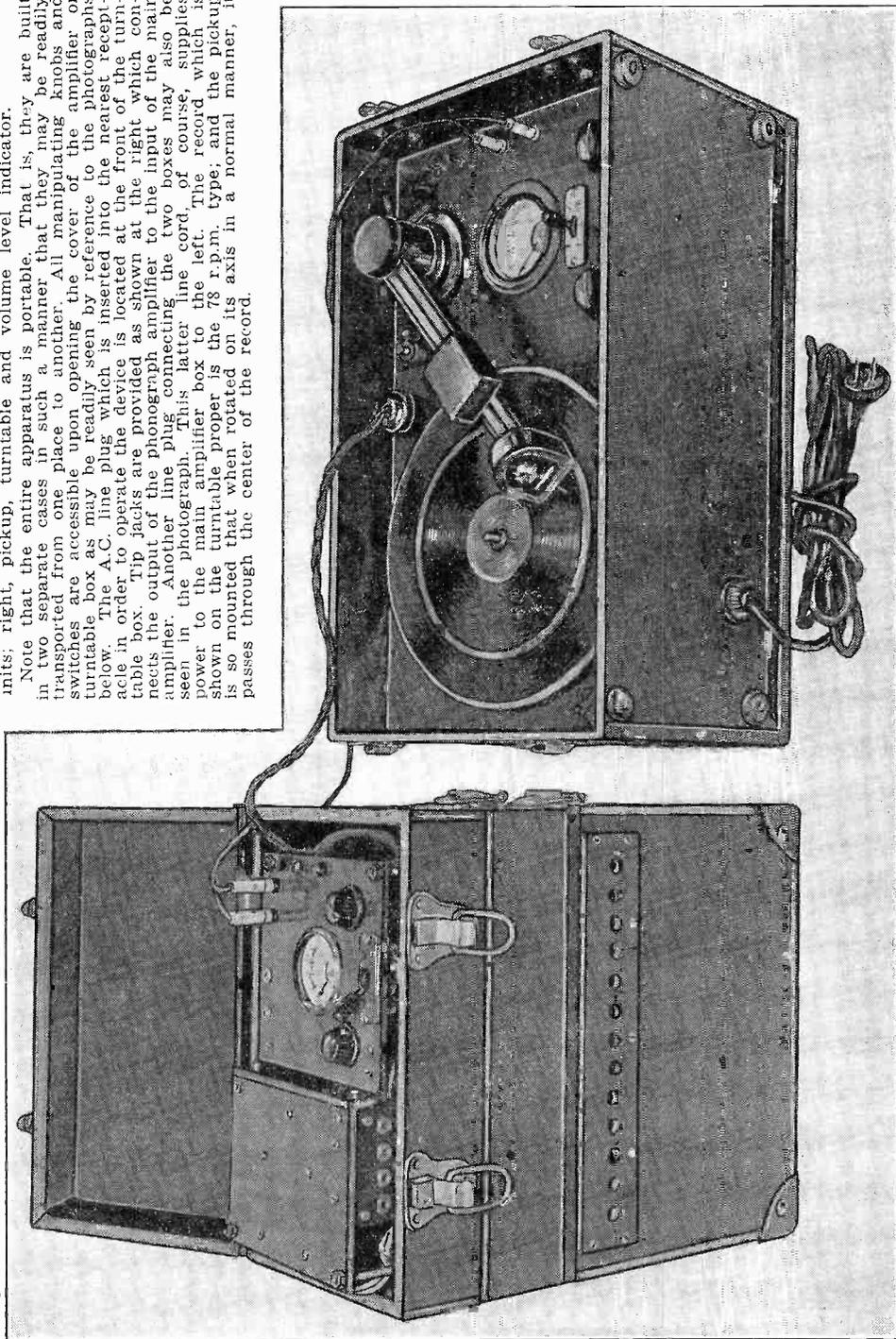
The chokes in the power supply were carefully chosen for weight, size and resistance. The latter figure must not exceed 300 ohms per choke to permit a satisfactory voltage supply. An electrolytic condenser was used for filtration because it combines small size and weight with high capacity.

Four wires connect the power supply to the amplifier. The two outer leads supply '27 and '45 filaments. The two inner wires between the lower units are the plus and minus of the "B" supply. The minus connection is used in addition to the frame work for the sake of certainty.

As shown in the diagram of the amplifier, Fig. 72, the grid and plate circuits of the tubes are isolated from each other electrically by a condenser and resistance filter network. This re-

Fig. 70. Left, three stage audio amplifier and indicating and control units; right, pickup, turntable and volume level indicator.

Note that the entire apparatus is portable. That is, they are built in two separate cases in such a manner that they may be readily transported from one place to another. All manipulating knobs and switches are accessible upon opening the cover of the amplifier or turntable box as may be readily seen by reference to the photographs below. The A.C. line plug which is inserted into the nearest receptacle in order to operate the device is located at the front of the turntable box. Tip jacks are provided as shown at the right which connects the output of the phonograph amplifier to the input of the main amplifier. Another line plug connecting the two boxes may also be seen in the photograph. This latter line cord, of course, supplies power to the main amplifier box to the left. The record, which is shown on the turntable proper is the 78 r.p.m. type; and the pickup is so mounted that when rotated on its axis in a normal manner, it passes through the center of the record.



sults in the greatest possible amplification without circuit oscillation. All of the important wiring in the three units is made with shielded wire, with all of the shields grounded. This precaution is absolutely necessary in the switching panel.

Note the angle at which the microphone transformer is tilted in the upper panel, Fig. 71. This is for reducing the A. C. hum picked up from the power transformer and chokes. This microphone transformer is as far from the power transformer as it was possible to locate it. With the transformer as shown, the hum picked up is sufficiently small not to be noticeable.

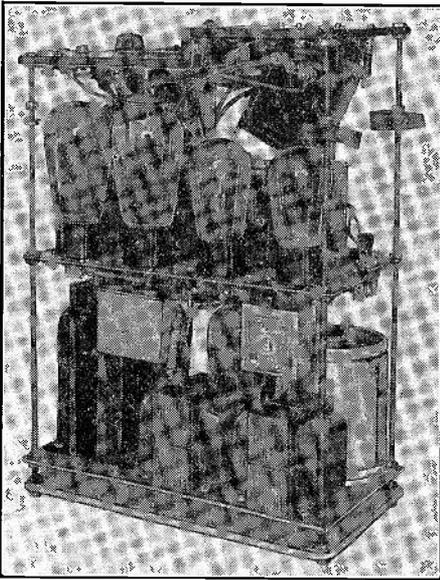


Fig. 71. Interior view of the amplifier cabinet of the portable sound recorder.

The switching arrangement is such that in one position the various units are connected for recording, and in the opposite position they are then connected for playing back the record through a speaker. In either the playback or the neutral position, the battery circuit supplying the microphone is open. The milliammeter is connected permanently in one of the microphone legs. To read the current in the other leg, it is only necessary to reverse the microphone plugs.

The amplifier is cushioned from mechanical shock by means of sponge

rubber underneath and on the threaded steel rods.

The carrying case is of black imitation leather. The dimensions are 9"x12"x18", and the total weight is about 30 pounds.

The volume indicator panel is located in the turntable carrying cases so as to minimize the number of wires between the amplifier and the recorder.

A 250,000-ohm potentiometer, R 12, Fig. 76, is used for varying the input signal to the tube, thus controlling the swing of the indicating needle. This potentiometer is purposely located inside the case so that once the setting is made, there is no chance of accidentally changing it. A 50-ohm rheostat, R15, controls the filament voltage on the level indicator, while the plate voltage is controlled, by a 10,000-ohm potentiometer, R13.

In this turntable case are located two ordinary plug receptacles connected in parallel. One of these connects to the main lighting circuit, while the other supplies A. C. to the amplifier. The output of the amplifier is connected to the cutting head by means of a cord and plugs, the latter being three microphone plugs which are red, green and black. The color system is used to facilitate the making of the connections when speed in setting up is necessary. Phone receptacles are provided in the amplifier for monitoring purposes.

The dimensions of this case are 9"x13"x18", and its total weight is about 25 pounds. It is made of the same material as the amplifier case and one man can easily carry both of these cases.

Fig. 73 shows one of the newer types of portable machines that is all contained in one compact portable case. This machine is made for recording on blank aluminum or celluloid records. The feed screw obtains its drive through the worm, which is built around a clamp, which fastens over the turntable spindle. The feed screw is of the buttress thread type, and its slow rotation is obtained by a worm gear which is fastened at the end of the screw shaft. This worm gear meshes with the worm on the clamp. The cutting head weight has built into it a latch which is about 3/32" thick and which is so mounted that it fits into

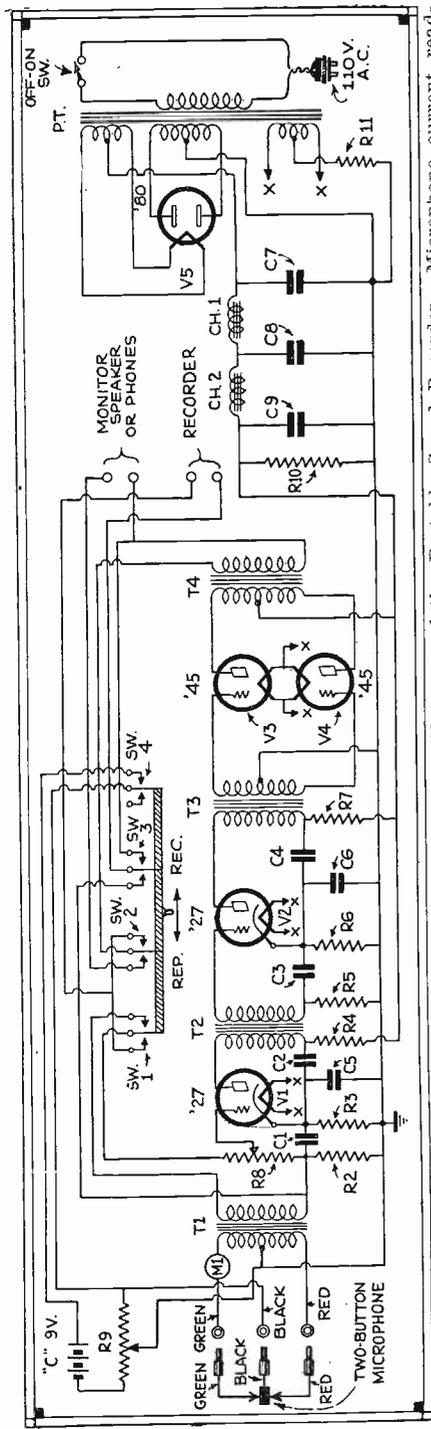


Fig. 72. Schematic circuit of the amplifier case of the Portable Sound Recorder. Microphone current readings for circuit button are, obtained by reversing the position of the plug of the 3-conductor cord. The filtering shown is very important.

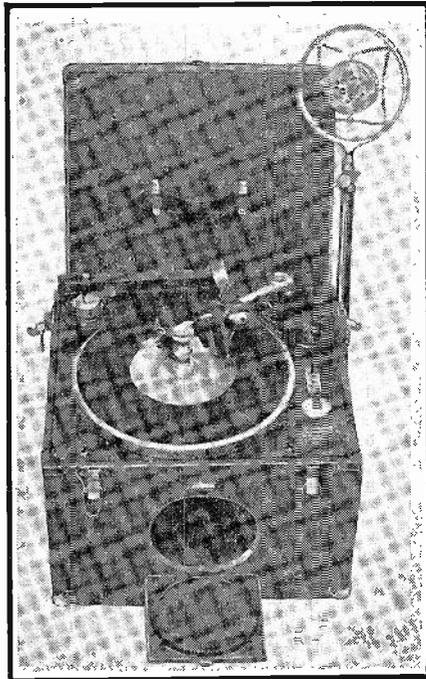


Fig. 73. Speak-o-phone, A.C. operated portable recording machine complete in one case.

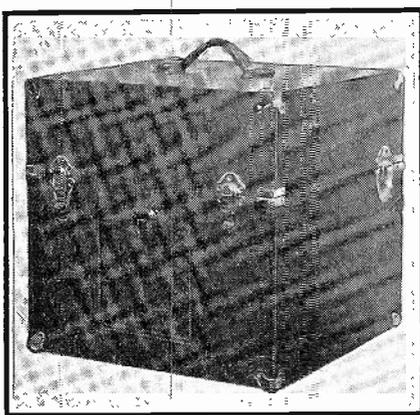


Fig. 74. Portable machine of Fig. 73, ready for transportation.

the bottom of the screw thread. The feed screw, upon being rotated, moves the cutting head across the face of the record by means of this latch. Upon completion of the recording, the latch is pulled out of the buttress thread and the whole assembly is then pulled over to the end of the feed screw. The clamp worm is then removed from the spindle and the feed screw is swung over to the side. The record is now available for playback.

On the right side of the panel are located three binding posts for the microphone. The latter is fastened directly to these posts without the aid of any battery. The current for the microphone is supplied from a power supply that is built especially for it and incorporated in the amplifier which is located inside the case. The volume control knob is located next to the binding posts, and is of the modified "H" attenuator type. Below the volume control is the main control switch which is of the anti-capacity design. When this switch is thrown to one side the microphone and cutting head are in the circuit ready for recording. For reproduction, the switch is thrown in the opposite direction and the pickup and speaker are thrown into the circuit. As is seen in Fig. 73, the loudspeaker is provided with a hinged cover so that in transit, the speaker cone is protected against damage. The machine is easily portable, its total weight being about 45 pounds and is entirely A. C.

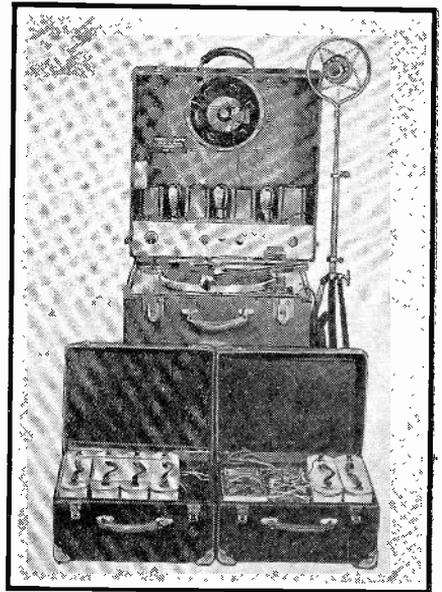


Fig. 75. Speak-o-phone battery operated portable recording machine.

operated. Fig. 74 shows the unit ready for transportation.

A fine example of a battery operated portable recording unit is shown in Fig. 75. Four cases comprise the unit. One case contains the recording amplifier which is of the conventional 3 stage transformer coupled type, entirely battery operated. Above the amplifier is

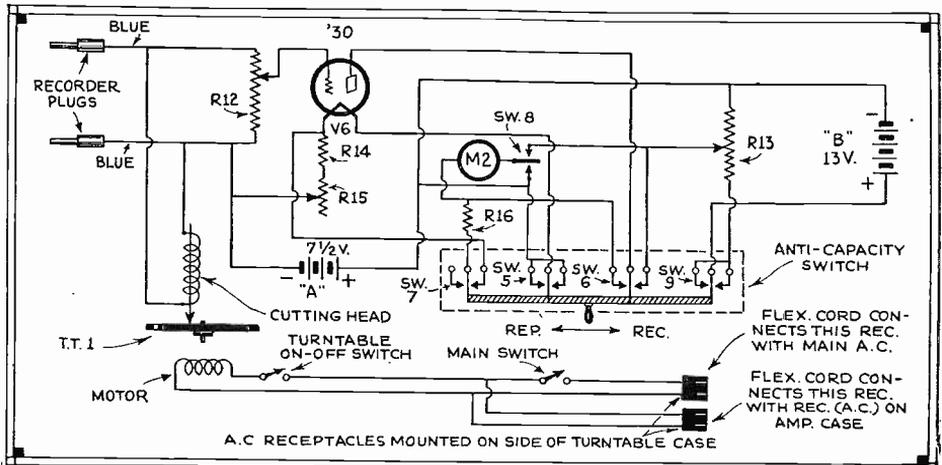


Fig. 76. Connections within the turntable case of the Portable Sound Recorder. Tube V6, in conjunction with meter M2, is a volume level indicator.

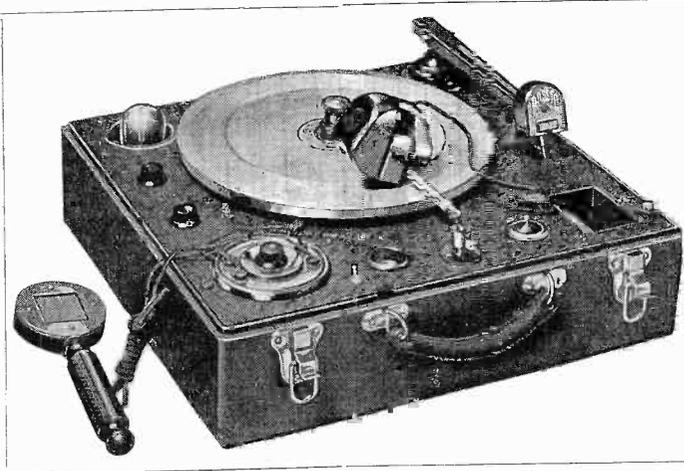


Fig. 76A. The portable kit arranged for recording; the pickup arm is resting in off position and the cutting head and feed screw are in operation. Microphone at the left, '27 microphone amplifier tube at upper left.

The recording unit measures 18"x18"x10" and weighs 35 lbs., while the amplifier unit measures 21"x20"x9½" and weighs 30 lbs. The battery cases each weigh 30 lbs. The microphone and stand are carried in a waterproof container. This apparatus is especially adaptable for expedi-

tions, carnivals, circusses, in fact—for any location where no electric current is available.

Fig. 76B. Kit arranged for play-back. The cutting head is seen put away in its recess and the pickup in its operating position. The disc at the lower left is the switching mechanism.

The type of needle used for play-back work varies with the type of record upon which the recording has just been made. If it is of the wax type then, of course, a softer needle must be used than if the record is of the more or less conventional type illustrated in the photograph at the right.

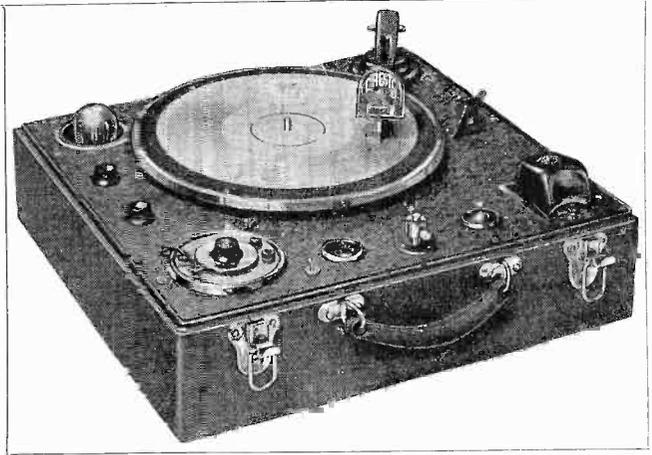
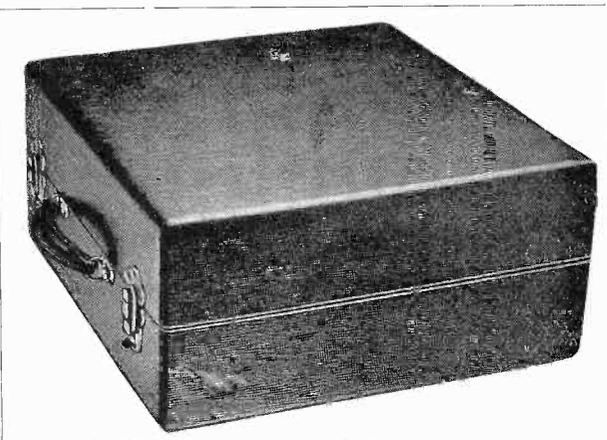


Fig. 76C. The portable recording kit, with case closed for carrying.

Notice that in Fig. 76A, above, the motion of the cutting head is not the same as the motion of the pickup shown in Fig. 76B. In the former instance, the motion of the cutting stylus is linear while in the latter case, the motion of the pick-up arm swings in an arc. This is detrimental in the higher speed records since the diameter of such records are small but only becomes appreciable when long-playing records, that is, large diameter records, are being used.



located the loudspeaker. This is of the permanent magnet dynamic type and its fidelity of response is equal to that of the electro-dynamic speaker.

The second case contains the turntable, feed screw and cutting head, and pickup. The turntable is driven by a powerful 6 volt motor which develops more than enough torque to make a 12" blank aluminum or celluloid record. Below this case, are shown the battery

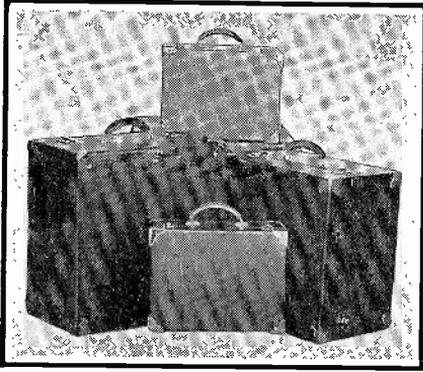


Fig. 77. Battery operated portable recording machine ready for transportation.

cases. One of these contains the batteries for the "A" and "B" supply to the amplifier, while the other contains the batteries for the turntable motor. These are of the "Hot Shot" type, and all are connected in parallel to eliminate the necessity of changing batteries often. In setting up, the amplifier is connected to its supply by means of a cable, while the motor is connected by a pair of leads to its associated batteries. The microphone and cutting head are then connected to the amplifier and the apparatus is then ready for recording. Playback is obtained by substituting the pickup for the microphone and the speaker for the cutting head.

Fig. 77, shows the unit ready for transportation. The recording unit measures 18"x18"x10" and weighs 35 lbs., while the amplifier unit measures 21"x20"x9½" and weighs 30 lbs. The battery cases each weigh 30 lbs. The microphone and stand are carried in a waterproof container. This apparatus is especially adaptable for expeditions, carnivals, circuses, in fact—for any location where no electric current is available.

CHAPTER 14

33 1/3 R. P. M. Recording

Slow speed or 33 1/3 recording entails a few more problems than 78 R. P. M. recording. This slower speed gives the record more playing time than at the higher speed. A 12" 78 R. P. M. record plays 4 1/2 minutes while the 12" 33 1/3 record plays a full ten minutes. The 16" record will play 15 minutes. This fact alone gives this type record a decided advantage. The saving in recording discs is quite a bit, and the convenience in having long programs on one disc has an appeal. The 16" disc has a distinct field of application in the recording of radio programs. More and more radio artists are having records made of themselves while they are on the air, and since the average radio program is of 15 minutes duration, it is readily seen where the 16" record has a big advantage over the 12" 78 record. As it is now, these radio records are made on 12" 78 R. P. M. records which are faded from one to the other, and a 15 minute program requires at least 3 records. On playback the continuity of the program is destroyed by the changing of records.

LOCATION OF NEEDLE IN GROOVE	VELOCITY-- INCHES/SEC.
INSIDE	16.25
MIDDLE	31.5
OUTSIDE	46.5

Fig. 78. Tangential needle velocities on 78 R. P. M. Records.

Slow speed records are also adaptable to the home movie camera in which the pioneering work is now being done. In a short time the amateur movie maker will be able to make his own home talkies.

In Fig. 78, is given the tangential velocities of 78 R. P. M. records, while in Fig. 79, is given the tangential velocities for the 33 1/3 R. P. M. records.

It is noticed that the needle speed is much lower on the slower speed record. Because of this, the recording and reproducing problems are somewhat increased. Naturally, since the speed of the needle is lower the total available

distance for recording will be shorter. It is very difficult to make good recordings on the inside of the record because of this decreased velocity. This is

LOCATION OF NEEDLE IN GROOVE	VELOCITY-- INCHES/SEC.
INSIDE	13.5
MIDDLE	20.5
OUTSIDE	27.5

Fig. 79. Tangential needle velocities on 33 1/3 R. P. M. records.

especially true in the reproducing of the high frequency modulations. We know that the lower the frequency, the greater will be the amplitude. In other words, the frequency varies inversely as the amplitude. Therefore, high frequencies record with very little amplitude, but this small amplitude represents considerable energy, and no difficulty is experienced in reproducing these modulations if the needle is very sharp. When a needle is new, it is capable of doing its best work, and therefore it is for this reason that the 33 1/3 R. P. M. records are always started from the inside. In Fig. 80, is shown where this inside groove should start. To start it at a smaller diameter would be detrimental to good quality. The proper placing of the pickup is also very important to good reproduction. Heretofore in 78 R. P. M. recording, it has been the custom to place the

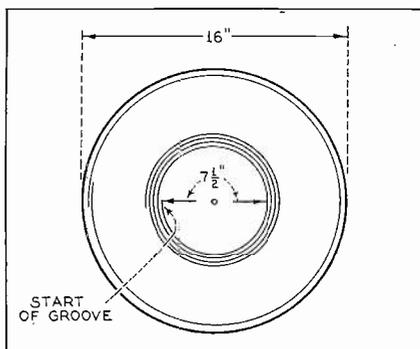


Fig. 80. Location start point on 16" 33-1/3 R. P. M. records.

P. U. so that the needle hits the exact center of the turntable. Because of the comparatively short ratio of the record, this is considered the proper placing, but in 16" records, this rule does not hold. In recording, the cutting head is guided across the face of the record in a perfectly straight line. Obviously, therefore, the proper way to reproduce such a record is to have the reproducer travel across the face of the record in a straight line. This would necessitate the use of a feed screw, which is not very practical for commercial purposes. In the placing of the 78 R. P. M. pickup so that the needle hits the center of the turntable, the straight line reproduction is very nearly obtained as is seen in Fig. 8. The arc obtained is almost equal to its chord. If we now take a 16" record

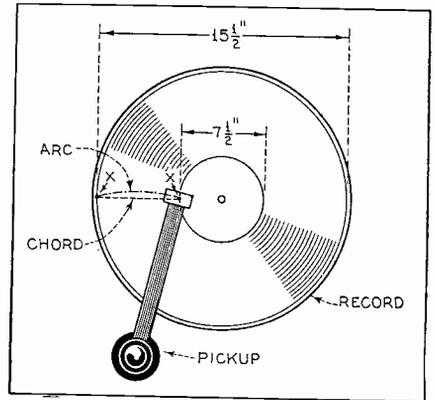


Fig. 82. Pickup location for 33 $\frac{1}{3}$ R. P. M. records.

indicates the section traversed by the P. U. The pickup is now placed so that the needle point strikes either end of x—x. Note that the arc described between points "x"—"x" is very nearly a straight line as it should be.

In 33 $\frac{1}{3}$ recording, the surface noise will be found to be more pronounced than in the higher speed.

The frequency of this scratch is in the neighborhood of 3600 cycles and for this reason is more objectionable. In commercial recording, this surface noise has been diminished considerably by improving the record material, but unfortunately in instantaneous recording, no determined effort has been made to attack this noise.

Scratch in recording is due to two things. First, the hardness of material used, and second the angle the diamond needle makes with the record. Aluminum should be of a medium hardness and should be well lubricated or waxed. If the material is too hard, the needle will rip and tear the record and terrific noise will be the result. If it is too soft, the danger of destroying the record will be increased. It is a good policy, after purchasing a ready made 16" recording disc to go over it with a piece of waste that has been soaked in wax. It is very important that the disc be spotlessly clean, and in cleaning only a piece of soft cheese cloth should be used.

In Fig. 83, is shown how a steel recording needle normally sets in the cutting head. Note the steep angle

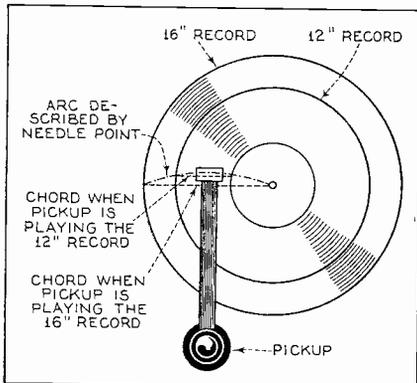


Fig. 81. Pickup location for 78 R. P. M. records.

and place the pickup in the same location, we note that from where the recording starts to the end, the arc described has a comparatively short radius, and therefore is not nearly equal to the chord. In other words, the plane of the armature is not perpendicular to the plane of the record, and as a result, fidelity of reproduction is not obtained. The pickup should be placed as shown in Fig. 82. The procedure is as follows: A blank piece of paper, 16" in diameter upon which is drawn a circle of 3 $\frac{3}{4}$ " radius to represent the inside of the groove and a circle of 7 $\frac{3}{4}$ " radius to represent the outside groove is used. A pencil line is then drawn across the paper passing through the center. A portion of this line "x"—"x"

that it makes with the record. This angle can be changed by bending the needle, but since the latter is of hardened steel bending will cause it to break. If a diamond needle is used, it should

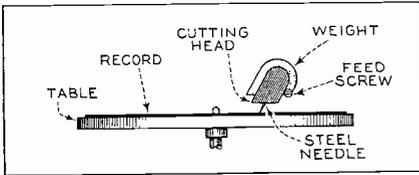


Fig. 83. Steel recording needle normally set in recording head.

be bent as much as possible as shown in Fig. 84, so that the sides barely clear the record. The shanks of diamond needles are made of soft metal, such as brass, and bending is a comparatively simple matter. Another precaution to take is to see that the point of the needle is not too sharp. If it is too sharp, then its tendency will be to cut the record instead of compressing it. Good $33\frac{1}{3}$ R. P. M. records can be made if a little care and patience are exercised, and the recordist should not be too easily discouraged if his first few trials are unsatisfactory.

As has been stated previously, the field of application for this slow speed instantaneous record is increasing by leaps and bounds, and the most interesting one is the home talkie field. Considerable work has been done on the sound on disc method, and in the very near future a machine will be marketed for use by the amateur. While, no material is available for publication on this apparatus, Fig. 85, shows a simple schematic drawing of the same. The turntable motor is connected to a gear box which has a vertical shaft to drive the turntable. From one side of the gear box a flexible shaft connects to the camera. In making the sound picture, the film is marked with a punch, and a corresponding mark is put on the record. The recording head is then placed on this mark and the section of film with the hole is placed in the aperture. The switch is then thrown and the action started after a few seconds have elapsed to allow the motor to come up to speed. In the showing of

the picture, the film is placed in the projector with the punched hole in the aperture and the pickup is placed on the start mark, then the motor is started.

The patching of the film, in case of breakage, is not as simple as it is in the case of the silent film. The sound film has a certain number of frames per foot to correspond with the sound on the disc. If these frames are decreased by removing a few, synchronism of the action with the sound is com-

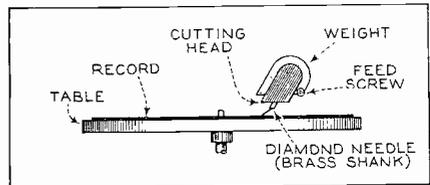


Fig. 84. Diamond needle in cutting head. Note bent shank to decrease surface noise.

pletely destroyed. Therefore, it is very important that when the film breaks, each frame that is removed, preparatory to the patching, should be replaced with a blank frame. This procedure protects against the loss of synchronism.

The question of playback needles is another serious problem in $33\frac{1}{3}$ aluminum records. The fibre or thorn needle, unless treated, wears out before the end of the record is reached. To prolong the life of these needles some manufacturers have impregnated the needles with bakelite or shellac, and it

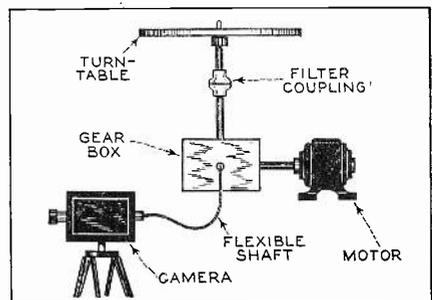


Fig. 85. Method of synchronizing camera with recording machine for the making of home movies.

is surprising how much longer the life of these needles has been prolonged. Where a fibre needle barely finished one 12" 78 R. P. M. record in good con-

dition, it is possible now to play 4 12" records without resharpening. This means that the needle will easily last through a 15 minute record.

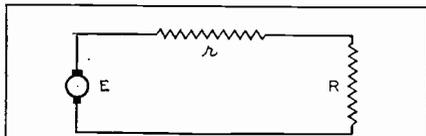
CHAPTER 15

Impedance Matching

The subject of impedance matching is very important to the home recordist, and the proper matching of these impedances cannot be stressed too strongly if the recordist expects quality records.

The recording head must match the output impedance of the amplifier, and the pickup must also be matched to the input transformer if the latter is used. If the pickup is fed directly into the grid and cathode of the first amplifier tube, then the impedance must be high. As has been pointed out before in Chapter 4, if the impedance is too high, the hum pickup becomes objectionable. If the impedance is too low, maximum power transfer is not effected.

The following discussion, while quite elementary, is illustrative of how power is transferred from a source to a load and is especially applicable to the cutting head.



- TABLE 1 -

R	R+r	I	P _{LOAD}	P _r
1	11	9.10	84	830
2	12	8.34	140	700
4	14	7.15	204	510
10	20	5.00	250	250
20	30	3.33	222	111
30	40	2.50	187.5	62.5
40	50	2.00	160	40
50	60	1.66	138	28

Fig. 86—

In Fig. 86, is shown a simple series circuit: "E" represents a source of electric energy, such as a generator or vacuum tube; "r" is the internal resistance of the generator or vacuum tube, while "R" represents a load. When the circuit is closed, current flows from the source "E" into the two re-

sistors. A certain amount of power is required to force this current through the resistors; this power is numerically equal to I^2r for the power in the resistor "r" and I^2R for the power used up in the load.

If the source had no internal resistance, all the power coming from it would be usefully employed in the load "R", but actually this is impossible. Some of the voltage "E" is used up in the internal resistance of the source whether it be a battery, a generator, or a tube, and the remainder is used in the load.

The first thing to do is to calculate by Ohm's law the current in the cir-

cuit:
$$I = \frac{E}{r+R}$$
; then calculate the power

used up in the two resistors I^2r and I^2R ; then, in order to find out how efficient the system is, calculate the ratio between the power usefully employed to the total power available.

In Table 1, data has been tabulated, using "E" equals 100 volts and "r" equals 10 ohms and "R" having different values.

Referring to the table, note that the power taken from the generator decreases as the load resistance increases, but that more and more power is used in the load, and less and less is lost in the internal resistance of the generator. When the load resistance "R" is equal to the internal resistance "r", it is noted that the greatest amount of power is taken by the load and that no further adjustment of the latter results in greater power being used in the load. At this point, half the total power taken from the source is used in the load and half in the source. As the load resistance is increased beyond this point, the power in both load and generator decreases, but the efficiency increases.

In other words, the power usefully employed in the load rises from a low value to a maximum and then de-

creases; power wasted in a generator steadily decreases. Of the total amount of power taken from the generator more and more is usefully employed as the load resistance is increased. This simply means that the efficiency of the system as a whole increases as the external or load resistance increases.

The foregoing conclusions give us two alternatives in the transfer of power. We can either concern ourselves in obtaining the maximum possible power to be taken from a source and transferred to a load; or we can concern ourselves with getting a certain amount of power transfer at the highest possible efficiency.

For example, let us take a 500-ohm line which must be fed from a power tube whose plate impedance is 2,000 ohms. It is very evident that a considerable loss in power will take place if the tube was connected directly to the line. If the tube was 500 ohms the efficiency would be 50%. The problem here is how to match the tube to the line. This problem is solved by the use of a transformer which is connected between the tube and the line and which provides maximum power transfer if it has the proper turns ratio. The ratio would have to be $\sqrt{2000 \div 500}$. Then, as far as the load is concerned, it is looking into a 500 ohm tube and, as far as the tube is concerned, it is looking into a line impedance of 2,000 ohms. If the transformer is properly designed there will be little loss in power.

In radio work the power is very small and circuits are so designed that maximum power transfer takes place. Maximum power transfer is of greater importance than maximum efficiency. From reference to Table (Fig. 86), as it has been pointed out before, it is obvious that when the resistance of the load is equal to the resistance of the tube, maximum power transfer is obtained. However, it has been determined that the maximum undistorted power is transferred from a tube to a load when the latter is equal to twice the impedance of the tube.

Let us take for example an audio amplifier which is to be used only for voltage amplification. In order to get

the greatest voltage out of a low impedance tube, it is necessary to work it into a very high resistance so that, of all the voltage available, the greatest part will appear across the load resistance. Thus, in an audio frequency amplifier, the plate circuit works into a very high impedance. In a resistance coupled amplifier, this plate load is a very high resistance, while in a transformer coupled amplifier the impedance of the primary of the transformer is very high in comparison with that of the tube.

In home recording the greatest problem is to match properly the impedance of the recording head to the output of the recording amplifier. There are two possible ways of how to connect the cutting head to the amplifier. First, it can be connected to the secondary of the output transformer and, second, it can be connected directly to the plates of the power tubes. If the cutting head is connected across the secondary transformer, then the impedance must be equal. If the cutting head is connected to the plates of the two power tubes, the impedance of the cutter must be equal to twice the combined impedance of the two tubes. For example, if 2-245's are used, the plate impedance of each is 1,900 ohms, and the impedance of the two in push-pull is 3,800 ohms. Therefore, to get maximum power transfer, the impedance of the cutter must be 7,600 ohms. Unfortunately, commercial recording heads are made with an impedance that does not exceed 5,000 ohms. The size of the wire used in winding the coils and the limited space in which they must fit are the governing factors. Therefore, it is very difficult to obtain a cutter that properly matches the plate impedance of the tubes. It is recommended that an output transformer be used at all times if quality records are desired.

A good many people make the mistake of using a low impedance head across the voice coil of the dynamic loudspeaker. This procedure is dangerous from two viewpoints. In the first place, shunting the cutter across the voice coil halves the impedance of the load if the two impedances are equal. Maximum undistorted power transfer is not possible now because the

load impedance is not equal to the line impedance. If the low impedance cutter is connected directly to the output transformer there is grave danger that there will be a bad mis-match. In low impedance units a difference of one or

two ohms, while it does not affect the operation of the unit, makes it very difficult to match this unit to a line. It is for this reason that the writer has continually favored the use of high impedance recording heads at all times.

CHAPTER 16

How To Make Duplicate Recordings

At the present writing there are two methods available to the amateur whereby he can make duplicates of his original recording.

The first one is known as "dubbing", and the word dubbing, derived from "doubling" is an old term in the phonograph field. In the days of soft wax, cylindrical records, duplicates were made by a doubling process consisting of a reproducing machine connected to several recording machines by means of pipes. This was before the days of the microphone and amplifier and the sound being reproduced mechanically from the original record was sent through the pipes and made to actuate the cutters on the several recording machines. Later, a mechanical pantograph arrangement was developed for duplication, and finally copies were made wholesale by means of the electroplating process, which is the second method available to the amateur for making duplicates. This process will be described later in detail.

In Fig. 87 is shown a typical dubbing layout. In this method another instantaneous record is made by playing the original back through an amplifier, the output of which is connected to the cutting head which cuts another record. In other words, the set up is the same as that used in making the original record except the microphone is replaced by the electric pickup, turntable and record. The amplifier used can be the same one that was used for the original record. If this is not readily available any other good quality amplifier will do. In dubbing instantaneous records, the gain required is not nearly as much as that required in making the original recording. This is due to the fact that the output of the pickup is around 1 volt whereas in the case of the microphone it was in the order of microvolts. For this reason, the level must be matched very carefully, otherwise, overloading will result. If the feed screw is made to cut 92 lines to

the inch or more this overloading may be the cause of cutting over from one groove to the next with the result that the new record will not track. In the case of pre-grooved records, these lines are only 80 lines to the inch and while double tracking may not result, difficulty may be had in keeping the recording head on the record.

It must be borne in mind that to obtain good results a good pickup is absolutely essential. This pickup can be either one of high impedance or one of 200 ohms.

Since the primary impedance of the microphone input transformer is 200 ohms, the 200 ohm pickup can be connected directly to the transformer as shown in Fig. 88. If a high impedance pickup is used the connections are made at the transformer or preferably at the base of the tube. If these connections are not easily accessible a pickup adapter may be used. These adapters are easily obtainable at any radio store at a cost of but a few cents.

In dubbing the quality of the new record is not as good as the first record. In the first place the question of scratch is to be taken into consideration. The original record had a certain amount of surface noise which is readily picked up and recorded, thus giving the dubbed record twice the amount of scratch as the original. If care is exercised in making the original and good material is used for the record, the surface noise will be very little and the quality of the new record will very nearly approach the original. Some people recommend the use of a scratch filter, but in the writer's opinion this is detrimental to good quality. The scratch frequency is in the neighborhood of 4,000 cycles and if the scratch is to be eliminated all frequencies above 4,000 cycles will have to be cut out. For records where only voice is recorded the use of a scratch filter is permissible. These scratch filters may be obtained ready made and in reality they are

nothing more than the ordinary tone controls that are so popular on many radio receivers today. The tone control is tuned to the bass section and since the high notes are cut out, the scratch disappears.

If more than several copies are to be made, the same original record must not be used. After a few "dubs", the records become too worn for good dubbing, although it will still be good for ordinary reproduction. The proper procedure is to use each dubbed record to make another, but at best too many copies cannot be made. This is quite obvious when it is realized that the scratch is additive and the level of the surface noise, after a dozen copies are made, is above the recording level.

The other method of making copies of the original record is known as processing and is the logical one to choose if a great many records are desired, but costly if only a few are needed. The procedure followed is the same as that for the commercial phonograph records, that is, a master, mother and stamper are required before the pressing can be done. The procedure is as follows: The instantaneous record is dubbed on to a soft wax disc. This wax disc is then treated in some manner to make its surface conductive, usually by dusting its surface with very fine graphite. An electrical connection is then made to this graphited surface and the soft wax is immersed in an electroplating bath. After a suitable period of time, during which the plating solution is kept in motion, with respect to the wax and the current densities are carefully controlled, there is deposited on the surface of the wax a layer of copper. Since the graphite layer on which this copper is built up is very thin and very uniform in character, the copper shell which has now been formed will fit tightly into each of the minute grooves on the wax. Fig. 89 for example, the dark portion represents the cross section of the grooves on a soft wax and therefore the cross section portion represents the copper which has been plated on this surface.

This copper layer or shell, when separated from the wax, constitutes an exact copy of the original recording except that it is negative in character,

bearing ridges where the original record bore grooves. This thin layer of copper, only a few thousandths of an inch thick, is called a matrix, or sometimes a master negative. After being reinforced by backing it up with thicker metal it may be used in the record press to make a few of the familiar black pressings or finished records. For the amateur who only wants a few copies this matrix will be as far as he need go in the processing, but if several hundred copies are required, then it would be unwise to try to get along with this one matrix, because there would be grave danger of losing the entire recording because of some accidental damage to it. Therefore, additional electroplating process must be resorted to in order to provide enough stampers for use in making finished records. The first of these steps is to electroplate the master negative to obtain one or more master positive records, sometimes known as mother records, which are in all respects similar to the finished record except that they are composed of metal instead of the familiar black compound. These metal records then become the new source from which are derived, by electroplating, as many stampers as may be required for use in producing the finished records.

The final step in the process of producing a finished record is the pressing of the black compound, using a stamper as a die. The record stock is heated on a steam table until it becomes quite soft. It is then rolled into a plastic ball and placed on the stamper, which is heated by steam in the press to much the same temperature as the steam table. The press is then closed, and by means of a hydraulic pressure of more than a ton per square inch, the record material is pressed into the minute sound grooves of the stamper. Cold water is then turned into the dies, and after a short interval, the press is opened and the record is separated from the stamper. It is then ready for immediate use if desired. This operation is repeated as many times as required to provide the desired number of copies.

One method whereby copies have been made fairly successfully is by using the original metal recording as the

wax master. The disc is treated the same as the wax by graphiting the surface and electroplating to obtain a copper negative. The process from here on is the same as described above. The only objection to this method is the shallow groove. In making the original cut the groove was compressed into the metal, no material being removed. As a result of this the groove is only about .0015" deep as compared to the .003" deep groove that is cut into the wax. Difficulty therefore might be experienced in playing back with a steel needle if the pick-up and turntable are not level. This process is not recommended if many high quality copies are desired.

In conclusion it might be stated that the amateur must not expect too much from the processed records if his original is not very good. In dubbing, as has been stated previously, there is a loss in efficiency which cannot be avoided and if the original was only fair, the new record might be poor. The original record must be very good if the copies are to be good. If this is not so, then the money spent will be wasted unless the copies are desired for

sentimental reasons. As has been repeatedly stated before, the making of very good records is not at all difficult if only care and patience are used in conjunction with good apparatus.

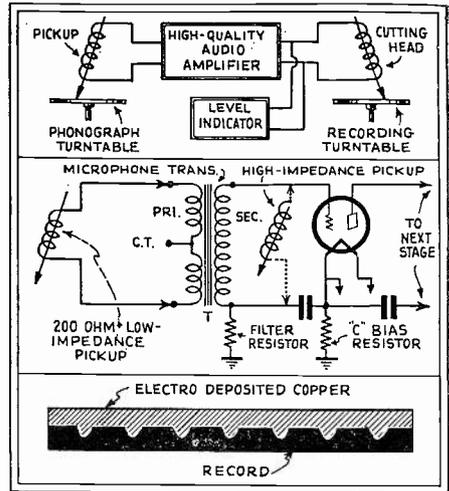
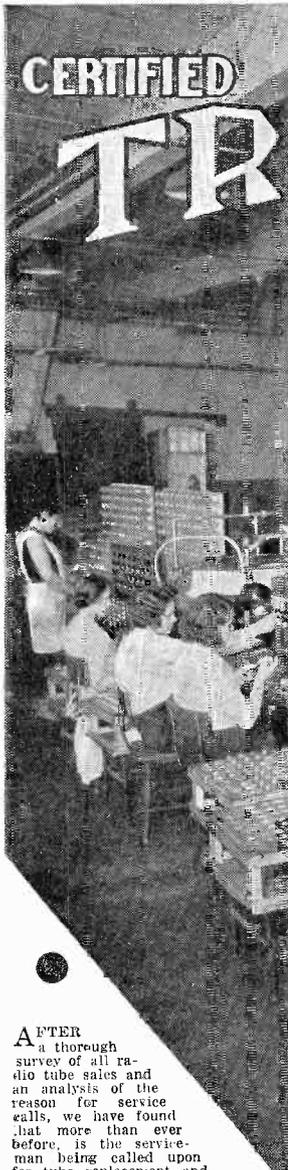


Fig. 87. A "dubbing" circuit layout.
 Fig. 88. Connections of both high- and low-impedance pickups.
 Fig. 89. Cross-section of copper and wax records.



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Plate Volts (max.) 180
5 prong Y type base

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Heater Fil. Amps. 1.75
Detector Plate Volts 45
Used as amplifier
Plate Volts ... 90-135
5 prong Y type base

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Fil. Amps. ... 1.5
Plate Volts ... 180-250
Negative Grid
Bias ... 33-50

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A. C. Volts ... 300
D. C. M/A ... 125

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T-171 Fil. Amps.5
T-171A Fil. Amps.25
Plate Volts ... 90-180

TYPE T-112A
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T-12 Fil. Amps.5
T-12A Fil. Amps.25
Plate Volts ... 90-180

TYPE T-551
T-551 is a screen grid variable mu tube designed to eliminate cross talk and distortion and reduce static to a minimum, interchangeable with T-224 in most circuits.
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Heater Current ... 1.75
Plate Volts ... 250
Screen Volts ... 90
Grid Bias Volts ... -3
Plate Current (ma.) 6.5

TYPE T-247 PENTODE
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Fil. Current ... 1.5
Screen Volts ... 250
Plate Volts ... 250
Grid Bias Volts ... -16.5
Plate Current (ma.) 32.5
Power Output ... 2.5
Watts ... 2.5

TYPE T-235
T-235 is a Variable Mu Screen Grid Tube similar to the type T-551. Type T-235 is especially adaptable to sets with automatic volume control.
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Heater Current ... 1.75
Plate Volts ... 250
Screen Volts ... 90
Grid Bias Volts ... -3
Plate Current (ma.) 7

TYPE T-201A
T-201A is a standard battery operated tube for use as detector and amplifier in any circuit.
Fil. Volts ... 5.0
Fil. Amps.25
Plate Volts ... 45-135

TYPE T-226
T-226 A. C. Amplifier for radio frequency and audio stages. Raw A. C. is used on the filament.
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Fil. Amps. ... 1.32
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Bias ... 1 to 1.5
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Fil. Current06
Plate Volts ... 90
Grid Volts ... 4.5
Plate Current (ma.) 1.8

TYPE T-231
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Fil. Current18 amp.
Plate Volts ... 135
Grid Volts ... -22.5
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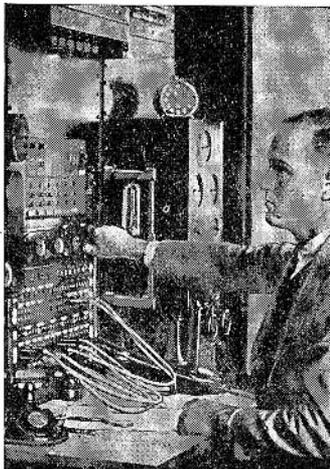
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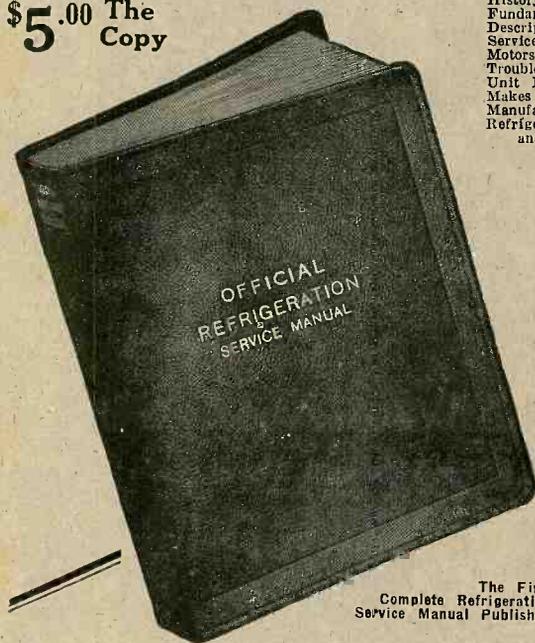
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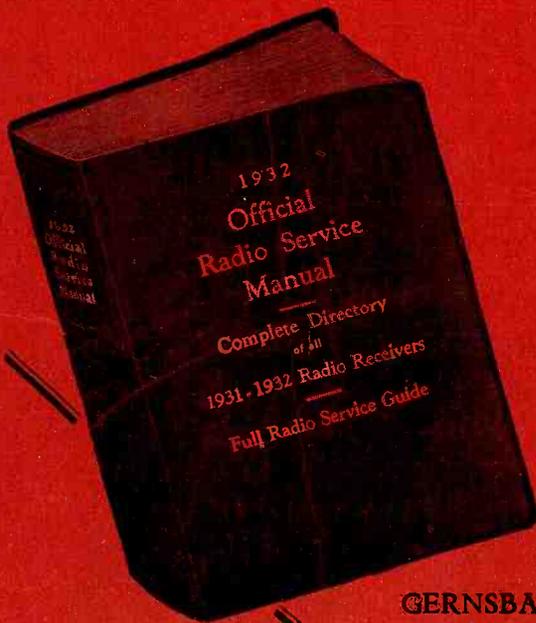
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