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LESSON
60 RA

PHONOGRAPH PICKUPS AND RECORD REPRODUCTION

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RADIO-TELEVISION TRAINING SCHOOL, INC.
5100 SOUTH VERMONT AVENUE • LOS ANGELES 37, CALIFORNIA, U. S. A.

PHONOGRAPH PICKUPS AND RECORD REPRODUCTION

Introduction

Since many radio and television sets and public address systems have phonographs in them, the radio-television serviceman should be capable of servicing these units. Information regarding the general characteristics of the phonograph pickup and the problems involved in obtaining and maintaining the best record reproduction will now be given. The principle parts or items involved in the reproduction of recorded sound waves from a flat disc record are shown in Fig. 1. They are the record, the pickup with its stylus, the tone arm and, of course, the motor for rotating the record which is lying on the turntable.

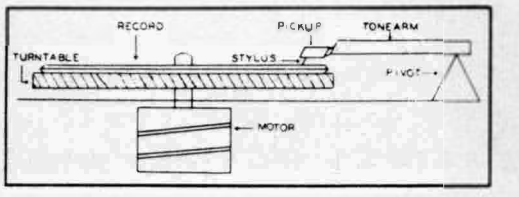


Fig. 1. Above is a sketch showing the principal parts used in phonograph record reproduction.

HISTORY

Thomas A. Edison invented the phonograph in 1877. His first model was a cylinder covered with tin foil and a needle attached to a sheet of paper as the reproducer. Since his first crude model, many outstanding changes and improvements have been made, all of which are for longer record life and better tone quality of reproduction. The wax cylinder was invented by Chichester A. Bell and Charles S. Fainter in 1885. The unit was known as the graphophone. Then in 1895 Mr. Edison made outstanding improvements on the wax cylinder design.

The flat disc was introduced by Emile Berliner in 1887. This design employed a stylus which cut a zigzag groove of a given depth around a center of a disc. This device was known as the gramophone. The stylus was attached to a mouthpiece having a diaphragm or membrane. When sound waves were projected on to the diaphragm through the mouthpiece, the latter vibrated and cut a zigzag groove in the record. This same mouthpiece or diaphragm served as the sound projector. The sound waves were weak but understandable.

PRESENT DAY PHONOGRAPHS

Progress in the design and improvements of phonographs received a tremendous boost upon the development of the electronic vacuum tube and the loudspeaker. Today it is possible to obtain very realistic reproduction and a large number of playbacks from phonograph recordings. Good quality of tone and amplitude change with a low amount of background noise are obtained.

With all of these improvements we find that there are many more technical servicing problems. One or more will affect the type of reproduction obtainable. It is for this reason very important for the serviceman to understand how the various designs operate. This will enable the serviceman to offer suggestions to customers in obtaining better quality reproduction with a minimum amount of wear.

All phonograph records have grooves in them in which a stylus (needle) glides in a spiral with respect to a common center about which a phonograph record rotates. It is the purpose of the groove and the stylus to operate a mechanical device which will in turn develop an electrical signal for the operation of a tube in an amplifier. The output of this amplifier in turn drives a loudspeaker so that the signal may be reproduced in the form of sound waves and heard at the desired intensity.

Although it seems to be a very simple task for a groove and a stylus to operate together in the production of a mechanical motion, it is another problem to develop an electrical signal voltage which is free from amplitude and frequency distortion and noise. Furthermore, it is a problem to prevent the stylus from damaging the groove. This is true regardless of the type of recording, that is, whether the groove is modulated vertically or laterally. However, the material presented in this lesson applies to lateral recordings since this is the only type sold to the public.

In Fig. 2 is shown a quarter of the top view of a phonograph record. This record has not been grooved, that is, it is the original blank. In Fig. 3 is shown the same quarter of the phonograph record, but with parallel grooves in it. These grooves are cut by a formed cutting tool which is forced into the surface of the relatively soft material of which the record blank is made. Since the cutting tool is generally held in a stationary position with respect to the circumference of the disc or record, a spiral like groove is formed by rotating the disc or record and by moving the cutting tool away or toward the center of the disc about a hundredth of an inch per revolution. This means that the next groove starts along side the first one. The entire surface of the disc or record is, therefore, cut by a single spiral groove which is continuous from the beginning to the end of the record. The length of the groove depends upon the number of grooves per inch and the diameter of the disc. They vary in length from a few hundred feet to about 2,000 feet per record.

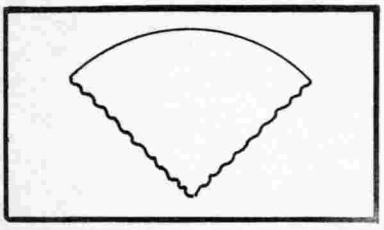


Fig. 2. Here is shown a section of the top view of a record blank without a groove cut into it.

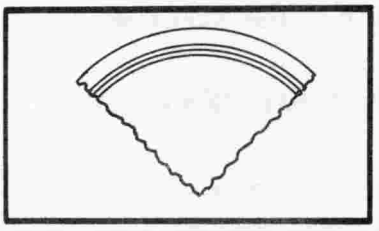


Fig. 3. This drawing shows a section of a record with several unmodulated parallel grooves cut into it.

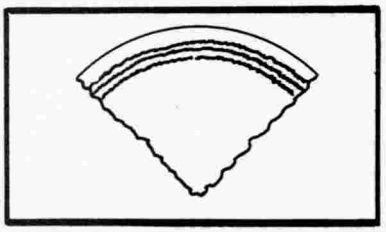


Fig. 4. Here the grooves are modulated with a mixture of sound frequencies.

Before discussing the shapes of the grooves in the grooved record, let us examine the appearance of the record which has a groove in it that is modulated by sound frequencies as shown in Fig. 4. Note in particular that each groove is, in general, in parallel with the previous one, and that the grooves never cross each other even during the greatest modulation. When a ball-tipped stylus is held within the continuous spiral

groove on the face of a record, the stylus will be slowly drawn across the disc as the record is rotated. Then if the stylus holder is mounted on an arm called the tone arm, the arm will swing across the record under the action of the screw-like spiral in the record. The stylus, therefore, is in contact with the entire length of the groove on the record.

A cross section of two grooves within the standard record is shown in Fig. 5. Note that the bottom of each groove is rounded and that the sides of the grooves are curved, that is, not straight, and that there is a separation between the two adjacent sides of the grooves cut in the record. The grooves in a microgroove recording are shown in Fig. 6. Here the bottom of the groove is very pointed, the cutting tool being at a 90 degree angle and considerably smaller in size than the groove for the standard recording. It, therefore becomes obvious that the tip of the stylus must be made to fit the groove in the record being played. Fig. 7 shows the tip of the microgroove and the standard styli as used in playing the records cut by the cutting tool in Fig. 5 and 6.

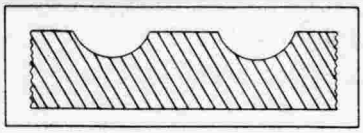


Fig. 5. This is a view of two adjacent grooves cut by the stylus in a standard record.

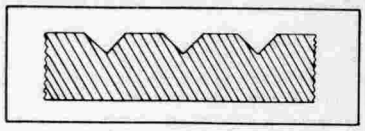


Fig. 6. The cutting stylus for a microgroove recording cuts this type of groove in the record.

The importance of having a stylus of the proper dimensions is illustrated in Fig. 8. The stylus at the left is entirely too small for the groove in which it is sliding, while the stylus at the center is too large, and the one at the right is properly seated in the groove. In general, the stylus must be firmly held by the groove on both sides or we will experience distortion, sometimes referred to as "rattling." Fig. 9 shows the relative difference between the microgroove and standard styli fitting into a groove of a standard record. The playback stylus should always be the smallest size which will not produce rattling. This is the condition which gives the best frequency response and the lowest surface noise, and naturally the least distortion.

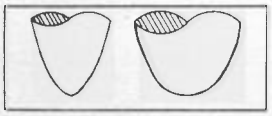


Fig. 7. The shapes of the tips for the playback stylus for the microgroove and standard recordings are shown here.

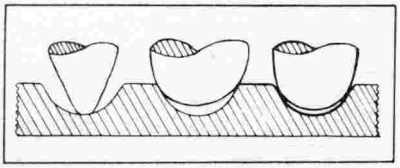


Fig. 8. The stylus shown at the right is properly seated in the groove of the record.

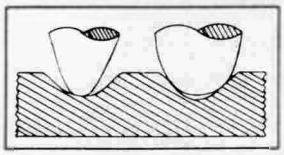


Fig. 9. The microgroove stylus is shown seated in the standard record groove at the left end and at the right is the proper stylus seated in a standard groove.

Record makers are giving careful consideration to the shape of the groove in the recording. It is for this reason that considerable care must be exercised in the selection of the proper playback stylus. It can be said that the older records employ the larger stylus which has a diameter at the tip of about 3 mils (.0030 inches). The microgroove record, like the Columbia LP (long playing) and the Victor 45 (45 R.P.M.), require playback styli having a tip diameter of about 1 mil (.0010 inches). Then many of the 16 inch transcriptions (33 1/3 R.P.M.), as used in broadcasting stations, employ a stylus

with a tip diameter of about 2 mils (.0020 inches). The instantaneous lacquer discs employ playback styli having a tip diameter between 2 and 2 1/2 mils. These lacquer discs generally have a paper base and are almost unbreakable.

The shape of the tip of the playback stylus must be maintained in order to obtain a good quality without damage to the recording. It is a well known fact that a worn playback stylus will not slide smoothly in a groove and will tend to cut off the sharp corners with its worn edges and cause excessive wear on the groove. A badly worn playback stylus, or a smaller tip on the stylus than that which is required by the groove will cause high frequency response to be cut off as the higher frequencies will be quickly worn off the groove, thereby lowering the quality of reproduction. A worn stylus generally does not affect the low frequency response. A high quality recording can only be capable of delivering the material recorded in the groove when the stylus slides properly in the groove, and of course, when all other factors affecting quality are met.

STYLI MATERIALS

All of the various playback styli are made of hard materials in comparison with the material used in the record. In general, there are five different types of playback styli and they may be listed as the steel, chromium, osmium, sapphire and diamond. The number of playbacks which may be obtained from each of the various materials vary at the rate of about 5 for steel, 50 for chromium, 250 for the osmium, 5,000 for the sapphire and over 25,000 for the diamond, the number of playbacks being dependent upon the weight of the pickup. This definitely indicates that the jewel stylus materials are ideal for high quality reproduction, although they have the disadvantage of being somewhat more brittle and may be broken by shock. This may occur by accidently dropping the pickup on the rim or edge of the turntable.

As a technician, you should know about these and the other different types of styli in phonograph pickups and their general characteristics so that you may advise your customers and also insert the type of stylus which will give the performance desired by a customer. There are many other different types of phonograph styli. In addition to those already mentioned, there are bamboo, cactus, thorn, nylon and the plastic types. Then there are the combination plastic and sapphire and metal alloy types.

STEEL STYLI

The steel styli usually give the greatest volume and the fullest tone. This means that good high frequency response and volume may be received. Good high frequency response usually results in higher noise, scratch and hiss level. Steel styli, however, wear rapidly and, therefore, should not be used to play more than a few records in order to prevent the depositing of material in the grooves and the damaging of the records themselves. Steel styli are, therefore, not recommended for automatic record changers. They are used exclusively by the operators of many broadcasting stations and on many of the old phonograph pickups weighing more than several ounces.

CHROME POINT STYLI

By plating the tip of a steel stylus with chrome, it is possible to increase the life of the stylus without loss of tone or volume characteristics. This stylus may be used for the purpose of playing from 25 to 50 plays, depending upon the stylus pressure or the weight of the pickup. The additional plating of the chrome on the point of the stylus hardens the point and, therefore, gives the additional performance. Fig. 10 shows the chrome tipped stylus. Note in particular that the stylus is round at the end and not sharp. The rounded tip is the desired shape for the end of a stylus.

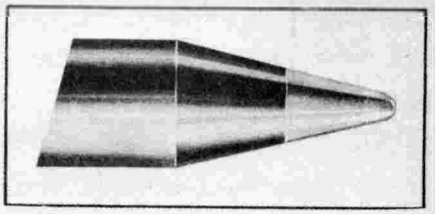


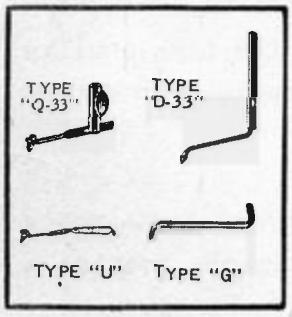
Fig. 10. This view shows a chrome tipped steel stylus.

NATURAL STYLI

Natural styli such as bamboo, cactus, and thorn all have about the same general characteristics and primarily reduce high frequency response and noise as well as record wear. With the loss of performance we also observe distortion and low quality. These styli are not suitable for record changers as they have relatively short life and often become broken. These styli can only be used on recordings designed for 3 mil playback styli.

METAL ALLOY AND SAPPHIRE TIPPED STYLI

In Fig. 11 are shown a number of tip-radius styli. These styli are designed for one mil recordings. These styli have unique characteristics in that the type Q-33 and type D-33 employ special metal such as osmium and sapphire tips. These styli reduce surface noise and stylus talk and are especially designed for phonograph pickups made by the Astatic Corporation. These metal alloy tips come in many shapes and sizes and may be used for 1,000 to 5,000 playbacks without change. These tips, when properly alloyed and polished to a high degree, increase record life. After they are installed, they should be left in the pickup and be undisturbed as the point wears to fit the record groove and the changing may result in severe record damage. These metal alloy tips are recommended for record changers. Sapphire styli have a correspondingly longer life and are more expensive. They are harder, hence extra precautions must be taken against dropping and changing the position of the stylus. The sapphire type of stylus is especially recommended for automatic record changers.



Courtesy
The Astatic Corp.

Fig.11. One mil tip-radius stylus.

STYLUS REPLACEMENT

It is a well-known fact that the term permanent point or stylus is improperly employed. In other words, there is no permanent stylus. Continuous playing causes the stylus to change its original shape. It is, therefore, of utmost importance to always

consider the condition ofastylus when servicing a phonograph pickup giving improper results.

STYLUS TIP RADII AND THEIR APPLICATIONS

A careful study of the type of performance received from stylus tips of various radii have been made by the engineers of the Clarkstan Corporation of Los Angeles, California, U.S.A. In general, the following findings apply to stylus tips of various radii. Note the comments made about each of the different stylus tips. You may wish to refer to this information when you encounter a difficult service problem involving stylus tips.

.0030 inches radius (orange-black) standard. These are for use with nearly all shellac pressings (standard phonograph records) andvinylite pressings made from the same record stampers in the plants of record manufacturers. The popular recordings use tips of this radius.

.0025 inches radius (red-green). For vinylite transcriptions (commercial recordings) this tip radius gives the best results. Whenever it is necessary to play both shellac and vinylite transcriptions with the same stylus, this particular radius is recommended. The National Association of Broadcasters have specified a tip radius of .002 inches for transcription reproduction.

.0022 inch radius (red-red). A tip radius of this dimension has also proven to be satisfactory for general transcription reproduction as well as many acetate recordings.

.0020 inch radius (red-black). Atip radius of this dimension may be used with some of the finest grooved transcriptions and acetate recordings.

.0015 inch radius (brown-green). Many of the very high quality vinylite transcriptions take this size radius satisfactorily without rattling. Many of the high quality foreign records which are imported into this country require this tip radius for satisfactory reproduction.

.0010 inch radius (brown-black). Many manufacturers of long-playing, fine-groove records such as the Columbia's LP microgroove and the RCA Victor 45 records require a stylus tip of this radius.

.0040 inch radius (yellow-black). The Clarkstan Corporation engineers have found that a special stylus for use with old type records having a high surface noise is helpful. The undue surface noise comes from several sources. The most important source of noise is that caused by the particular grain size of the materials in the record and the manner in which it wears. Since the average grain of the material in the record is shorter than the more important frequencies of the desired signal, the larger radius stylus will favor the signal over the noise level. This special diameter tip can be obtained on special order from this manufacturer.

THE RMA STYLI TIP RADII COLOR CODE

Since it is difficult for the individual to measure the tip radius of styli, the Radio Manufacturers Association have adopted a color code which applies to stylus radius identification. The significant figures are the third and fourth to the right of the decimal point. For example, a tip radius of .0030 inch will be colored orange-black. A tip radius of .0025 inch will be colored red-green. The last color being furthest away from the tip end of the stylus.

0-black	3-orange	6-blue	9-white
1-brown	4-yellow	7-violet	
2-red	5-green	8-gray	

STYLUS TALK

The owners of phonographs may complain about stylus talk which is the noise that is heard by the vibration of the stylus in its holder, referred to as the phonograph pickup. This noise is often annoying on a phonograph where there is no cover over the turntable. This noise can be kept at a minimum by using a light weight phonograph pickup and also by placing a circular sheet of felt about 1/16 inch thick on the turntable before placing the record on the table. This tends to prevent the record itself from vibrating like a sounding board near the area where the stylus is sliding in the groove. It is also possible to glue a strip of felt around the upper or lower edge of the cover of the phonograph turntable cabinet.

PHONOGRAPH RECORDS

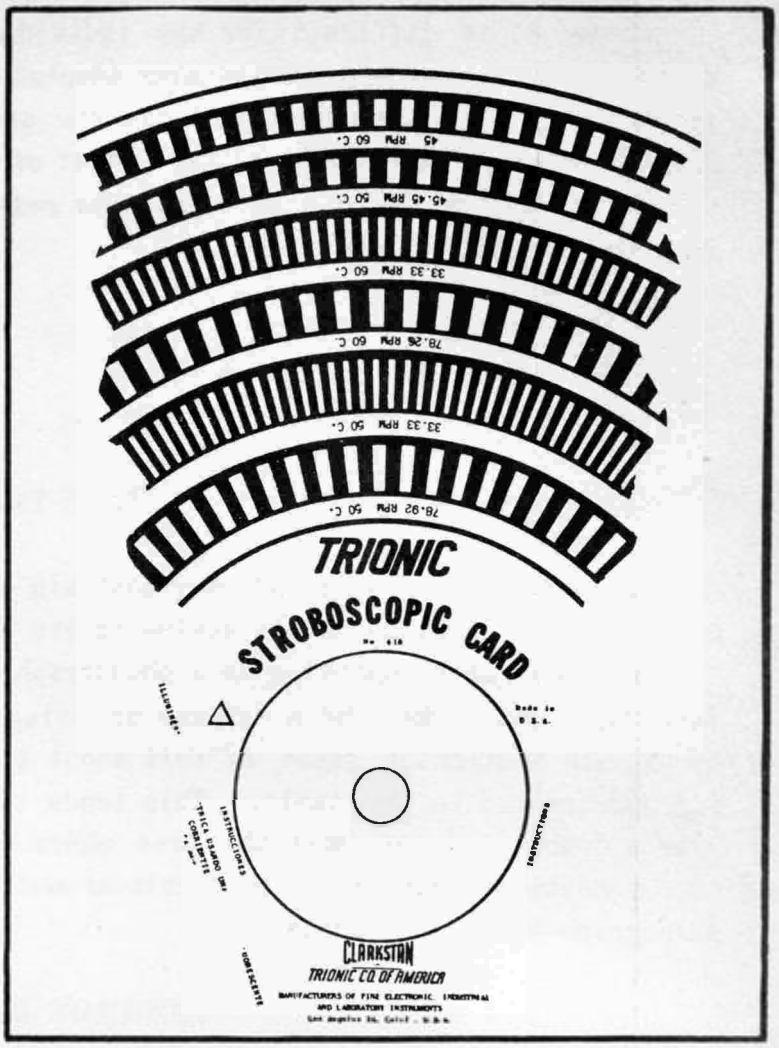
Phonograph records, as used by the public, are all flat circular discs, varying in thickness from 1/32 to 3/16 of an inch and in diameter from 6 to 16 inches, the diameter usually being 6, 8, 10, 12 and 16 inches.

The center holes are usually fit over posts about 5/16 inch or 1 1/2 inches in diameter. The regular, standard or popular records are usually made out of a black composition material held together by shellac, while the long playing records are made of a high grade vinylite (rubber-like) material. Home recording machines use record blanks having an aluminum base covered with a thin layer of acetate (film). Lacquer covered paper discs are also available to the public for home recording purposes.

RECORD ROTATION SPEED

The revolving speeds of phonograph records are limited to three. They are 33 1/3, 45 and 78 revolutions per minute. The revolving speed of a phonograph record must be held within close limits for best quality of reproduction. The speed at which a turntable is rotating can be checked by using a stroboscopic card similar to the one shown in Fig. 12. Only a section of the entire circular card is shown here. These cards pro-

vide a remarkably accurate check on the revolving speed of the phonograph turntable. The card is placed directly over the center post of the turntable. With the aid of the glow or light received from an electric lamp it is possible to see the black and white segments stand still. For example, the turntable will be revolving at 45 r.p.m. when the outer segments of the disc appear stationary when viewing the disc with light received from a lamp connected to a 60 cycle per second power line. You may obtain these cards from the Clarkstan Corporation, Los Angeles, California, U.S.A. at a very reasonable price and serve a very useful purpose.



(Courtesy, Clarkstan Corp.)

Fig. 12. A section of a Stroboscopic Card is shown here for use in checking turntable speeds of 33 1/3, 45 and 78 r.p.m. with either 50 or 60 cycle power line frequencies.

CARE OF PHONOGRAPH RECORDS

A perfectly good new phonograph record can be and may be ruined in one playing by a broken or chipped stylus. The continual use of a damaged phonograph stylus will destroy or ruin a good record. Customers should be advised that needles (styli) wear out, and that worn out styli can damage new records with only a few playings. If an unusual amount of distortion or noise is heard upon the playing of a record, the phonograph should be stopped immediately and the record examined for wear. The presence of a large amount of loose record material on the record and stylus definitely means a damaged stylus. A long playing stylus, whether it be metal or sapphire, may have suddenly become damaged by an accidental drop. To continue the use of such a stylus will ruin many records. The following points should be observed in maintaining phonograph records in good condition.

1. Keep records away from heat, as this will warp them and shorten the life of the record when played.
2. Keep all records in their envelopes and albums, preferably laid flat to prevent warping.
3. Use good styli and replace them when they become worn.
4. Use a hair brush and brush the dust from the grooves of a recording in order to avoid grinding the dust and lint into the grooves.
5. Do not leave records on the posts or on conventional stackup type of record chang-

ers as this causesthemto warp. The heat within the changer compartment may cause excessive warping.

PHONOGRAPH PICKUPS

The mechanical energy transferred from the record groove to the stylus is converted into an electrical signal voltage by the phonograph pickup. The efficiency of the pick-up at the various sound wave frequencies indicates the relative performance of the device. In other words, the higher the signal voltage and the more uniform this voltage remains without waveform and amplitude distortion over a given frequency range, the better the performance of the phonograph pickup. The designers of the phonograph pickups take into consideration all of the performance characteristics for the cost involved in making the device. It is for this and other reasons that we hear a great variation in the tonal quality received from various phonographs. When we know the general theory and practice involved in the construction and operation of the various types of phonograph pickups, we can do a better job in repairing and maintaining the equipment in which these devices are used.

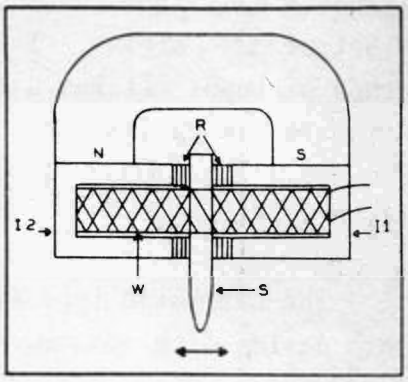


Fig. 13. Drawing showing the principal parts of an electromagnetic phonograph pickup.

There are different methods used in converting mechanical energy to an electrical signal. In general, they are known as the magnetic, crystal, ceramic and photoelectric. Each is named after the methods envolved in producing the signal voltage.

THE ELECTROMAGNETIC PHONOGRAPH PICKUP

In the electromagnetic phonograph pickup, the stylus, either in itself or in conjunction with an armature, causes a change in the number of magnetic lines of force being cut by a coil of wire. This type of p phonograph pickup functions just like an alternating current generator. It has three basic parts and they are; a permanent magnet, a field winding and an armature. The typical horseshoe type of permanent magnet is shown in Fig. 13. The iron pole piece I1 is especially fitted and mounted to the end of the south pole of the horseshoe magnet. When the entire assembly is held at right angles to the groove in a record, the stylus movement will be indicated by the double headed arrow - the "direction of stylus motion." This movement causes the armature to change the lines of force passing between the upper and lower ends of the pole pieces I1 and I2.

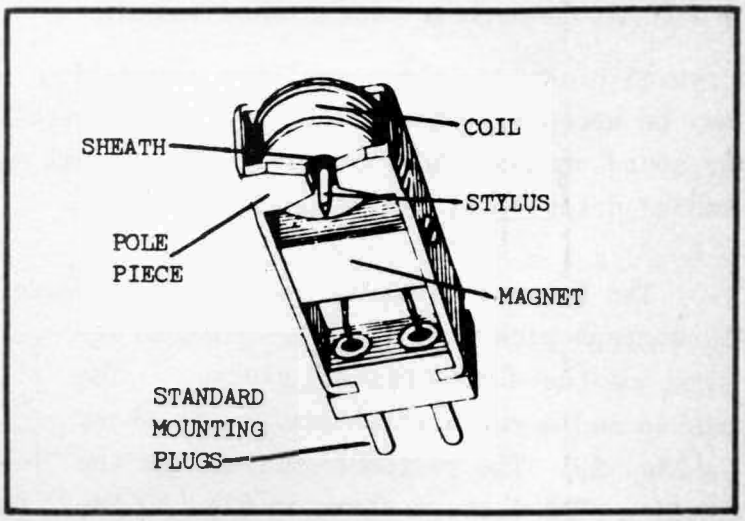


Fig. 14. The principal parts of the Clarkstan Corp.magnetic type R.V. pickup are shown here.

There are various ways of causing the stylus to cut the required number of lines of force and it is the unique design features that gives one manufacturer of electromagnetic pickups an advantage over the other, as small changes in design can cause a large difference in performance. The various components forming the Clarkstan type RV phonograph pickup are shown in Fig. 14. Note in particular that a rectangular permanent bar magnet is used to provide the necessary lines of force conveyed by the special shaped iron pole piece. In this design the stylus is held by a sheath away from the ends of the two pole pieces to the left and right of the stylus. This design offers an entirely new approach in magnetic phonograph pickups. It has a removable stylus as shown in Fig. 15. The stylus, which is the armature can be inserted and removed without the aid of tools as shown at the left in Fig. 16. Then after insertion, the stylus is seated with the thumbnail as shown at the right in Fig. 16.

(Courtesy Clarkstan Corp.)

Fig. 15. The stylus for Clarkstan RV pickup is shown here.

The Clarkstan type RV phonograph pickup is a high fidelity and nearly a distortionless device with extreme simplicity and ruggedness. The frequency response curve for this device is shown in Fig. 17. Note that there is less than a 2 decibel overall variation from about 25 to 20,000 cycles per second. This pickup may require a simple R or RC network, that is, a single resistor or a resistor and capacitor connected in parallel for high frequency attentuation. The relative change in frequency response is shown in Fig. 18. This pickup has such excellent fidelity that it can be used in broadcast studios for AM and FM stations. It has somewhat lower signal output voltage than the more popular types of ceramic and crystal pickups. A pre-amplifer consisting of a single stage pentode amplifier tube may be necessary when using this pickup with low gain power amplifiers in public address or sound systems in factories. The signal output is lower than that obtained from the second detector of most superheterodynes.

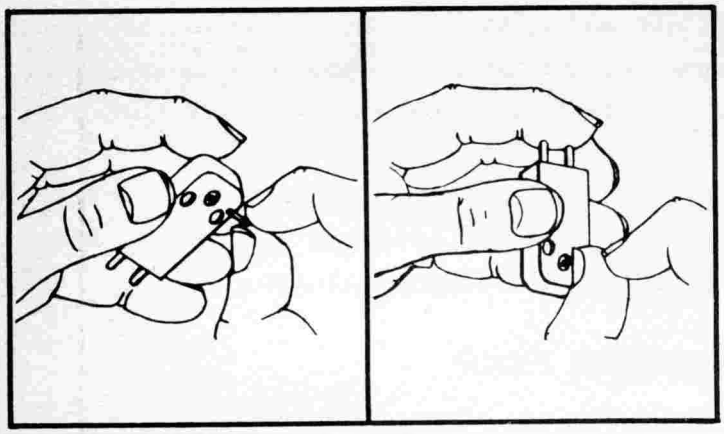


Fig. 16. It is easy to change the stylus in the Clarkstan Corp. type RV pickup cartridge. At the left the stylus armature may be inserted or removed without the aid of tools. At the right the stylus is seated with the thumbnail.

The General Electric Company of Syracuse, New York, U.S.A. bas developed a magnetic phonograph pickup of the same general design as the Clarkstan RV pickup. The pickup and a replaceable stylus are shown in Fig. 19. The customer can change the stylus. The 4 steps shown in Fig. 20 indicate the operations involved. The long playing records require the 1 mil stylus, while the standard or conventional records require the 3 mil stylus.

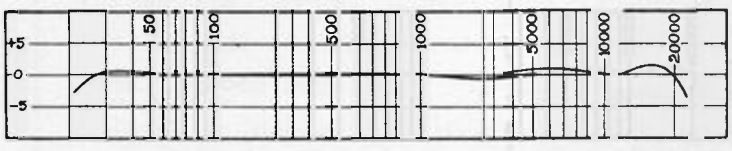


Fig. 17. Frequency response curve for the Clarkstan Corp. type RV electromagnetic pickup is within a 2 decibel change between 30 and 20,000 C.P.S.

These Clarkstan and General Electric phonograph pickups are technically known as variable reluctance types. These pickups are not affected by changes in humidity and temperature.

THE CRYSTAL PHONOGRAPH PICKUP

The piezoelectric effect is one means of obtaining signal voltage from a mechanical force. This piezoelectric effect is a characteristic of several kinds of crystals. In brief, a crystal may be said to have three axis, namely electrical, mechanical and optical or X, Y and Z respectively. In radio we do not concern ourselves with the Z or optical axis. With piezoelectric crystals, when an electrical stress is applied to the X axis, a mechanical stress is produced at the Y axis, and conversely, when the Y axis is subjected to a mechanical stress, an electrical stress or e.m.f. is produced at the X axis. The latter is the principle used when employing crystals as phonograph pickups. This use of crystals as a phonograph pickup is only one of many uses of crystals in the field of radio and electronics.

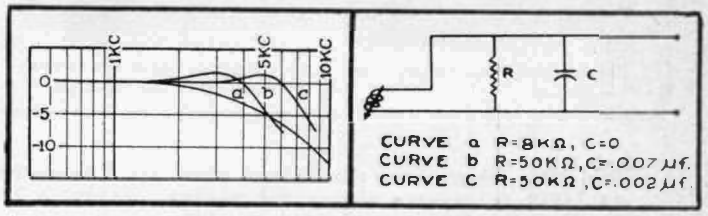
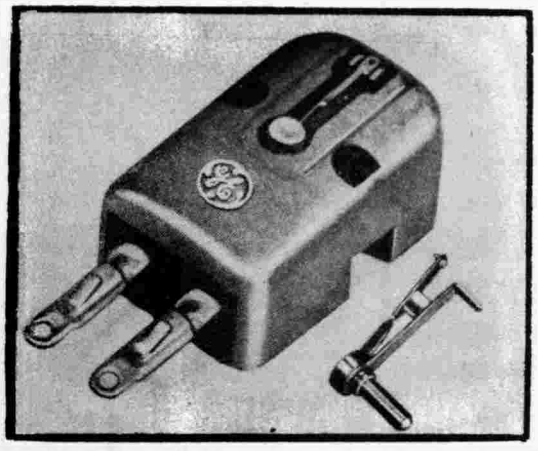


Fig. 18. Simple R and RC networks to produce various frequency response curves.

Crystal phonograph pickups employ bimorph Rochelle salt crystals. The basic crystal element consists of two slabs cut from a Rochelle salt block in such a manner that they, when assembled in a pickup case, respond to a torsional stress action. In Fig. 21 is shown the five basic items composing a crystal element within the cartridge. These are shown as items A, B, C, D and E. The items A, C and E are sheets of foil between which are placed the two crystal slabs B and D as shown in the drawing F. Here it can be seen that the item C is the inner foil between the two crystals, while the items A and E are connected together to make up the outer foil electrode.



(Courtesy, General Electric Company)

Fig. 19. The General Electric Company's variable reluctance phonograph pickup cartridge with replaceable stylus shown here.

When the two slabs of the crystal are assembled with the three foil electrodes as indicated, the assembly is capable of generating a potential between the inner and outer foils when subjected to a torsional stress. Polarity is marked at the terminals only to better show the assembly of the element. Actually, the polarity of the signal voltage developed is dependent upon the direction of the mechanical stress.

Fig. 22 indicates the cross-section view of the conventional-type crystal pickup. In this pickup the lateral motion of the stylus is transmitted to the crystal through a stylus chuck as a torsional or twisting motion. The crystal in itself is very brittle

and torsionally stiff. For this reason a special coupling arrangement is required and this is indicated by the use of an elastic rubber block or coupling between the chuck

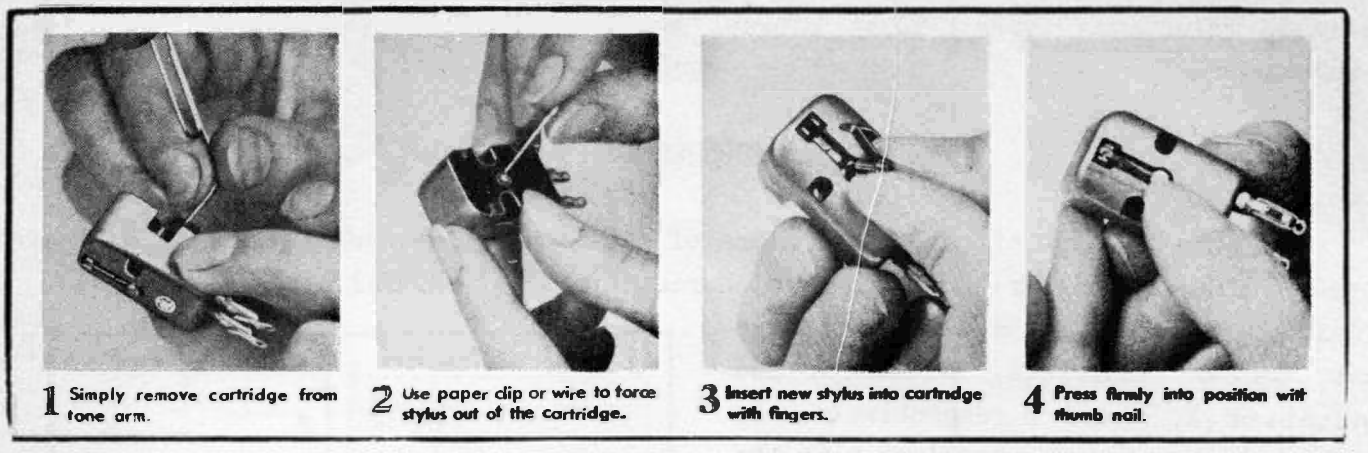


Fig. 20. These four operations show how the customer can change the stylus in the General Electric variable reluctance phonograph pickup. Either a 1 mil stylus for microgroove records or a 3 mil stylus for standard records may be used.

and the crystal assembly. This also explains why firm rubber blocks are employed in holding the crystal element in position. The view shown in Fig. 22 is from one side of the crystal pickup. This, therefore, means that the tip of the stylus will move to you and away from you in the playing of laterally recorded records. Through the coupling at the left end of the crystal is conveyed the torsional motion which places a stress on the two crystal plates which are held firmly together by the firm rubber blocks. The motion of the stylus causes pressure to be applied to the crystal and consequently an output voltage is developed in proportion to the pressure at the leads or terminals, as indicated at the right in Fig. 22.

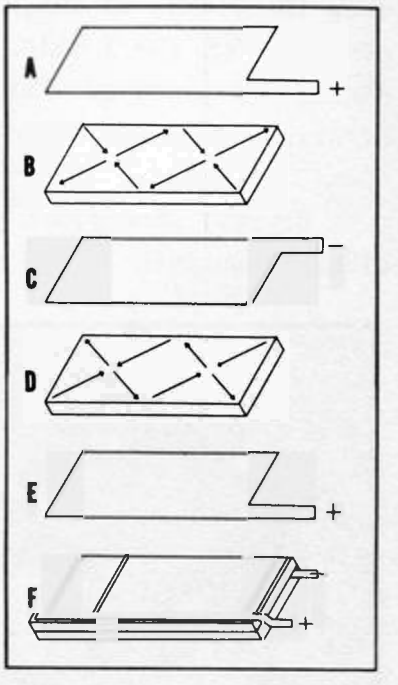


Fig. 21. Here are the items of a crystal element and also how it is assembled.

There are many unique designs in obtaining the conversion from mechanical energy to electrical energy, and the one described in Fig. 22 merely presents the basic idea. The structual details of another type of crystal pickup cartridge is shown in Fig. 23. The assembled cartridge is shown in Fig. 24. This crystal pickup cartridge is manufactured by the Shure Brothers located in Chicago, Illinois, U.S.A.

Phonograph pickups employing crystal cartridges using Rochelle salt crystal elements function best at temperatures between 70 and 80 degrees F. The relative humidity should be approximately 50 %. They act very much like human bodies in that wherever humans can work and live comfortably, the crystal element will function normally and have a long life.

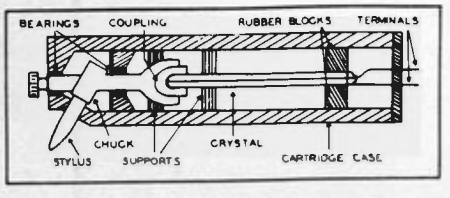
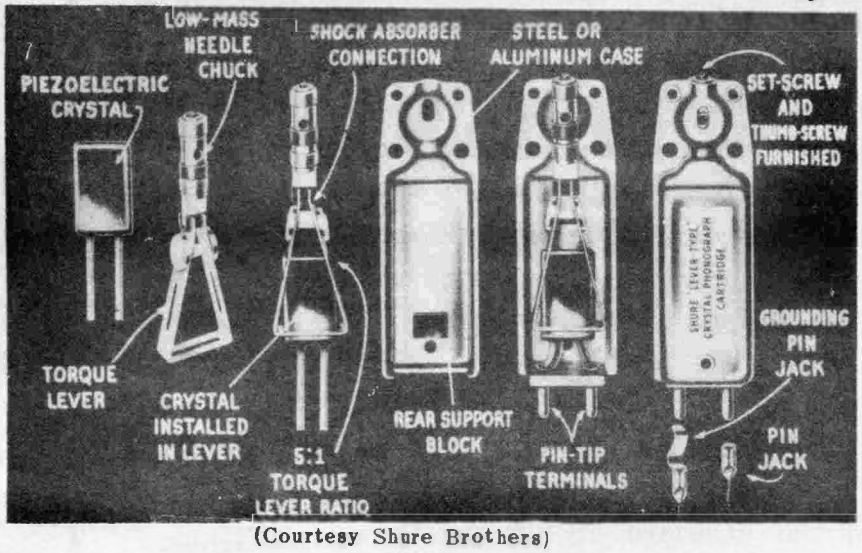


Fig. 22. Cross-sectional side view of a crystal phonograph pickup cartridge.

The effects of tropical climates on crystal cartridges and pickups must be taken into consideration by the serviceman. The effects of

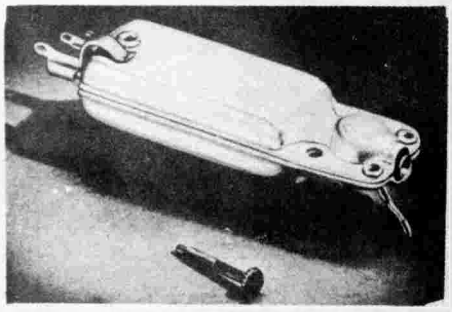
high temperature, high relative humidity and the growth of fungus all shorten the useful life of crystal pickups. In the tropics where very high temperatures are encountered together with high relative humidity, and especially during long daylight hours where the temperature is high and where the temperature is relatively low at night, these highly hydroscopic crystals tend to absorb additional moisture which lowers their internal resistance. This causes a loss in output and a change in frequency response. The loss of low frequency response is most apparent.



(Courtesy Shure Brothers)

Fig. 23. Structural details of a new lever type crystal pickup cartridge.

Whenever encountering crystal pickups which do not operate properly for the reasons given above, the crystal pickups should be removed and treated. In many instances it is possible to burn a light bulb of about 40 watt capacity inside the cabinet of the phonograph. This tends to maintain a fairly high but even temperature. This high temperature drys out a certain amount of the moisture from the atmosphere about the pickup, and in several days it will operate satisfactorily. Care should be taken to prevent the heat generated by this lamp from overheating the crystal. The temperature should not exceed 110 degrees Fahrenheit. The melting point of crystal elements is slightly above 120 degrees. Above this temperature the crystal element will become permanently damaged and the cartridge must be replaced.



(Courtesy Shure Brothers)

Fig. 24. The assembled crystal pickup cartridge is shown here.

The operators of radio-television service stores located in the tropics often find that when they have a stock of crystal pickups on hand which have been subjected to high temperatures, high relative humidity, and a great variation in temperature there is a need for the proper treatment of crystal pickups at regular intervals. This can generally be done by placing all of the crystal cartridges within a small cabinet and having a small opening near the top. The use of an electric lamp which will hold the temperature at least 10 degrees above the average temperature throughout the day, but not allowing the maximum temperature within the case to exceed 110 degrees, proves to be entirely satisfactory.

Some of the manufacturers of crystal cartridges provide unique containers in which they ship their cartridges to dealers. In Fig. 25 the crystal cartridge is held within a bottle having a tight fitting cover. This procedure is used by the Webster Electric Company located at Racine, Wisconsin, U.S.A.

RETRACTABLE STYLUS

Due to the fact that it is possible to damage the stylus of a phonograph pickup, we find the retractable feature is employed. The top view, the playing position and the retracted position for the Model Q1 Webster Electric crystal pickup cartridge is shown in Fig. 26. The top view of this figure gives the relative size of the crystal pickup cartridge within the pickup end of the tone arm. The net weight of the stylus on the groove of the record is 22 grams. When the pressure exceeds 2.5 ounces, the stylus leaves the record as shown in the retracted position, and the weight rests on the ball as shown.

(Courtesy)
Webster Electric Co.

Fig. 25. A crystal cartridge in moisture-proof container.

DOUBLE-STYLUS CARTRIDGES

To accomodate the playing of the standard 78 RPM and the 45 RPM long playing records, the Webster Electric Company developed the double-stylus cartridge. Their type F15 is shown in Fig. 27. This cartridge employs two separate styli to permit playing both the fine cut and standard records in conjunction with a single tone arm. Provision is made in the mounting to rotate the cartridge 180 degrees in the tone arm, thus bringing the proper stylus into position for the particular type of record being played.

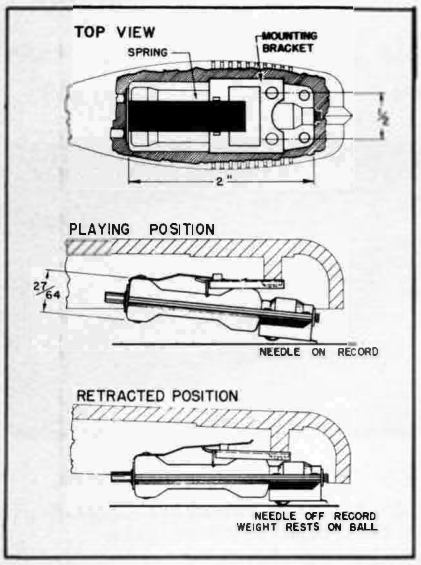


Fig. 26. Webster Electric Company crystal pickup cartridge with retractable feature. Model Q1.

FREQUENCY RESPONSE CURVES

Typical frequency response curves for crystal type pickups can be seen in Fig. 28. Note that the frequency response characteristics vary with the type of recording being played. The average output voltage is about 1 volt. When taking into consideration the response characteristics chart, it is important to maintain a load of approximately 500,000 ohms in the output of the crystal pickup. The capacity of the shielded line from the terminals of the crystal to the amplifier to which it is connected should be as specified by manufacturer or approximately 100 mmfd. This is about the capacitance in one foot of shielded cable.

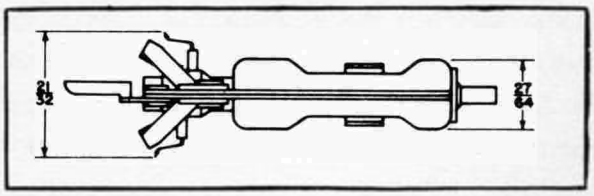


Fig. 27. Drawing of a double-styli crystal cartridge for playing fine and standard recordings. Webster Electric Company, Model F15.

Although the crystal type of phonograph pickup is inexpensive, it does have limitations in performance characteristics. Rather low high-frequency output voltage is obtained and poor performance is obtained in areas where there is a great variation in temperature and relative humidity. These pickups do, however, work satisfactorily under normal living conditions.

The ceramic type pickup is the newest development of the three types of pickups mentioned. It was found through experimentation with ceramic materials that some such materials could be given piezoelectric properties and that such properties would be maintained. In choosing a material for this use, sensitivity, freedom from temperature variation, and ease of handling were the main factors. Barium titanate was found to have the

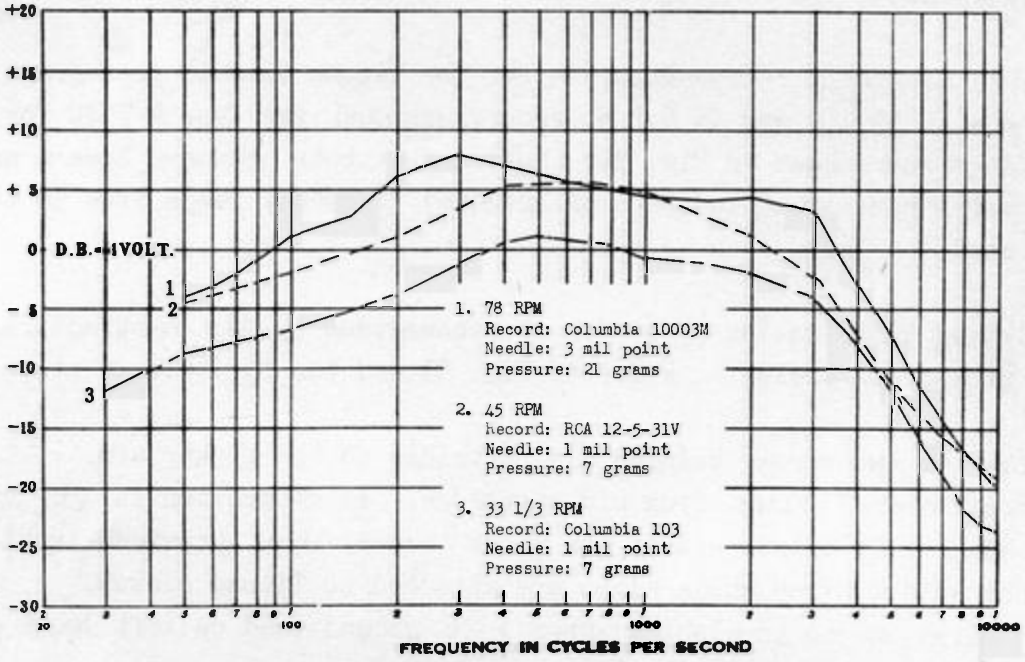


Fig. 28. Frequency response curves received from the Webster Electric Company, Model F15 crystal cartridge using three different test records.

best combination of these properties so it is used in its ceramic form. The ceramic material is cut into short narrow strips and covered with a thin coating of decomposed silver. Two such pieces are held together by soldering them to a thin metal armature. One end of this armature is clamped in the container of the phonograph pickup, thus forming a hinge. To the other end of this armature is soldered the supporting end of a sapphire tipped stylus. The signal developed is carried away by two contactors held against the outside surfaces of the two opposite pieces of ceramic. Rubber pads on either side of the assembly act aslateraldampers and thus limit or control the amount of movement. The ceramic type phonograph pickups have relatively high resistance when checked on a low voltage ohmmeter for circuit continuity and have a circuit capacitance of about 1000 micromicrofarads. This pickup will deliver .75 volts of signal voltage at a frequency of 1000 cycles per second from a standard 78 R.P.M. recording.

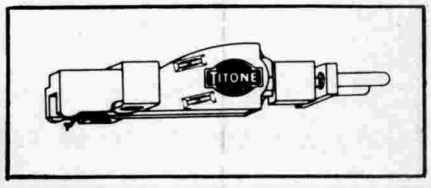


Fig. 29. This is a drawing of the tone ceramic type phonograph pickup cartridge.

A typical ceramic element phonograph pickup unit is about 1/2 inch square and has an overall length of 2 3/8 inches including the tip jacks. The tip of the stylus can be seen at the left end of the assembly. This type of pickup is rugged and although weighing 18 grams, a downward force of 3 ounces is sufficient to cause the two stylus guards to touch the record. A picture of this same pickup

showing its relative size appears on the cover of this lesson.

This pickup does not deteriorate in time or lose its efficiency during humid periods. It is moisture and fungus proof and retains its operating efficiency in temperatures ranging from minus 65 to plus 160 degrees Fahrenheit. A large number of these ceramic phonograph pickup cartridges were marketed by the Sears Roebuck and Company, Chicago, Illinois, U.S.A. under the trade name Syntronic, although made by the Sonotone Corporation, Elmsford, New York, U.S.A.

The overall frequency response curves for the Titone ceramic phonograph pickup type W-7530 for use with 33 1/3 and 43 R.P.M. recordings and the type W-7540 for use with 78 R.P.M. recordings are shown in Fig. 30. Notice that both pickups have a uniform 10 db rise at 400 cycles per second and have an extended frequency range from 50 to about 7000 cycles per second.

The following installation procedure is recommended by the manufacturer of the Titone ceramic phonograph pickup: Refer to Fig. 31 and the following 6 steps.

1. Remove the two screws holding old cartridge to the pickup arm.
2. Detach terminal clips from old cartridge. If connection in old cartridge was not made with clips, solder the wires to new clips provided in kit. CAUTION: Do not solder wires while clips are attached to Titone pickup.
3. Plug clips on to terminal adapter with ground lead on left hand pin (looking from front of cartridge in playing position).

   NOTE: On AC-DC sets it is necessary to unground the cartridge. This is accomplished by pushing back slightly on rubber sleeve, then cutting the grounding strap. Be sure to remove any free metal parts that may result from this operation.

4. Mount the Titone cartridge using the size of screws supplied that match the threads of the old screws.
5. Removal of needle guard completes the installation.
6. If the volume is insufficient upon completion of the installation, it may be due to the use of an equalizer network in the input circuit which is not necessary with the Titone pickup. In such a case, remove the equalizer network and make the connection directly.

The usual frequency response corrective network used in connection with crystal phonograph pickups, to be described later, is not necessary with this pickup. However, if it is necessary to reduce the intensity of the lower audio frequencies, then the relative amount of reduction can be seen in Fig. 32. Note: There is a drop of about 5 db in the signal voltage at 55 cycles from no resistor at R to a value of 2.0 megohms for R, then there is an additional drop of 5 db to each of the other values of 1.0 and 0.5 megohms. This change may be expected when feeding directly into the grid circuit of the

first audio amplifier tube. A somewhat lower change may be expected when feeding into a .5 megohm volume control as usually found in a radio set.

PHOTOELECTRIC CELL PHONOGRAPH PICKUPS

Servicemen may encounter a unique phonograph pickup known as the photoelectric cell pickup. This type of phonograph pickup incorporated within the tone arm a pin-point light source, a pickup stylus with a suitable mirror attached and a light sensitive photoelectric cell. The mechanical energy is converted into an electrical signal by this combination. Power for the light source or lamp is obtained from a radio frequency oscillator operating on about 200 kilocycles so that the reversals of the A.C. in the circuit will be above audiability. Light from this source is directed toward the mirror

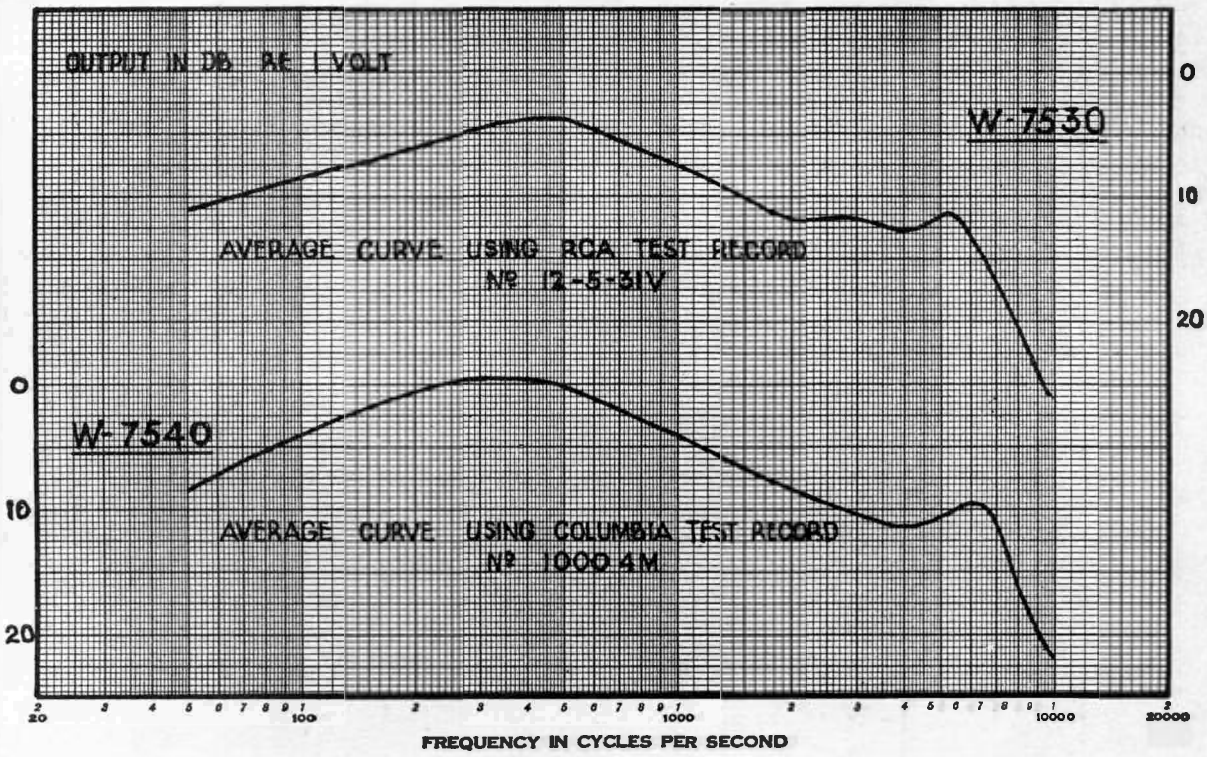


Fig. 30. Frequency response curves for Titone ceramic type phonograph pickups.

which is attached to the stylus. The reflected light from this mirror strikes the light sensitive photoelectric cell which causes a voltage to be developed in proportion to the light reflected. Since the mirror is attached to the stylus, vibration of the stylus causes changes in the reflected beam of light striking the photoelectric cell, thus giving the varying voltage.

This type of phonograph pickup is light in weight, however, proper amplitude and frequency range requirements are difficult to maintain. Whenever called upon to service this type of pickup, try to obtain service data from the manufacturer and always use exact replacement parts.

TONE ARMS

The tone arm is designed to hold the pickup cartridge to minimize tracking error.

This means that the shape of the tone arm, and in particular its length, is of a value which keeps the pickup cartridge at right angles with respect to the groove in the record over the greatest area in the travel of the stylus from the starting groove to the final groove. It must also be designed to prevent resonance at any frequency, as resonance which is the natural vibration or frequency of the complete assembly may cause microphonic feed-back. Seven typical tone arms are shown in Fig. 33. All the models pictured except the 400 series are for use with 10 and 12 inch records. The 400 series is for the playing of all lateral transcriptions. The S series pictured may be for playing transcriptions or for regular 10 and 12 inch records. In general, tone arms for ceramic cartridges are characteristically the same as those employed with crystal cartridges. With magnetic type pickups we have greater weight of the pickup and the tone arm, and because of this a counterbalance arrangement is often incorporated in the tone arm for this type of pickup.

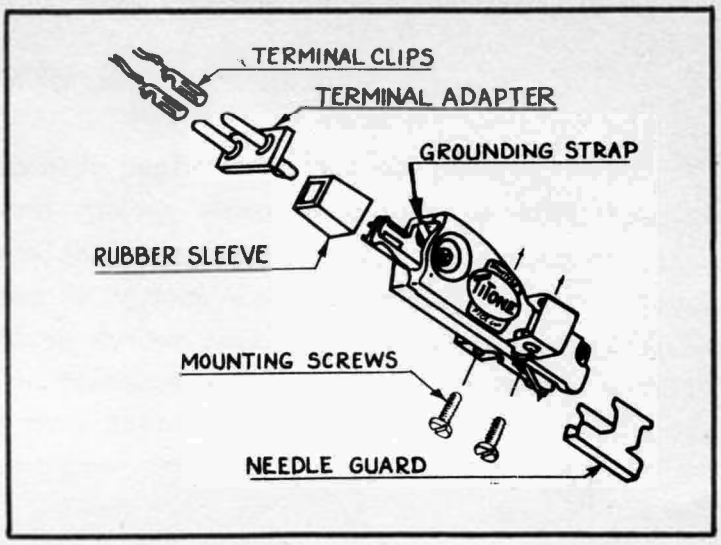


Fig. 31. This view shows the parts used in making the Titone ceramic type phonograph pickup.

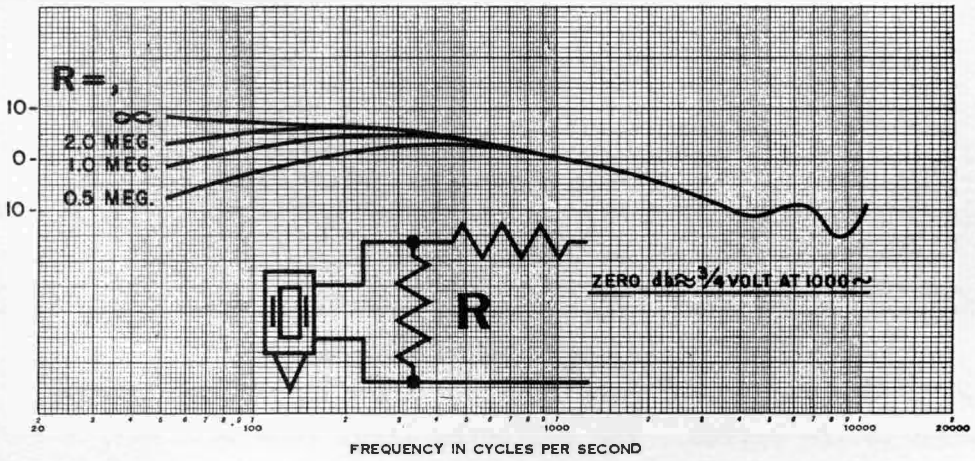


Fig. 32. Frequency response chart for Titone ceramic phonograph pickup using R network shown. Curves show response with different values of R.

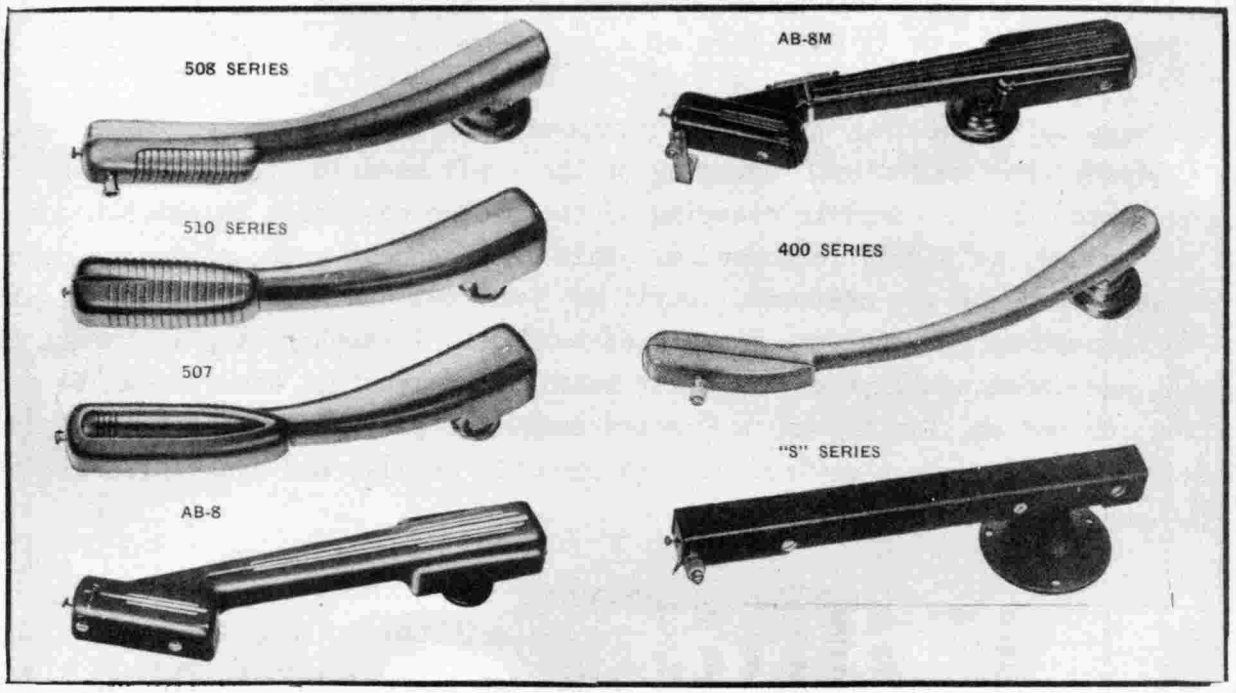
You may get an idea of a counterbalanced tone arm by looking at the AB-8M pictured in Fig. 33 and also the S series tone arm. Such a counterbalancing action is often made adjustable through the use of set screws, movable weights, and spring tension.

Fig. 34 shows a guage manufactured by the Clarkstan Corporation, Los Angeles, California, U.S.A. for measuring the downward force or pressure exerted by the tip of the stylus on the record groove. It is possible for the serviceman to demonstrate to a customer the weight of an old type phonograph pickup with this guage, and thus cause the sale of a light weight pickup after completing a radio service job. You will note that

the guage is calibrated in both grams and ounces for the convenience of the user.

SERVICING PICKUPS

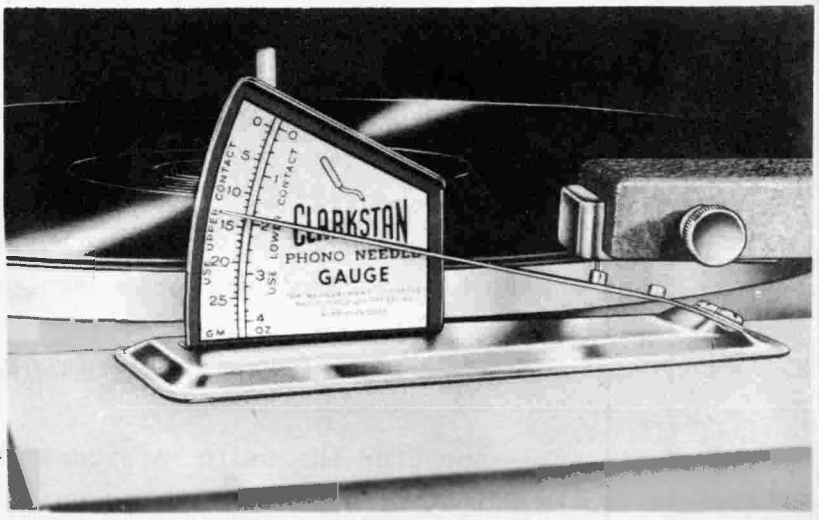
Phonograph pickups employ delicate parts such asthepickup cartridges and the styli used in them. It is the radio servicemans job to determine the condition of the pickup



(Courtesy, Astatic Corp.)

Fig. 33. Here are shown seven different types of phonograph tone arms.

and stylus. A turntable and an amplifier as well as a loudspeaker enable simple listening tests. A phonograph motor board with mounting holes drilled to accomodate each of the various types of turntables and tone arms may be devised. The input of the amplifier may have two short leads with clips so that proper connections may be made to the output of the pickup cartridges. Often the cartridge may be held in the fingers to play the record while making the brief test.



(Courtesy, Clarkstan Corp.)

Fig. 34. Clarkstan, Model 301 guage for measuring stylus point pressure.

The simple test desc ibed above does not permit complete and accurate measurements, but it will enable the radio serviceman to establish whether or not a unit is operative or defective. This may save the inconvenience or delay of returning it to the manufacturer before complete inspection and test. Many of the manufacturers of phonograph pickups and pickup cartridges maintain a 2-day service and their devices are guaranteed for one year against

faulty workmanship and material.

The serviceman never attempts to repair a damaged phonograph pickup. A complete replacement of the pickup cartridge is made. In nearly every case the serviceman can obtain a replacement pickup. This pickup may be obtained from the manufacturer of pickups. In other words, a pickup manufacturer usually recommends a suitable replacement. The information regarding the model or type number is generally provided by the set or pickup manufacturer in the form of a replacement list.

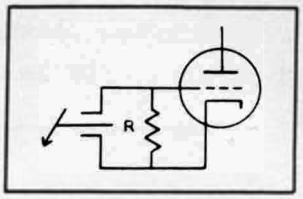


Fig. 35. The frequency response can be changed by varying the value of R.

It is very important for the radio serviceman to impress upon the customer that periodical changing of the styli used in phonograph pickups or the complete changing of the pickup cartridge in which a permanent point is maintained, is highly recommended. This is dependent upon, of course, the number of playings made by the customer. Styli do wear out and when badly worn, take revenge on the record by cutting down the glazed surface. A sapphire tip is harder than a steel stylus and consequently causes greater wear on the record. Records can be and are being played, on and on, far beyond the rated number of plays with the same stylus. A badly worn stylus can damage several hundred records easily, and every precaution must be taken to see that this does not happen.

GENERAL SERVICE NOTES

The following additional general service notes are helpful in servicing phonographs:

1. Check pickup cartridge for defects.
2. Check all rubber mountings and rubber couplings to see if they have dried out.
3. Check motor speed.
4. Check shielded pickup lead for defects.
5. Check and replace rubber tires on drive wheels that are worn or defective.
6. Check and replace worn or defective gears.
7. Check and replace worn drive belts.

In the event that a replacement is made, then the manufacturers recommended part should be used. The only time that substitution of a part other than that recommended should be made is when the factory recommended replacement is not available.

PHONOGRAPH TONE CONTROLS

It is often necessary for the radio serviceman to introduce a tone control or equalizer circuit in the output of a phonograph pickup to entirely satisfy the listener. This is generally the case when the radio set or amplifier used in connection with the pickup was not originally designed for phonograph operation.

Everyone has his individual taste insofar as tonal response is concerned, and a good

understanding of the application of tone controls or equalizers, as they are sometimes called, give the radio serviceman another opportunity to offer a worthy service.

Since crystal pickup cartridges are high impedance devices, they should, therefore, be connected across high resistance loads. These loads usually being of any value between .25 and 5 megohms. In general, it can be stated that the lower the value of the resistor across the output of a crystal pickup, the lower will be the low frequency response. This is due to its high no-load or open-circuit impedance at low frequencies. This is shown in Fig. 35 and Fig. 36. In Fig. 35 you will find the schematic diagram of the output of a crystal pickup feeding into the input circuit of a tube. In Fig. 36 note that the high frequency output of the crystal pickup is not modified while the low frequency output at about 50 cycles is considerably modified with the use of different values of the resistors having the values of .25, .5, and 1 megohm resistance.

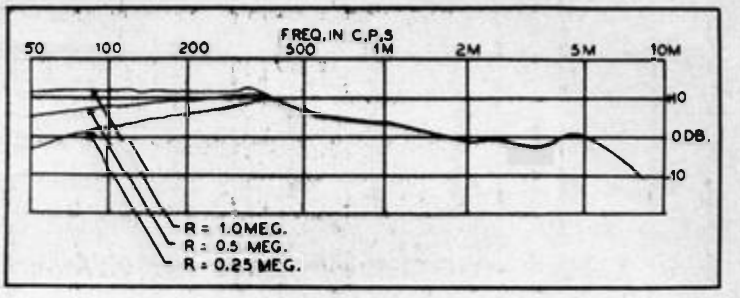


Fig. 36. Response curves for different values of R as used in Fig. 35.

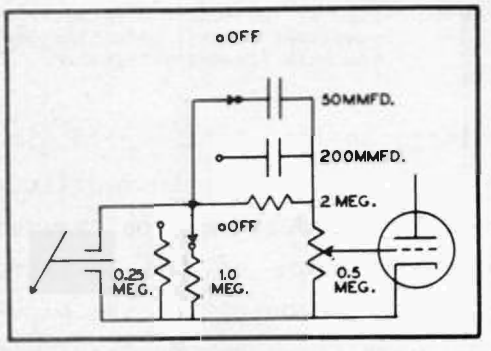


Fig. 37. Schematic diagram of an equalizer circuit giving three types of response curves.

In general, one of the above values of the load resistors will give satisfying tone characteristics to the average listener, however, the critical listener may wish to obtain a greater latitude of tone control, and in this instance, a modification of the low frequency as well as the high frequency response or output of the crystal pickup, insofar as the amplifier is concerned, may be made. In Fig. 37 can be seen a schematic diagram of a 3 position tone control. The 50 and the 200 mmfd. capacitors offer lower values of impedance at the higher audio frequencies causing more voltage to appear across the volume control. The frequency response characteristics received from each of the 3 positions are indicated in Fig. 38.

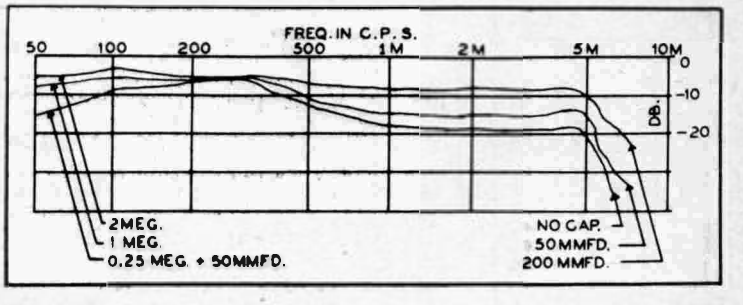


Fig. 38. Chart showing frequency response curves using equalizer circuit shown in Fig. 37.

Should the customer prefer only a modification of the high frequency response of a phonograph pickup, then the circuit combination shown in Fig. 39 may be employed. This consists essentially of the original resistor serving as the load, while a series resistor is connected to the output of the pickup. Across this resistor a capacitor is connected having a value between 100 mmfd. and 250 mmfd. Again these capacitors cause more of the higher audio frequencies to be conveyed to the grid of the tube than the

lower frequencies. The type of performance received is illustrated in the frequency response curve shown in Fig. 40. Note that the top curve indicates the relative output over the entire frequency range using a 250 mmfd. capacitor. Then the lower curve indicates that the ontput responses to high frequency end has materially decreased when using no capacitor at all across the resistor R1.

Phonograph pickups of the high impedance type such as the crystal are designed to operate with the length of the cable connected to them. In other words, no additional cables should be added without first taking into consideration the effects upon the output frequency response of these crystal pickups. Many of the standard shielded crystal pickup leads have a capacitance of 100 mmfd. per foot, and this capacitance becomes very effective in reducing the high frequency response of a crystal pickup when the cable is several feet long. Phonograph pickups should, therefore, be placed relatively close to the input amplifier tubes.

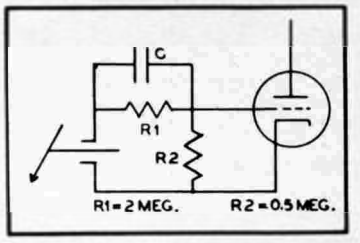


Fig. 39. Schematic diagram of an equalizer circuit affecting only the high frequency response.

From the information given above, we find that the voltage applied to the grid circuit of the first tube connected to the output of a phonograph pickup can be modified. The low frequency response may be reduced by reducing the value of the resistor connected across the output of the pickup. Then the high frequency response may be increased by connecting a resistor in series with the output of the crystal pickup to the regular load and by connecting a small capacitance across this resistor. When employing a capacitance as a tone control, we automatically obtain a variation in the voltage applied to the grid circuit of the first amplifier tube. This varying voltage is a result of the variation of the capacitive reactance of a capacitor as the frequency of the input signal changes.

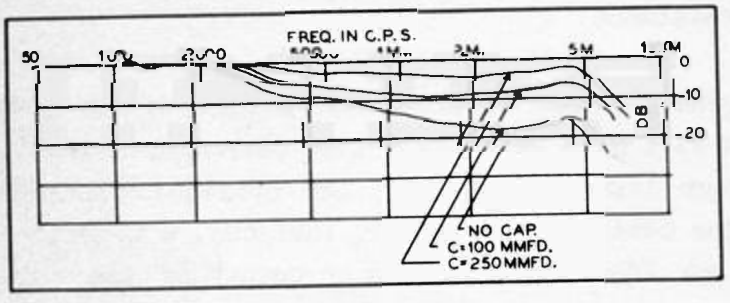


Fig. 40. Response chart showing high frequency response using equalizer circuit shown in Fig. 39.

—THE END—