Chapter 5

Stylus, Cartridge and Arm

Careful attention to manufacturer's instruction must be paid when installing cartridge in head. Hum and noise in a system are often due to error in grounding and wrong wiring of cartridge.

WHEN disc or tape recordings have been properly set into motion, the next step is reconverting the wiggles in a groove or the magnetism on a tape, first into electrical voltages, and ultimately into hi-fi sound. Part of the electrical job is accomplished in disc reproduction through the combination of the stylus, cartridge and tone arm. With tape, it is done by one element, the reproduce head.

All hi-fi styli today are made of some sort of precious or semiprecious stone. The diamond has for some years been promoted as the ideal stylus material because of its hardness. It should wear longer than sapphire, its leading competitor, and it is almost impossible to break under normal use. But the advantages of diamond styli are not so overwhelming as popularly supposed.

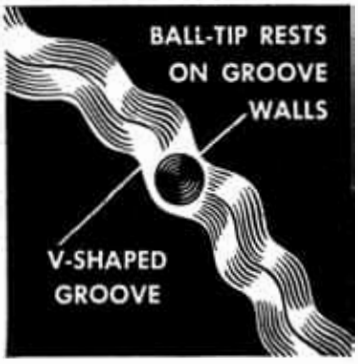
Because of its hardness, the smooth ball tip which the diamond stylus must have is not always very easy to achieve. The purchase of a diamond stylus is no guarantee of perfection, as there have been such styli marketed with needle-sharp points which cut their own grooves in records. Others are so badly polished that they give the groove walls a rough scraping at every pass.

With the stylus forces commonly used today—upward of 6 grams—a high-quality diamond is the only stylus to use. But any diamond has a crystalline structure which, no matter how it is cut, will show some end grain, just like the roughness at the end of a wooden board. This grain can be seen clearly under a microscope.

A sapphire tip, on the other hand, can be given a mirror sheen, much smoother than anything possible with a diamond. This is accomplished by flame-polishing, where heat causes the surface of the jewel to glaze. The problem now is the practical matter of taking advantage of this tip smoothness.

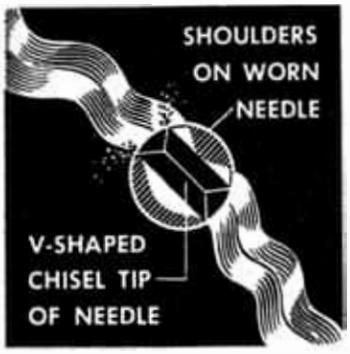
The only way this can be done safely is through the use of a very low stylus force,

Drawings by Tetrad

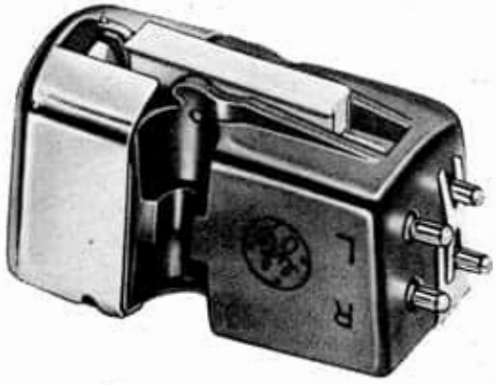


A GOOD NEEDLE FUNCTIONS SMOOTHLY

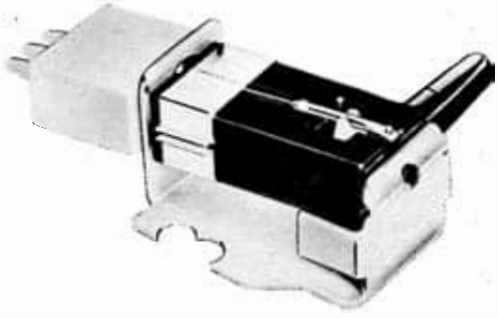
Graphic demonstration is given in these two drawings of what happens when a stylus tip is worn and how a new, smooth diamond tip rests on the groove walls of record.



A WORN NEEDLE SHOULD BE REPLACED



General Electric stereo-magnetic cartridge has .5 or .7 mil diamond stylus. Response is 20-20,000 cps ± 3 db for the .5 mil; pressure: 2 to 4 grams.



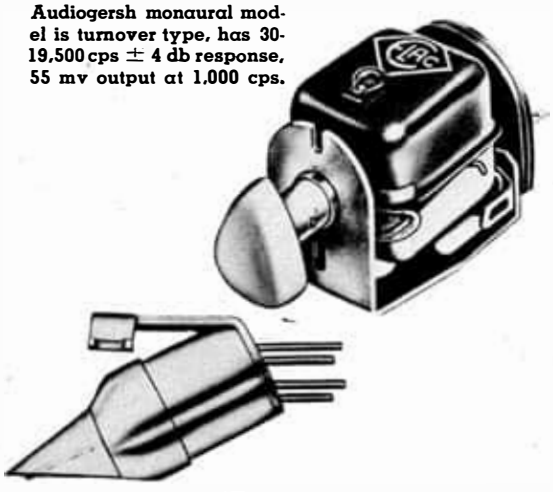
Electro-Voice Series 20 stereo model is priced at $15 for the single-diamond stylus cartridge. Diamond stylus replacement is $7.50; sapphire, $2.50.

of two grams or less. We were very close to such forces with commercial pickups, when stereo came along and kicked them upstairs again. As we will see, stereo tracking forces are considerably greater than those for monophonic cartridges, but when the time comes—if ever—that we get consistently good tracking at less than two grams, then perhaps the sapphire will come into its own.

If sapphire can be polished much more smoothly than diamond, then the only question remaining concerns wear. And exhaustive tests at Electro-Sonic laboratories over thousands of hours at these low tracking forces have shown *no sapphire wear at all.*

Even the hard diamond can't make such a claim under today's usual operating conditions, and so your stylus should be inspected periodically for wear. Rather strong claims have been made for diamond wear, with the safe period varying from 500 all the way up to 2,000 hours. Since

Audiogersh monaural model is turnover type, has 30-19,500 cps ± 4 db response, 55 mv output at 1,000 cps.

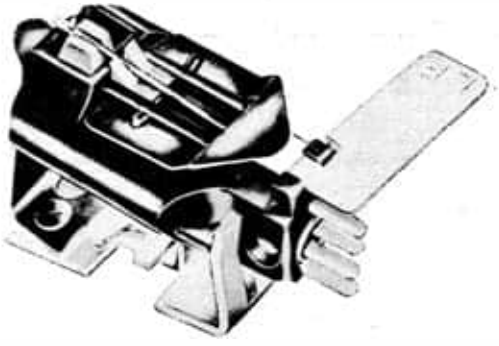


Stereodyne cartridge made by Dynaco Inc., is designed to fit into tone arm developed by this company.

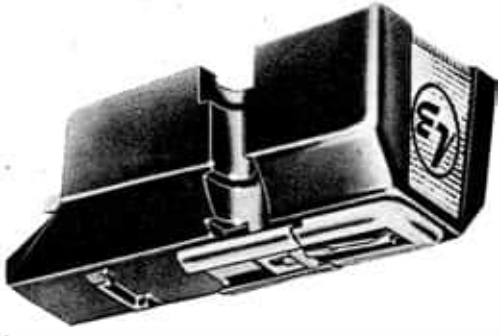
Audiogersh Corporation makes the two Stereotwin cartridges shown below. Both have .7 mil diamond styli, 30-18,500 cps ± 2 db response, 25 mv output at 1,000 cycles. Cross talk is below —20 db.

Shure Custom stereo Dynetic has 20-15,000 response, .7 mil stylus tip, tracks at 4 grams.

Duotone stereo turnover cartridge is British import, has 40-15,000 cps response, 1 v output. Tracking force is 2 to 4 grams; it has four terminals.



Electro-Voice ceramic stereo model can be used on magnetic phono inputs. Response is 20-20,000 cps ± 2 db. Channel isolation is 28 db at 1 Kc.



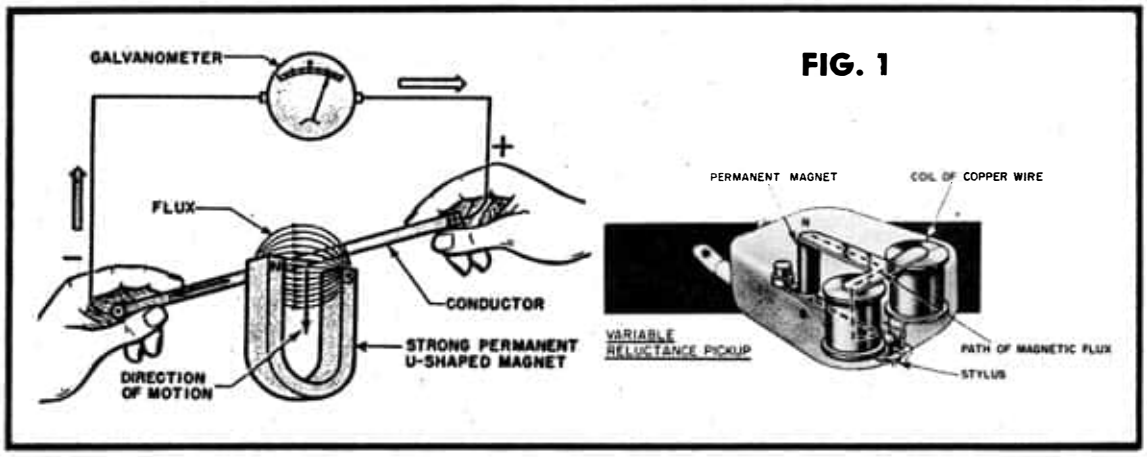
the actual safe period of diamond use will depend largely upon the equipment with which it is used, the wise procedure is to start giving it fairly frequent microscopic inspections after the first 300 hours.

This should be done on a regular schedule, for when a worn stylus becomes apparent in the reproduction, permanent damage has already been done to the record. The only way to be certain of stylus condition is to examine it under a microscope of 50 or 100 power. As soon as the length of the worn flat exceeds the tip radius, the stylus is due for replacement or repolishing.

With the stylus tracing the winding path of the groove, the next item in the chain is the pickup, or cartridge, which must translate this mechanical motion into an audio voltage. Phono pickups are classified either in terms of their method of generating a signal, or of the characteristics of that signal. On the latter basis, pickups are described as either amplitude responsive or velocity responsive. These terms are explained in Chapter 6, where we will see that the characteristic of the record cutter is a composite of both these types, and either type of pickup must therefore have its own inherent characteristic modified somewhat.

Any pickup is known technically as a *transducer,* because it converts mechanical motion into electrical signals. Transducers are widely used in electronic instrumentation, and just about every type of trans-

Below, left. Electromagnetic induction is caused by metal bar moving through magnetic force lines; meter registers current. Below, right, simplified drawing of variable reluctance magnetic cartridge components.



ducer known has at one time or another been tried for record reproduction. But of all the principles employed, only two account for the great majority of phono pickup designs today.

Nearly all present pickups are either magnetic or piezoelectric in principle. The magnetic types are in effect miniature electric generators, and they obey the same laws of physics as do the huge dynamos in electric power stations. The principle in each case is that of electromagnetic induction, which is illustrated in Fig. 1.

As the metal bar is moved through the magnetic lines of force, there will be a voltage induced in it as indicated on the meter. If the bar is twisted into a coil, more voltage will be generated because more lines of force will be cut. This is basically all there is to the magnetic phono pickup: a magnet, a coil, and a linkage which permits the stylus to move one or the other of them.

Since a moving coil and a stationary magnet will induce a voltage, as will a moving magnet and a stationary coil, we have both moving-iron and moving-coil type pickups. The mass of a magnet is too great to be moved readily by a tiny stylus, however, and so in the moving-iron types there is usually a third element, called an armature, in the magnet gap.

In this case both the magnet and the coil remain stationary, while the moving armature attached to the stylus varies the reluctance of the magnetic path and thereby induces a voltage in the coil. Hence the name "variable reluctance," by which this type is usually known. In the electrodynamic cartridge, on the other hand, the coil itself actually does move within the field of the magnet. In either type, a pair of flexible wires attached to the ends of the coil carries off the signal to the compensator and preamplifier.

The voltage output of magnetic cartridges is considerably less than that of the piezo types, and it varies considerably among available models. Some types put out as little as 0.01 volt, while others deliver up to 0.2 volt. The output of the moving coil types is usually considerably less than that of the moving iron variety, and a step-up transformer is therefore usually required between the pickup and the amplier input. Both of the magnetic types are essentially velocity responsive.

The other basic type of pickup operates on one of the several piezoelectric effects, in this case the generation of a voltage when the material is mechanically strained, the amount of voltage being directly proportional to the amount of the strain. The material is either a slab cut from a natural *crystal* of sodium potassium tartrate, commonly called Rochelle salt, or a synthetic *ceramic* material, usually barium titanate or lead zirconium titanate.

Recent developments in crystal technology have resulted in pickups of quite high fidelity, although Rochelle salt crystals are still rather sensitive to excessive heat and humidity, as well as mechanical shock. The ceramic cartridge, however, is fairly impervious to these weaknesses.

Shure stereo Professional Dynetic cartridge has 5 mv output per channel, 3-6 grams tracking force. Response: 20-15,000 cps ± 3 db; four terminals.

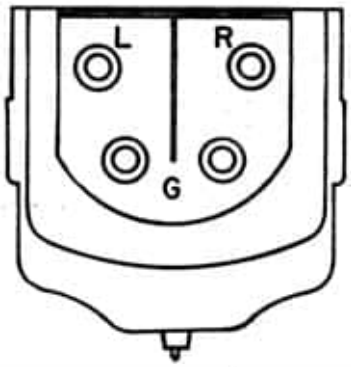


Diagram of Shure connection to tone arm wires. Left and right channels and both grounds are marked; 3-lead types need single wire to ground.

Above are some of the stylus pressure gauges available. At left is one by Clevite Walco, at right is a Garrard. The Walco gauge is unusual in that it has no springs; it uses movable counterweight.

The best piezo cartridges, both crystal and ceramic, closely approach the average magnetic pickup in fidelity. Their outputs range between 0.5 and 1.0 volt, with most hi-fi types running about midway between at 0.75 volt. This is much higher than the typical magnetic output, and a preamplifier is therefore unnecessary. Other advantages of piezo pickups are freedom from hum pickup, and relatively low cost. They are essentially amplitude responsive.

The primary purpose of the tone arm is transporting of the pickup, while maintaining the stylus in proper relationship to the groove. It also carries the electrical wiring which connects the pickup to the amplifying system. Since the arm must not in any way impede the motion of the stylus and pickup, it must have low mass and stiffness, and high compliance, both in the vertical and lateral directions. A really good arm is therefore a very finely designed and machined piece of precision equipment.

The design and adjustment of the tone arm also largely determine the stylus force, usually by means of sliding counterweights or springs. With present stylus forces being on the order of only a few grams, a change of merely a gram or two can make a whale of a difference in tracking ability and record wear. For this reason, the force should be checked periodically, and adjusted if necessary.

The cutting stylus on a commercial recording machine is mounted in a lathe mechanism which moves the cutter across the face of the disc in a straight line. The tone arm, on the other hand, is mounted on a pivot which causes the pickup to move in an arc. The difference between the straight-line movement of the cutting stylus and the curved movement of the reproducing stylus is called *tracking error*, and is illustrated in Fig. 2.

Tracking error causes distortion and record wear, and should therefore be held to a minimum. Any good arm will minimize tracking error, provided it is properly installed. The distance of the pivot point from the center spindle is critical with any given arm design, and it is therefore essential to follow manufacturers' directions.

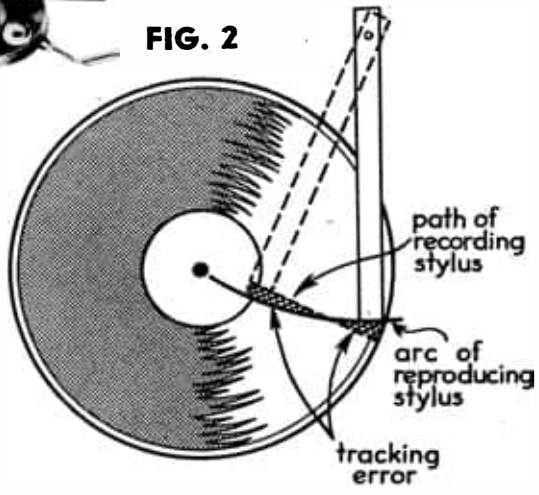
When the stylus is correctly mounted in the pickup, the pickup in the tone arm, and the arm on the motor board, the stylus as it rides in the record groove should be perfectly vertical to prevent uneven wear on the groove walls. But since the stylus is rather well concealed when the record is playing, it is often difficult to determine its angle visually.

Garrard transcription pickup arm is adjustable for length, height, stylus angle and pressure. The Model TPA 10, as shown, is a monaural type.

London Records and H. H. Scott have cooperated in designing this arm with its integral stereo cartridge. Tracking force is 3.5 grams, the diamond stylus is 0.5 mil; $89.95.

Lafayette stereo PK-270 arm is made of lightweight, die-cast aluminum, comes in 12- and 16-inch lengths. It sells for $17.50 and $19.50. Plug-in heads take monaural and stereo.

FIG. 2

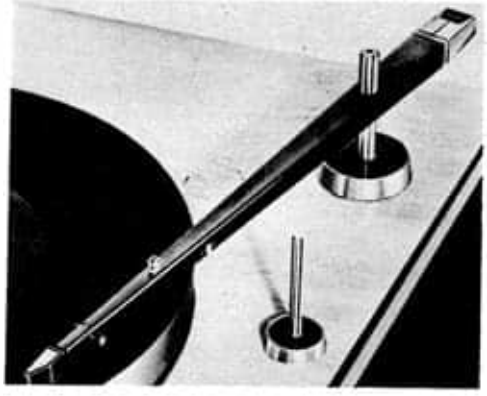


Drawing at right shows the difference in motion between the original cutting stylus and your tone arm. This is called the tracking error.

The best way is to use a small mirror, preferably about the thickness of a record. The mirror is placed on the turntable, and the pickup placed gently on the mirror. The stylus and its reflection should then be perfectly in line when viewed from any angle. If there appears to be any bending between the two, then there is need for adjustment. Since this angle will vary with the height of the stack on record changers, the best compromise is simply to adjust the stylus to vertical with a stack thickness half that of the number of records you usually play.

A tape reproduce head operates on the same principles as the moving-iron phono pickup. A recorded tape is really a series of tiny magnets, which in reproduction are drawn rapidly past the coil in the tape head. Voltages are then induced in the coil in accordance with the magnetic pattern on the tape. In the tape head this coil has a metal core, but the principle is still that of the moving iron transducer.

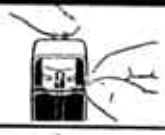
The purpose of the core is to conduct the magnetic flux away from the tape and into the coil, for greater signal strength, better frequency response and less distortion. The core is bent around in the shape of a ring, with the ends of the ring closed so tightly that the gap is barely discernible.



Shure integral stereo arm and cartridge has a 20-20,000 cps response, ± 2.5 db, with a more than 20 db at 1,000 cycles channel separation.

NEEDLE REMOVAL INSTRUCTIONS

SPRING-HELD (G.E. "slide-in" needle assembly)



TO REMOVE:
Push red button down and turn so that needle assembly will be at a right angle to cartridge. Slide needle forward, out of assembly.

TO REPLACE:
Hold red button down. Slide new needle in. Make sure LP tip corresponds to "arrow" or LP position on red button.

TO REMOVE:
Slightly lift retaining spring with fingernail. Grasping needle by "handle" carefully lift out of position.

TO REPLACE:
Slightly lift retaining spring; hold needle by "handle"—place in position with arm resting on small forked post.

TO REMOVE:
Grasping needle by "handle" pull it sideways out from under spring.

TO REPLACE:
Holding needle as before, push squared portion under spring.

HORIZONTAL PUSH-IN NEEDLES (friction-held)

TO REMOVE:
Grasp shank of needle with tweezers—pull straight out, horizontally from front of cartridge.

TO REPLACE:
Push shank in gently with fingers or tweezers until seated.

TO REMOVE:
Grasp wide flat portion of needle with flat tweezers—pull straight out, horizontally from front of cartridge.

TO REPLACE:
Grasp as above and insert needle into cartridge slot until firmly seated.

CLIP-HELD NEEDLES

TO REMOVE:
Insert fingernail under front edge of silver colored clip of needle—pull needle assembly from cartridge.

TO REPLACE:
Place rear leg of needle clip into rear cartridge slot and snap needle into place. Make sure needle shaft is in fork of needle guide.

SCREW-HELD NEEDLES

TO REMOVE:
With small screwdriver, remove screw holding the needle.

TO REPLACE:
Insert screw in hole in needle's base—align needle in cartridge recess and tighten screw.

FRICTION-HELD NEEDLES

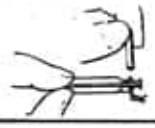
TO REMOVE:
Raise needle tip with fingernail and move it to side as shown. Holding needle at shank, lift from socket.

TO REPLACE:
Press shank of needle into socket until seated. Rotate needle into forward position. Make sure needle is in fork of needle guide.

HEX-NUT-HELD NEEDLES

STEP 1
Remove cartridge from tone arm by removing the two retaining screws.

STEP 2
Carefully slide wire lugs from the terminals on cartridge.



STEP 3
Using small pliers or hex-nut wrench (supplied with each Walco needle) remove nut from top of cartridge. Needle may now be removed.

STEP 4
To replace: Insert needle shaft upward in hole, with tip between guard arms. Holding needle in position, place washer, then nut, on shaft—tighten with hex-nut wrench.

TWIN NEEDLE TYPE
LP (red) needle must be removed first, as in Steps 1-4 above. If 78 rpm needle is to be replaced, too, its own hex nut is now exposed under LP needle position.

CAUTION:
LP needle goes between forked guards of cartridge; guards for the 78 rpm needle are part of the assembly which holds cartridge in place.

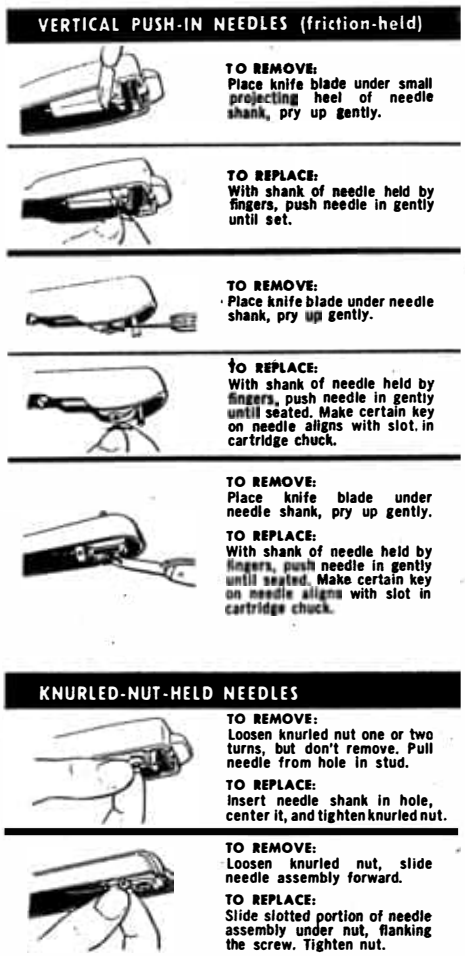


Chart by Clevite-Walco

The size and shape of the gap in this ring is very important in determining the fidelity of the head response. If we want to be able to handle up to 15,000 cps, for example, then the tape would have up to 15,000 complete magnetic reversals on whatever length of tape passes the head in one second.

At the standard speed of 7½ inches per second, for example, the length of one wave on the tape would be (7.5 ÷ 15,000), or 0.0005 inch. The wavelength of 15,000 cps at 7.5 ips is therefore only one half mil (a mil is 1/1,000 inch). But the head gap must be even smaller than that, for experiment has shown that the output is almost zero when the gap length is the same as the recorded wavelength. But when the gap length is half the wavelength, then the induced signal is maximum.

We can infer from this that to reproduce frequencies up to 15,000 cps with 7½-ips tape, we must have a head gap of one quarter-mil.

Better equipment today has quarter-mil heads, which are a far cry from those which once limited the frequency response of 7.5-ips tape to 7,500 cps. We now have that additional octave of response, but since the gap is almost a short circuit, it isn't likely that we will see the day that it will be cut in half again, to permit full fidelity at 3.75 ips.

The Stereo Story

The first important difference in stereo disc reproduction begins right at the stylus. Whereas a tip radius of 1 mil was considered standard for monophonic microgrooves, we now often find stereo car-

tridges equipped with 0.7 or even 0.5 mil tips.

To understand how stereo cartridges differ from the monophonic varieties discussed earlier in this chapter, we must remember that in a monophonic groove, all of the information is contained in a side-to-side wiggling of the engraving stylus, in a system known as *lateral* recording. The reproduction motion involved in lateral recording is shown in Fig. 3(A).

It is also possible for the engraving stylus to have an up-and-down motion, to make a record known as vertical or hill-and-dale. The first serious attempts at stereo recording therefore naturally used a combination of vertical and lateral recording, with one channel assigned to each of the two types of movements. The basic principle of reproduction in such a system is shown in Fig. 3(B).

Note that the stereo cartridge has two generators driven by the common stylus, as opposed to the monophonic type which has only one. Thus the stereo cartridge is inevitably heavier and stiffer than its monophonic counterpart.

In the vertical-lateral stereo system shown in Fig. 3(B), one channel of information is presented by the lateral displacement of the groove, while the other channel is represented by a varying depth of the groove. A more symmetrical system is the 45-45 arrangement, which has now been adopted as standard in the United States, and many other parts of the world as well. The reproducer system is shown in Fig. 3(C), and might be thought of as the vertical-lateral system tipped at a 45-degree angle.

Now the signal information is contained in the diagonal displacement of each groove wall. One set of stylus motions, affecting generator *A*, is along a line of 45 degrees to the record surface, and moving between northwest and southeast. The effect of one half-cycle of a heavy *A* signal is shown in Fig. 3(D). A second set of motions, between northeast and southwest, similarly affects generator *B*.

As shown in Fig. 3(D), the groove deepens under modulation, but only the left wall moves with an *A* signal, and only the right wall moves with a *B* signal. Thus in effect each wall of the groove is modulated separately, and each wall represents one channel of the 2-channel stereo system.

In a true stereo signal, however, both channels will be active. In this case both groove walls will have a tendency to move, and there will be a resultant motion in two

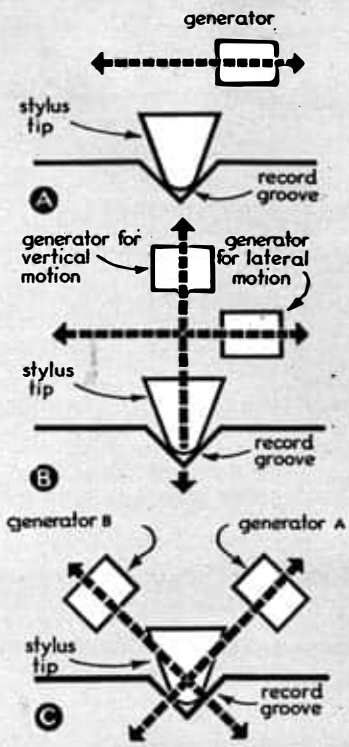
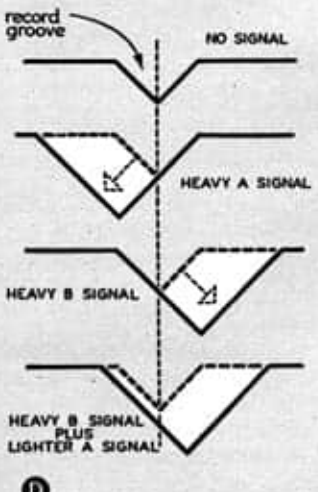


FIG. 3

See text for explanation of stylus movements



Stylus, Cartridge and Arm

directions. The effect of a heavy *B* signal plus a lighter *A* signal is shown in Fig. 3(D).

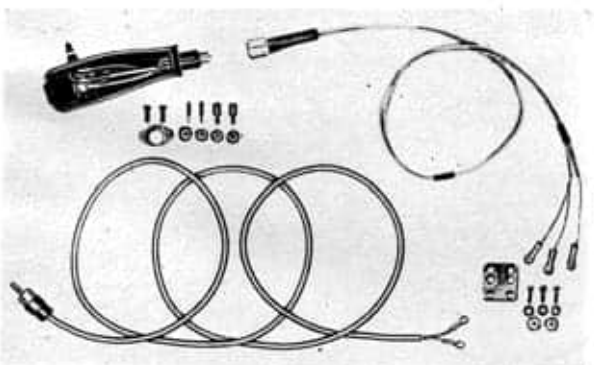
The stereo pickup may be either of the magnetic or piezo type, but in either case each of the generators should respond only to its own component of the complex groove motion. The more accurately they do this, the greater will be the isolation between channels, and the more realistic the stereo effect will be. The best stereo cartridges will have a channel separation of upward of 20 decibels.

If you are beginning in hi-fi, and definitely intend to go stereo after starting with an expandable monophonic system, you should get a stereo cartridge at the outset. Since the stereo pickup will play both stereo and monophonic records, while the monophonic pickup will severely damage stereo records, the monophonic type is a total loss when making the conversion.

Most good monophonic tone arms will track stereo all right, but their connectors and wiring must be modified. Stereo cartridges, since they have two separate generators, require 3- or 4-wire connections, while the monophonic variety uses only two. Conversion kits are available for this modification for many arms, and the changeover is quite a simple job.

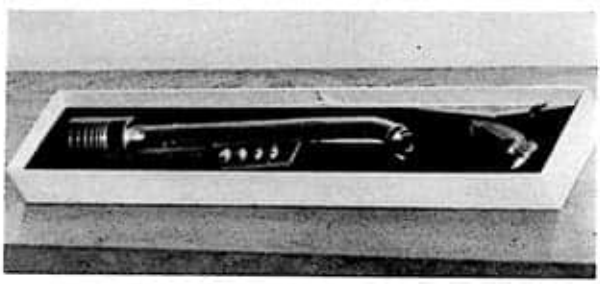
The stereo tape head is in effect two half-track heads stacked atop each other. With stereo heads the tape system is completely compatible, in that it will not only handle stereo, but can also record and play monophonic half-track tapes as always. Thus converting an existing tape recorder to stereo is a fairly simple process of replacing heads.

Of course, the conversion of either tape or disc to stereo also involves additional electronics, the discussion of which begins on the next page. •



Left: Garrard stereo conversion kit consists of new head with a three-wire connection, cable for the arm, terminals, shielded-lead phono plug.

Above: Stereodyne phono cartridge is combined in novel tone arm assembly which mounts in a single mounting pole. Price: $50.



Stereo conversion kit by Rek-O-Kut is designed to convert company's monaural arms to stereo. It includes head, arm, terminal; 4-wire type.