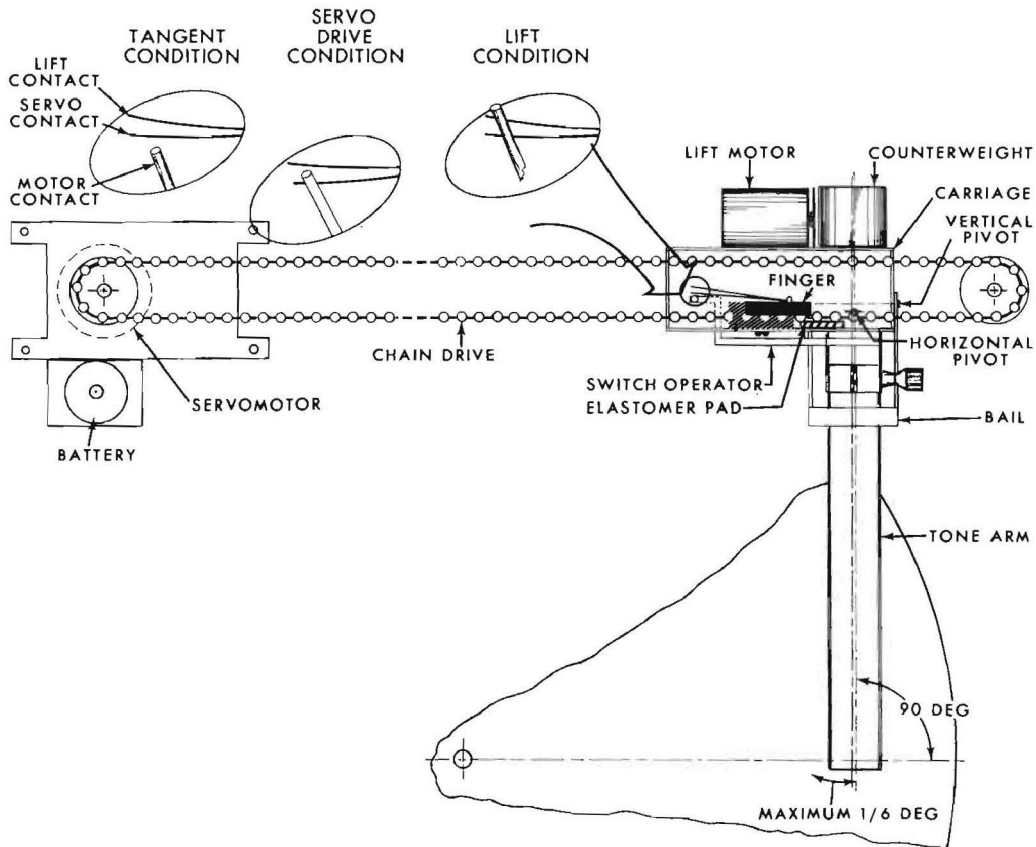


THE RABCO SL-8 SERVO-DRIVEN STRAIGHT LINE PHONOGRAPH ARM

by the RABCO Engineering Staff



Tone-arm linkage closes drive circuit when tone arm pivots from tangent position. Gimballed tone arm is supported in carriage on nylon rollers. Chain drive, connected to servomotor through 500:1 gear reduction, advances arm. Arm grips chain between metal finger and elastomer pad when arm is placed in the playing position.

SCHMATIC DIAGRAM OF THE SL-8

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Why a Straight Line?

Phonograph records are recorded by machines that drive the recording stylus in a straight line across the master record. In nearly all of the playback devices sold today, however, the pickups swing in an arc. The deficiencies of this mounting have long been recognized. To overcome them, straight-line-motion devices have been built in the past, but all have suffered from three basic difficulties.

The first is that a much larger force is required to overcome the friction effects in such mechanisms. This is because moving an arm on a carriage in a straight line is far more difficult than pivoting an arm through a small angle about a fixed bearing, even if the carriage is provided with the best bearings.

The second difficulty is that the wire-cable stiffness becomes a problem when the cable has to be pulled by such a straight line device. In a properly designed pivoted arm, the cable is merely bent or twisted through a relatively small angle.

And, finally, the most objectionable feature of prior straight-line arms is that the inertia of the arm and carriage, when they move as a unit parallel to the radius of the record, is much greater than the equivalent reflected mass of a pivoted arm. In the case of a pivoted arm, only a small part of the arm has the velocity of the cartridge, while most of the arm merely pivots through a small angle about a fixed point. In properly designed pivoted arms, the counterweight is located close to the pivot so that its moment of inertia contributes relatively little to the moment of inertia affecting the stylus. The net result of all this is that the stylus "sees"

only a part of the total inertia of a pivoted arm and its counterweight.

Since things are not perfect in this imperfect world, one has to add to all the above difficulties such things as dirt and/or roughness of the tracks, bearing friction, imperfections of the wheels, and so on — so that the actual forces required to drive some of the old straight-line arms were even greater than theory would indicate.

The above is not meant to infer that there are no serious deficiencies in pivoted arms, and some of them will be discussed below. The point we want to make is that the servo-driven arm described here combines the advantages of straight-line motion without the disadvantages of prior systems where the mechanisms providing the straight-line motion were driven by the stylus itself.

Lighter and Lighter

The trend today is to ever lighter pickup forces to ensure both higher fidelity and longer record life. The reason for the improved fidelity is that the effects of the softness of the record material are minimized by pickups having great stylus compliance and low stylus mass. In other words, if the stylus mass were zero and the stylus were supported by an infinitely soft compliance, the record would appear to be infinitely rigid and would give the finest fidelity. In practice, the inertia of the stylus is by no means negligible and the records do deform considerably.

The groove of a modern record has sides cut at 45 degrees to the vertical so that the lateral forces that move the stylus to produce the signal also produce equal vertical forces that tend to lift the stylus

out of the groove. Because of this, the downward force on the stylus must always be greater than any lateral force exerted on it. One would like to design a system such that the only lateral forces exerted on a pickup are those required to move the stylus to play the recording. Any additional lateral forces are undesirable and should be minimized. Among these must be the very considerable forces required to move the phonograph arm. Today, one can build a pickup that would play the records with a downward force of one-half gram. It is obvious that the lateral force available to move the arm is a very small portion of this half gram. What is more logical, then, than a servo to move the arm?

Tracking Distortion

The distortions caused by the lack of tangency between the pickup and the record groove are today well known. Perhaps the simplest way to explain the main trouble is to say that a sine-wave groove will produce a sine-wave motion of the stylus only if the stylus is constrained to move along a line perpendicular to the tangent to the groove, i.e., only if the stylus duplicates the motion of the cutter. If the stylus tip does not move along a perpendicular to the tangent — that is, not in a true radial direction — a sine wave groove does not result in an electrical sine wave, and this gives rise to serious distortion and, particularly in complex waves, to intermodulation effects. The bibliography appended to this brief article gives a detailed analysis of these effects for those who are interested in delving further.

In addition to the old straight-line, stylus-driven arms mentioned

earlier, many other efforts have been made to cope with the tangency problem. The standard off-set arm universally used today is a clever device which, nevertheless, suffers from several serious deficiencies. In an arm of reasonably compact length, the tangency error cannot be reduced to zero. If the off-set angle is chosen to result in the lowest distortion, the usual short length of the arm produces a large "overhang" of the stylus. This means that the stylus, if carried to the center of the record, would overhang the center by a fairly large amount, of the order of $\frac{1}{2}$ " to $\frac{3}{4}$ ". This magnitude of overhang, and the best off-set angle, produce very large side pressures on the stylus, often causing arms to jump the grooves. In most record players, the off-set angle, the amount of overhang, and the downward force are compromised to prevent groove jumping, and the resulting distortion is much greater than one could obtain with optimum design. The undesirable side force on the stylus, that is, the side pressure not caused by the musical modulation of the groove, requires that more vertical force, or more weight, be used on the pickup to keep it in the groove. This increases the wear of the record and of the stylus, and distorts the groove, which results in still further distortion of the signal.

Stylus Tangency

The steady-state force on the side of the stylus caused by the off-set arm angle produces another very interesting and only recently analyzed distortion. It can, perhaps, be explained simply by saying that while the body of the pickup can be kept tangent within one or two degrees by an off-set arm, the side pressure deflects the stylus in such a way that the stylus itself is not tangent to the groove. Thus the distortions which one is trying to eliminate by a bent arm raise their ugly heads again.

Longer Arms?

An obvious way to minimize the overhang and offset problem is to

use a longer arm, and this is sometimes done in commercial equipment. Unfortunately a longer arm adds mass to the pickup, something which is highly undesirable. This can be understood by imagining that the arm is very long — several feet, for example. When one pictures such an arm one realizes that the motion of the cartridge will be imparted to much of this arm, so that quite a large part of the arm would move with approximately the same velocity as the cartridge, and the "reflected inertia", as this is called, is felt by the cartridge. This extra mass tends to produce oscillations of large amplitude which are very difficult to damp out. The shorter the arm, the less mass is added to the cartridge. The ideal arm would be as short as possible, ultimately not many times longer than the cartridge itself. For many reasons, the practical length today is of the order of six or seven inches, which means the arm support is just off the record.

Skating

The effects of steady-state forces on the side of the stylus have been recognized for some time, as the bibliography shows, and recently manufacturers of high-quality arms introduced an expedient to minimize this effect. It is generally known as the anti-skating device. The reason for the name is that the force which tends to move the stylus toward the center of the record is known as the skating force; occasionally, when it exceeds permissible tolerances, the pickup jumps the groove and seems to skate across the record. Anti-skating devices take many forms, but basically, they are mechanisms that produce an opposing force so as to minimize the skating force. Unfortunately, the skating force is not constant and cannot be predicted in advance for any particular design of the arm. The skating force depends not only on the vertical force on the cartridge and the co-efficient of friction between the stylus and the record, but also on

the mass of the stylus and the compliance of its mounting, and the frequencies and amplitudes of the recording being played. For these reasons, the anti-skating devices can only be a compromise and a guess, and while using an anti-skating device is better than doing nothing, it cannot be a complete solution to the problem.

Linear Rigidity

Another little known cause of trouble in some phonograph pickups and in some arms is the lack of absolute rigidity in the direction parallel to the record groove. Any motion of the stylus along the groove gives rise to very serious distortion of the signal (see the bibliography re "Drag Distortion").

In all good modern cartridges the stylus tip is so mounted that it can only move laterally and vertically in a pre-determined plane — usually at the specified standard angle of 15° from the vertical. A correct arm must permit the cartridge to move easily in all directions except along the groove.

Why a Servo?

To summarize, then, it appears that the optimum way to play a record is to use a straight-line arm, tangent to the groove at all times, and to remove all possible extraneous work-loads from the stylus. The groove of the record has trouble enough moving the stylus from side-to-side and up and down up to twenty thousand times per second without also being forced to overcome frictions, unnecessary side pressures, and other loads that have heretofore been imposed on this delicate mechanism.

In the servo-driven arm, the stylus performs basically one function. It reproduces the recorded sound. Ideally one would like to make the cartridge and arm of negligible weight, but this would require a stylus of negligible mass and with an infinitely soft suspension. Since this is not possible, one needs a small amount of mass in the pickup to hold the pickup stationary while the stylus moves at audio frequen-

cies. This relative motion between the stylus and the pickup body produces, of course, the transducer output.

The RABCO SL-8

In the RABCO SL-8 mechanism the pickup is mounted on a straight, light, and fairly conventional arm. The arm is pivoted on simple hardened cone bearings so that it can follow the record grooving as any pivoted arm would normally do. The vertical pivots — those that permit the pickup to move up and down — are mounted as close to the plane of the record as practicable, so that warped records do not produce noticeable “wow” as the arm moves up and down. The bearings that support the arm are mounted on a carriage which travels along a straight track, and which is driven at the correct speed by the servo system. This servo is controlled by a pair of precious metal contacts. These contacts control the angle between the carriage and the arm. This angle is set to be 90° during normal record playing. If the arm deviates from tangency, the motor will drive the carriage in the desired direction so as to restore the angle to 90 degrees.

The SL-8 unidirectional servo system is inherently stable because any slight overshoot cannot produce oscillation. In case of overshoot, the carriage will simply slow down and wait until the angle is again just less than 90 degrees. In actual practice, the resulting steps are very small and the action is, in fact, not quite continuous because records are usually not quite round and the center hole is often slightly off center. The carriage follows the motion of the pickup in very small steps which are deliberately made to have gradual starts and stops. This prevents any disturbances from being transmitted to the pickup.

Balance

The counterbalancing of the arm merits special attention. There has been a continuing controversy regarding the use of unbalanced weights as contrasted to springs to

produce the correct vertical stylus force. We do not wish, in this brief paper, to get too deeply involved in this controversy. There are advantages and disadvantages in using either spring forces or counterweights to produce the necessary vertical forces. Consider first the truly balanced arm with its pivots through the center of gravity. The arguments for this arrangement are that tilting the turntable does not affect the action of the arm and that accidental lateral translations of the whole phonograph will not cause the arm to jump. Springs are used with such arms to provide the slight vertical force required for the cartridge. There are several things wrong with these arguments. It is true that if the arm is balanced about its pivot, linear translations, that is, straight-line motions and vibrations of the whole assembly, will not cause the arm to rotate. Unfortunately, most vibrations and translations of the whole mechanism are not linear. They may have large rotary components. This is particularly true when the phono assembly is mounted on springs and when it has large off-center masses such as, for example, the phonograph motor. When such a system is disturbed by the vibrations of the table or cabinet on which it is mounted, the system goes into oscillations which are not only linear but rotary as well. Under these conditions, whether or not the arm is balanced about the center of gravity doesn't make much difference. The arm will be disturbed and may jump the grooves. Most arms with modern pickups are nearly balanced, in any case, because the force required for the cartridge is usually very small, of the order of one gram. It is our opinion that the arguments for truly balanced arms and separate down-acting springs are largely not justified. In fact, as far as rotary vibrations go, it would be better not to use a counterbalance at all, but to keep the mass of the arm at a minimum. But then the arm would perform very badly under linear oscillations; so you can

take your pick and bet your money.

In order to minimize the controversy on the advantages of an arm being mounted about the center of gravity so as to withstand linear shocks, in the RABCO arm described here the vertical pivot axis does pass through the center of gravity. That is, it is off-set slightly from the horizontal pivot so that the horizontal linear vibrations do not cause the arm to move across the record. The vertical force is provided by an adjustable rotary counterweight which is so proportioned that each turn is equal to an unbalanced force (at the stylus) of one gram. We believe the whole matter of arm balance is a minor problem. All good phonograph systems should be mounted on springs and should be isolated from the vibrations of the room and of the cabinet not only to protect the arm from jumping, but to minimize acoustic feedback which is a much more serious problem.

One of the other arguments against using spring forces on the arm is that it is extremely difficult to make such a spring constant for various vertical positions of the arm, such as those experienced in record players. That is, as a stack of records get larger, the spring forces change. One could conceivably design springs of very great length, or other mechanisms, to keep the vertical force constant but, again, this is a fine point and in our opinion it is not important. A slight change in vertical pressure, kept within permissible tolerances, will not affect the performance of a cartridge. In the RABCO arm this is not a problem because the arm is not intended for record changers and it is assumed that one record will be played at a time so that the counterbalancing technique used will be entirely satisfactory.

Cables

The audio cables from the arm, and the servo control leads, are anchored to the carriage so that their stiffness is overcome by the servo motor and not by the stylus.

These wires can be of any desired thickness and with any desired shielding and their stiffness does not give rise to any difficulty, as is the case in other arms.

Some Details

Some additional technical details of the Servo Arm may be of interest. A crossed-wire contact is used to control the servo system itself. One gold-alloy wire, about 30 thousandths thick, is attached to the inner gimbal supporting the arm. This contact moves as the arm moves across the record. A very thin spring wire of platinum alloy is attached rigidly to the moving carriage at right angles to the movable gold wire. When the arm deviates from its correct position, that is, when the cartridge swings into an angle less than 90° , the two wires touch. This sends a small current into a transistor amplifier which, in turn, drives a Swiss high-precision galvanometer motor. The power for the entire arm is supplied by a standard size C flashlight battery. Because of the high efficiency of the Swiss motor, the battery life is practically equal to its shelf life. The motor, through a suitable large reduction gear train, drives a beaded cable. In the operating mode, the moving carriage is clamped to this cable and is moved slowly along the track so as to correct any angular error of the arm. As the carriage moves, the contacts open and the servo motor coasts to a stop. In practice the cartridge is always oscillating slightly so that the contacts make and break for short periods of time and the motor receives its current in pulses. Thus, it may operate either in a more-or-less continuous mode, or only occasionally. In any case, the gearing ratio, which is close to 500 to 1 between the motor and the cable pulley, is such that the carriage motions are very slow and the motor inertia is such that the motor stops and starts smoothly so that no disturbances are transmitted to the arm. In fact, one has to watch the carriage rather closely to see it move at all.

Trip

The servo is capable of moving the carriage faster than required for tracking 33, 45 or 78 RPM records, but is slower than that required to follow the run-off groove. When the stylus enters the run-off groove, the arm angle deviates rapidly from 90° and a second platinum contact wire is touched. This operates a second Swiss motor which lifts the arm off the record. The arm can also be lifted by means of a manually operated lever. In the up position, the servo system is disengaged, the carriage is disconnected from the cable driving it, and the whole carriage and arm system can be easily moved left or right by a handle provided for this purpose.

In normal operation, the arm should not have to be touched by hand because both the lowering and raising of the arm can be done by remote means, thus greatly minimizing the danger to the stylus and to the record.

Historical Note

We would like to insert a historical note about the development of this arm. It is the result of some fifteen years of experimental work. The patent describing the basic principles of the servo system was applied for in 1954 and was issued as No. 2,915,315 in 1959. Since then we have built many variations of the servo arm using photocell servo controls, AC driving systems, mechanical servos of various kinds, and many other experimental devices. All of these had some advantages and some disadvantages. The troubles that were most difficult to overcome in the AC driven system were hum and considerations of safety. While this work was being done, new electrical items appeared on the market, particularly high-efficiency small electric motors and transistors of suitable quality. These made the present battery-driven device completely practical.

It is believed that the arm is a happy combination of meticulous engineering, reasonable cost, and superb performance. We cannot, of

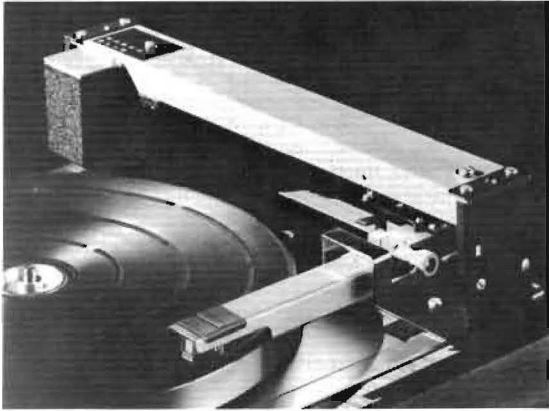
course, say that it is the final and ultimate arm for all time. No device can ever be. But certainly we are proud of its performance, and we shall exert every effort to continue to design arms for use with the best cartridges, the best turntables and the best records.

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EQUIPMENT REPORTS

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FLASHLIGHT CELL POWERS TOP-QUALITY TONE ARM

THE EQUIPMENT: Rabco SL-8, a straight-line tracking, servo-controlled pickup arm, for use with any cartridge and any manual turntable. Price: \$149.50. Manufacturer: Rabco, 11933 Tech Road, Silver Springs, Maryland 20904.

COMMENT: If ever a product could be characterized as "state of the art" the new Rabco arm is it. In fact, you might even call it ahead of the state of the art: not only does it handle today's best stereo cartridges with a degree of sophistication not encountered in any previous arm, but its characteristics suggest an ability to handle pickups themselves a jot or two better than anything presently available. In this latter sense it stands as a challenge to pickup designers, an incentive for them to advance their already fine products to new levels of finer performance. This sort of cat-chasing-tail spirit always has been a prime mover in audio, and it gladdens the soul to note that it still exists.

The SL-8 arm permits a phono cartridge to move across a record in a straight line, or radius, thus duplicating the path originally taken by the record cutter. This type of arm, rather than the kind that pivots in an arc, has been long considered a theoretically ideal goal. Such an arm would avoid problems inherent in a pivoted arm, such as lateral tracking error (the difference in degrees between the radius travelled by the record cutting head, and the arc described by a swinging arm). To be sure, this error is—in most of today's conventional or pivoted arms—quite small, but it is there because a swinging arm can be optimized for lateral tracking (i.e., can present the cartridge tangent to the record groove) at only two points on a record; at all other points it

is, strictly speaking "in error." Small, perhaps, but one of those areas into which perfectionists, unlike angels, will not fear to tread.

Another point: in presenting the pickup stylus constantly tangential to the record groove, and with equal amounts of the least possible pressure on both walls of the groove, perfect stereo tracing with the least possible record wear becomes a more attainable goal. Moreover, this general approach lends itself to an arm design that sidesteps the whole problem of skating, and the attendant need for an anti-skating or "bias" adjustment. Finally, such tracking can make for the best conditions of use of pickups with the highest compliance and the lowest tip-mass. It is especially good for elliptical styli.

Accomplishing these design aims, and more, can be credited to the Rabco SL-8 arm. It moves a pickup across a record in a true radius, with virtually no friction, negligible resonance effects, unprecedented low tracking force, no skating effects, minimum groove wear, and minimum stylus wear. What's more, although bigger and heavier than any tone arm yet encountered, it is extremely well engineered: everything about it, from the mechanism that moves the arm to the signal cables emerging from it, functions in a way that creates no problems of inertia, cable stiffness, or excessive mass to detract from the pickup's performance. It also is ruggedly constructed: after months of continuous use the SL-8 remains as responsive and foolproof as when first installed.

Physically, the SL-8 resembles a sliding T-square. The larger, fixed section houses the servo motor (which controls the arm movement) powered by a flashlight battery (C cell) which drives a bead-chain via precious metal contacts. Current drain of the battery is negligible, roughly the same as its normal "shelf life." The chain pulls a carriage that slips quietly and smoothly along four nylon wheels. Fastened to the carriage are vertical and horizontal gimbals that pivot the arm which extends outward from the carriage. The "business end" of this arm, the shell that holds the cartridge weighs with its Amphenol connector just one ounce. The vertical gimbals permit a normal amount of up-and-down play; the horizontal gimbals keep the arm tracking at a true tangent to the record groove—the slightest departure (found by CBS Labs to be plus or minus 1/6-degree, which bespeaks an amazing sensitivity) from true tangency is sensed by the horizontal gimbals, and transmitted to the servo which instantly corrects it.

User-adjustments, made when installing the arm, permit lining it up on a turntable and counterbalancing it. The shell unplugs to permit any pickup to be easily installed. When correctly set up, the only weight on the record and the only force in the groove is that provided by the cartridge itself. Everything else is "balanced out"—even the leads that carry the signal from the carriage do not become a factor in the arm's movement or the cartridge's response. Being anchored to the sliding carriage, they are effec-

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tively decoupled physically from the pickup head; as a result their thickness and shielding may be "ruggedized" without danger of stiffness and drag. The built-in stylus-force gauge is completely accurate: each complete turn represents just 1 gram. Cueing is manual and possibly a bit awkward until you get used to reaching over the record turntable to set the pickup down onto the record. The first models, by the way, lacked any internal damping which could give an impression of the stylus' bearing down "too hard" when you initially cue up. Actually, this wasn't so: the only force on the record, even when cueing up, is—to repeat—the preset tracking force of the pickup itself. Anyway, to make this operation smoother, Rabco has added some damping to the latest models. When the arm has traversed the entire record, it lifts automatically. You can recue from the beginning or at any point by sliding it back and setting it down again. If you wish to interrupt play at any portion of the record, you can simply lift the arm or press a small red button that lifts it for you.

In lab tests, the SL-8 arm was fitted with a Shure V/15 Type II and compared with the SME arm handling the same pickup. Results, to the extent that they could be accurately measured, were very similar, except for a slightly improved (lesser) low-frequency resonance with the Rabco arm. Lateral

tracking error, with the Rabco, remained zero across the record. Playing commercial stereo discs, the Rabco arm permitted the Shure to track at 0.5 gram, which of course is a lower force than the minimum of 0.75-gram recommended by Shure. Similarly, with other recent pickups, the Rabco let them track as low as, or slightly lower than, the recommended forces. One should not, however, expect to hear dramatic tonal differences when using the SL-8 arm: the tracing distortion inherent in the best of today's pickups likely is masking whatever improvement in tracking the SL-8 contributes. For this reason, plus the unit's cost and the need to use it in conjunction with a manual turntable, it isn't likely to become an audio "best-seller." We can, however, see it appealing to a knowledgeable and well-heeled group of perfectionists who must have the best available arm today which also is ready for the pickup of tomorrow.

The SL-8 arm may be purchased "as is" for installation as you choose. It also may be ordered through Rabco with the following optional accessories, additional cost indicated: Shure V/15 Type II installed at factory, add \$67.50; arm fitted to a Thorens TD 150 turntable, add \$85; walnut base for TD 150, add \$12; additional plug-in cartridge shells, add \$5 each.

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