REPRODUCTION OF MICROGROOVE RECORDINGS

Technical details covering the new Columbia LP records and the styli and turntable equipment required.

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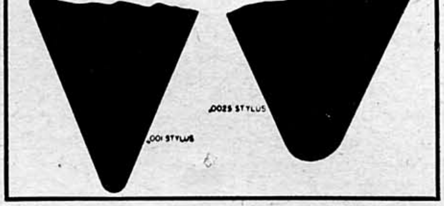
Jeanne Cagney, star of United Artist's "The Time of Your Life," auditions one of the new Columbia Microgroove records on the Philco 1405. This table model combination has two tone arms plus automatic record changer to play standard records automatically as well as the new Long-Playing Microgroove discs.

IT IS A GOOD many years since *Columbia* released a demonstration record with an announcer's voice saying, "Columbia Double Disc Records—Music on both sides! A different selection on each side! Double value for your money, plain as daylight!" Once more, with the Microgroove long playing records, *Columbia* is able to say, "Double value for your money!" This time their achievement represents the resolution of technical difficulties considerably greater in magnitude than those involved in providing an impression on both sides of the record.

It is of some historical interest to note that Edison manufactured vertical records recorded at approximately 200 lines per inch which in their day were technically superior to competitive products. It is also interesting that a diamond stylus was provided for playback. Edison's vertical records covered the approximate frequency range of 150 to 4000 cycles per second, which for his era was indeed remarkable. In producing the Microgroove discs, *Columbia* faced the problem of recording and pressing at groove pitches of 180 to 220 lines per inch on lateral records with a frequency response range from 30 to 10,000 cycles per second. Initially released pressings indicate that they have been extremely successful. Specifically, records ML4023 (Dvorak's Symphony No. 5 in E Minor, The Philadelphia Orchestra conducted by Eugene Ormandy) and ML4056 (a collection of operatic arias sung by Bidu Sayao), when reproduced on suitable equipment, are distinctly superior to usual standard speed recordings with regard to surface noise, frequency response, and "clean" reproduction. They are a great deal better than most audio and recording engineers expected them to be.

It should be borne in mind that an engineering staff concerned with Microgroove discs faces all of the not inconsiderable problems involved in recording and pressing under standard conditions multiplied by a dimensional factor of approximately 2, in addition to certain special considerations. To establish a reference for this, it may be pointed out that at 33⅓ r.p.m. using a .0025 spherical radius for the playback stylus tip, the 7-inch diameter groove will be down about 20 decibels in frequency response at 10,000 cycles per second. The smaller the diameter (the lower the relative velocity of the groove with respect to the stylus), the shorter is the wavelength at a given frequency and the more abrupt are the corners the stylus is required to track. When a half wavelength is comparable to the dimensions of the stylus, it can only bounce slightly in greatly distorted saw-tooth type waveforms. If the stylus radius is reduced to .001", it should be able to track a shorter wavelength successfully. This is true only if proper coupling to the groove is obtained, which requires proportional scaling down of groove dimensions. This leaves an excessive amount of land between the grooves and makes it possible to close up the pitch. (Loading effects on the cutter are neglected here since they may be properly compensated with little difficulty.) The amplitude of the cutter drive must also be lower in proportion. Note, too, that the diameter at which the 20 decibel loss appears for 10,000 cycles per second becomes proportionally smaller. Microgroove recordings are cut in no closer than a 4¾ inch diameter so that the difficulties are appreciably reduced.

Fig. 1. A comparison of stylus sizes used with regular and Microgroove recordings.



In all disc recording the excursion

amplitude is limited by groove spacing at low frequencies, which is the principal reason for constant amplitude recording below a turnover frequency around 300 to 500 cycles per second. This limitation does not appear at high frequencies recorded at constant velocity because the excursion amplitude at constant velocity is inversely proportional to frequency. In Microgroove recording the maximum amplitude of low frequencies is about half the amplitude possible with standard grooves. This introduces the advantage that high frequencies may be recorded at higher *relative* amplitudes (with respect to low frequencies) with Microgroove techniques. In standard groove recordings it is common practice to attempt to compensate for losses at high frequencies in the relatively small diameter portion of the records with equalization that boosts the high frequency energy. It has also been deemed desirable to use recording curves such as the NAB and Orthacoustic curves with considerable high frequency pre-emphasis to allow for noise reduction with de-emphasis networks in the playback system. In accordance with the figures discussed above, this would mean that the combination of pre-emphasis and diameter equalization in standard groove recording would require a rising characteristic amounting to between 35 and 40 decibels at 10,000 cycles per second at seven-inch diameters on 33⅓ r.p.m. recordings. In Microgroove recordings the obvious associated problems are minimized by the fact that a given high frequency excursion is relatively larger with respect to the maximum allowable low frequency excursion, plus the fact that the recorded section is not carried to as small relative inner diameters.

The design of playback cartridges for Microgroove records may include essentially the same mechanical properties as for standard records. However, the limitation on low frequency maximum excursions imposed by reduced land area between the grooves may again be used to advantage. With standard groove techniques there is an approximately equal amplitude tracking problem at low and high frequencies. With Microgroove dimensions the low frequency tracking problem is greatly reduced while the high frequency tracking problem is unaffected. This means that it becomes possible to favor high frequency tracking characteristics in the design of the pickup cartridge.

There is one important exception in scaling the dimensional relationships. In considering the reduction in surface area beneath the stylus tip when its spherical radius is reduced from .0025 to .001, the factor is squared. This is the derivation of the assumption that a tracking pressure of approximately five grams is suitable. If 20 grams is satisfactory for a .0025 stylus in a standard groove, then five grams may be accepted as suitable for a .001 stylus in a microgroove. In this connection it may be pointed out that high quality equipment for standard discs is usually designed with tracking pressures approximating 20 grams or less. If suitable precautions in connection with stylus materials, pickup arm design and turntable characteristics are followed, the five-gram tracking pressures are very satisfactory with properly designed cartridges.

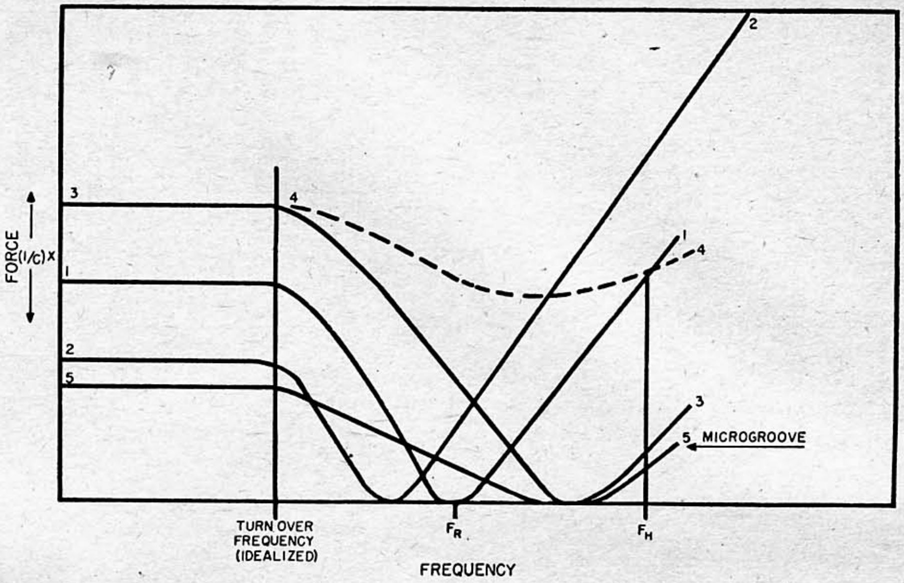


Fig. 2. Family of curves indicating design considerations for optimum pickup structures with respect to reactive and resistive forces.

The light tracking pressure brings up another problem in pickup design which is worthy of discussion. The lateral forces on the stylus must never be allowed to exceed the tracking pressure or the needle will be forced out of the groove. The forces acting on the stylus may be expressed in a simple differential equation:

$$\Sigma F = M\frac{d^2x}{dt^2} + R\frac{dx}{dt} - \frac{X}{C}$$

ΣF is the sum of all the forces acting on the stylus.

M is the moment of inertia referred to the stylus tip.

R is the damping factor in mechanical ohms.

C is the compliance of the stylus suspension.

x is the displacement of the stylus tip.

This states that the sum of the forces producing lateral motion at the stylus tip consists of the forces required to overcome the damping in the suspension, to accelerate the mass of the stylus and its suspension, and the force required to displace the stylus against its own stiffness. The stiffness term is important only where the displacement is large, hence principally at frequencies below the turnover point (approximately 500 c.p.s.) Good engineering practice in the design of

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Webster-Chicago's new Model 133 automatic Microgroove record changer. Equipped with a new balanced tone arm, the changer will handle ten 12" or twelve 10" records at 33⅓ r.p.m. turntable speed so that up to four hours of continuous record play can be obtained with a single loading. The unit is mounted on a metal base.

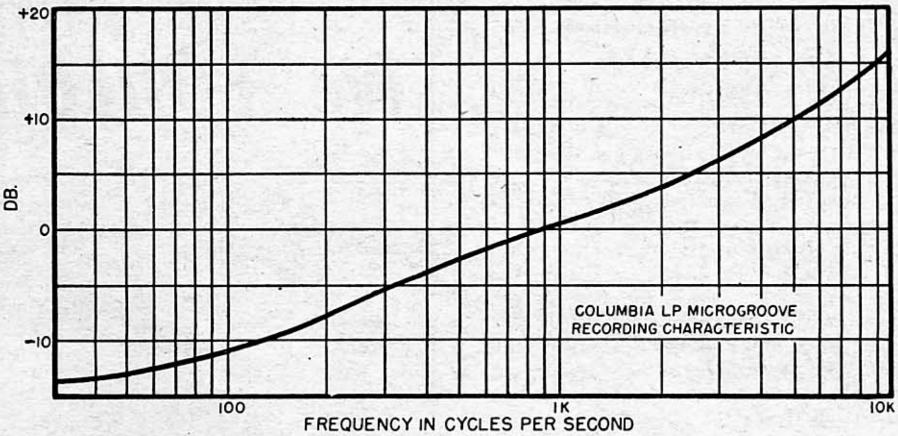

Fig. 3. Frequency characteristic of the Columbia long-playing (LP) Microgroove records.

Referring to the family of curves in Fig. 2, the total force is plotted against frequency. Curve 1 is an idealized condition for pickup characteristics intended for use on records with standard groove dimensions. In the region below turnover, the principal force is $\frac{1}{C}x$, at F_r the forces are resistive only, and at F_h the system is essentially mass controlled. Theoretically, with a record that includes unusually heavy bass passages, Curve 2 would be desirable with F_r moved downward and the stiffness reduced. With Microgroove recordings the maximum displacement at low frequencies is lowered, while it becomes possible to maintain the maximum high frequency excursion so that it is relatively larger with respect to the low frequency amplitude. This makes it practical to design the mechanical characteristics of the pickup in accordance with Curve 3, moving F_r in an upward direction and favoring the high frequency end of the spectrum. When large amounts of equalization (diameter plus high frequency pre-emphasis) are introduced, the curve is effectively modified to appear as shown by Curve 4. However, at low frequencies the magnitudes of the absolute values of this curve are lowered so that the low frequency end is actually lower than the curve indicated as ideal for standard records. Designing in accordance with these considerations makes it possible to produce a pickup for reproducing Microgroove records that has appreciable advantages over the mechanical design used for standard groove dimensions.

The unit load on the stylus and record material with Microgroove records with a .001 stylus at five grams tracking pressure has been shown to be comparable to the load with conventional reproducers at one ounce of tracking pressure. This means that conditions for wear of the stylus and the record may be assumed to be closely similar. Exhaustive investigations with conventional reproducers have shown that metal tips wear rapidly even on vinyl pressings, and that sapphire styli are only moderately superior in this respect. Surface dirt makes the vinyl record a lapping medium. The wear from a shellac disc is very much like grinding with a coarse stone whereas the wear from a vinyl disc is more like lapping with a fine stone. It is to be expected, and is demonstrated by test, that any stylus under given conditions will wear much longer on vinyl records than on shellac pressings. The softer materials such as osmium and sapphire do wear down, however, even on vinyl records. It must be borne in mind that the hardness scale is by no means linear,

Table 1. Specifications covering Columbia's LP Microgroove records. Tolerances indicate careful control of manufacturing processes to insure consistent results.

	10″ Record	12″ Record
Diameter	9⅞″ ± 1/32″	11⅞″ ± 1/32″
Thickness	.075″ ± .010″	.075″ ± .010″
Center hole	.286″ + .001″ − .002″	.286″ + .001″ − .002″
Concentricity	Run-out not to exceed .010″	Run-out not to exceed .010″
First record groove diameter	9½″ ± .020″	11½″ ± .020″
Minimum inside diameter	4¾″	4¾″
Eccentric groove diameter	4 7/16″	4 7/16″
Eccentric groove run-out	.250″ ± .015″	.250″ ± .015″
	Shape same as music grooves	Shape same as music grooves
Speed	33⅓ r.p.m.	33⅓ r.p.m.
	Groove Shape	
Included angle	87° ± 3°	87° ± 3°
Tip Radius	Under .0002″	Under .0002″
Width at top	.0027″ to .003″	.0027″ to .003″

and that even though sapphire is 9 and diamond is 10 the difference in hardness between them is very great. The hardness scale is an arbitrary scratch test source of information that does not truly indicate wear or penetration hardness. It is safe to say that no wear test will ever show diamond as being less than ten times the hardness of sapphire, and that 20 to 25 is probably a more realistic figure.

A given dimension for a flat surface worn on a .001 stylus is relatively larger, both with respect to the stylus and the groove, than a flat of the same size on a standard stylus. It is clear that a diamond stylus becomes even more desirable for playing Microgroove records than for standard types. It is worthy of note that many people have a misconception about the "brittle" qualities of diamond styli or are fearful of cleavage characteristics. High quality diamond styli are made from entire diamond crystals, and a chipped diamond stylus of this type is at least extremely rare. None has ever been observed in the experience of the writers.

It is, of course, a distinct advantage that the .001 stylus be used only on vinyl surfaces. Where both shellac and vinyl records are to be played, the shellac records will eventually wear a flat on the stylus that is not serious with respect to the abrasive shellac surfaces but is disastrously destructive for vinyl surfaces. With a properly ground *and polished* sapphire stylus used only on Microgroove vinyl surfaces at five grams tracking pressure in a well designed pickup cartridge and arm, it is reasonable to suppose that 500 to 1000 hours of playing time may be anticipated without difficulties.

It is obvious that the very light tracking pressures make the solution of mechanical problems considerably more critical. Vertical and lateral vibration of the turntable become relatively more important because low frequency disturbances are of greater magnitude with respect to the recorded signal than with conventional records. Hum and rumble must be at least six db. lower in order to have the same signal-to-noise ratio as with quiet standard records. The lower signal level also means, of course, that somewhat more voltage amplification is required for a given output from an amplifier and this, while not of serious consequence, inevitably requires lower inherent noise and microphonics for comparable results.

There has been some question as to whether noise suppression systems have real value in connection with the *LP* records. Earlier in this article it was mentioned that the surfaces of Microgroove recordings observed to date are exceptionally quiet. However, it is obvious that with any recording and reproducing system depending on a mechanically engraved signal, the accumulation of dirt and wear will introduce increasing percentages of noise. The surface noise from Microgroove records is initially appreciably lower than from average standard records, and consequently can be more completely removed with a given method of suppression. It is also true that since the average signal is lower, the signal-to-noise ratio with respect to turntable rumble, hum, etc., is appreciably poorer. This means that bandpass systems, such as the Dynamic Noise Suppressor originated by H. H. Scott, have a worthwhile advantage in connection with low frequency noise. With these records, as well as with other types, a thorough flushing of the grooves with soap and water periodically will aid in holding down the noise level.

The recording curve shown in Fig. 3 indicates a slope of approximately four db. per octave with a slight rise at both ends. This is sufficiently close to the NAB/Orthacoustic characteristic for satisfactory results with standard equalizers. —30—

International Short-Wave

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after another and were re-established in the interior. Besides these, four more stations were built—one in Kangting, one in Sichang, one in Kansu, while the other was mobile. The Kiangsi Broadcasting Station was taken over. Until V-J Day, the Central Broadcasting Administration, on its vast battle-fronts in the great interior, had under its control eleven broadcasting stations with a total of 18 transmitters, thus organizing a fairly-strong broadcasting network. The 11 stations were—Central, International (both in Chungking), Kunming, Kweichow, Fukien, Shensi, Sian, Hunan, Kansu, Sikang, and the mobile unit. With the exception of the latter station (broadcasts from which were directed primarily to the Third War Area), the areas served by these stations ranged from the local province or neighboring provinces, up to the whole country and even to America, Europe, and the South Seas. The total radiated power reached 145 kw., while the daily operation periods were more than 90 hours. Even though under extremely difficult conditions, Chinese broadcasting during the war years made obvious improvements over prewar days.

"On August 15, 1945 (August 14 in America), the war concluded victoriously and the Japanese surrendered unconditionally. The Japanese and the puppet governments had many radio stations in their occupied areas, and these stations had been taken over successively by the Central Broadcasting Administration since August 27. They were located respectively in these 21 cities—Nanking, Shanghai, Hankow, Amoy, Peiping, Tietsin, Paoting, Taiyuan, Shihchiachung, Kweisui, Tangshan, Tsingtao, Kaifeng, Hauchow, Hangchow, Canton, Taipei, Taichung, Tainan, Hualienkang, and Chiayi. The transmitters totaled 41,