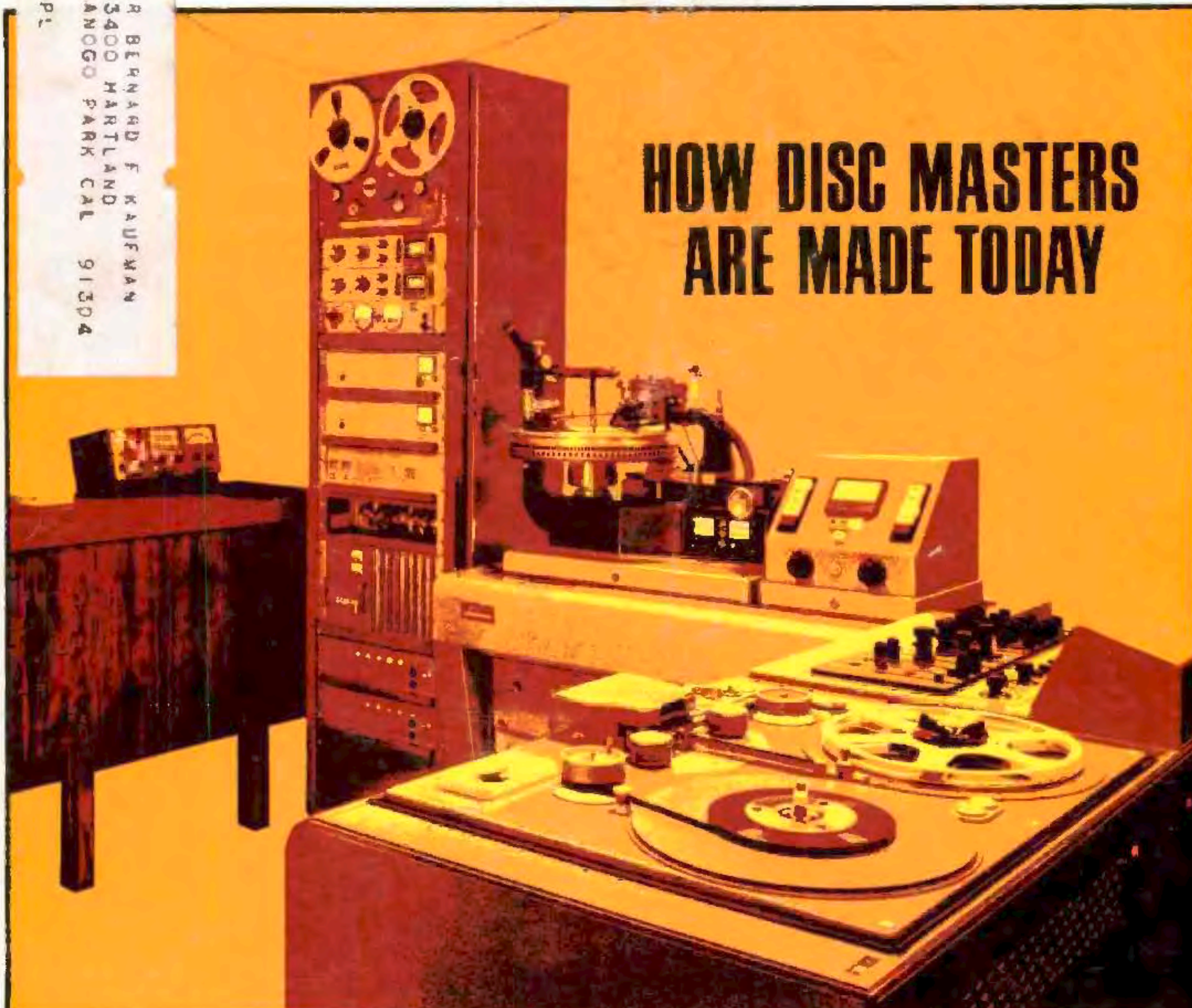

HOW DISC MASTERS
ARE MADE TODAY

Part of a cutting room at Sterling Sound.

How Disc-Masters Are Made Today

R. LEE HULKO*

RECORD MASTERING is both science and art. The production of quality record masters is dependent upon numerous factors, and is a precise co-ordination of man and machine.

Mastering is the step between recording and manufacturing. The master lacquer disc is electroplated after it is cut, and the metal part which is then separated from the lacquer contains ridges instead of grooves. This metal plate is used as a die on the press which stamps out the vinyl plastic records.

Without even considering the sound aspect, we are dealing with a precision mechanical operation. The size of a record groove is often two one-thousandths of an inch across, less than the thickness of a human hair, and its length on one LP can be almost a mile. With its wiggles up and down it must never get smaller than two mils, and from side to side it must never cross into the groove beside it. The master lacquer, or acetate as it is often called, must be perfect. The spacing and dimensions must adhere to rigid specifications to ensure that the record will play on all types of equipment, and the master should not present any problems in subsequent operations of plating and pressing.

*President, Sterling Sound, Inc., New York, N.Y.

The Cutting Lathe

State-of-the-art technology provides the mastering studio with high-quality tape-to-disc transfer equipment with a high degree of automation and reliability. The lathe, in its simplest form, is a machine which revolves the blank disc and slowly moves the cutterhead and stylus across the disc surface. The rate at which the stylus moves across the disc is referred to as the pitch and it is measured in lines per inch. When grooves are unmodulated they can be very close together, cut at fine pitch, but as modulation increases, the pitch must be increased to leave room for the "wiggles" of the groove. This is called variable-pitch cutting and the rate varies on a normal LP from about 400 lines per inch to perhaps 150 lines per inch. Fixed-pitch lathes are still used but their pitch must be set coarse enough to allow for the highest modulation, which wastes considerable space on quiet passages.

In stereo cutting, the stylus is modulated in a vertical plane as well as laterally so that some form of groove-width control is required in order to maintain a minimum groove size, usually 2 mils. Because of the "V" shape of the groove, width control is accomplished by deepening the groove, an action called depth control. During quiet or lateral passages the depth is decreased to conserve space, and as vertical modulation increases, the basic groove depth is increased. As depth is increased, basic pitch must also be increased proportionately to make room for the wider groove. This pitch-and-depth control must take place just before actual modulation so an advance head is needed on the tape machine to feed preview information to the lathe.

The Neumann VMS 66, a modern, sophisticated lathe, uses a computer to control pitch and depth in a way that wastes no space. The computer contains sixteen memory cells which store modulation and preview information separately. The memories are alternately charged and discharged every quarter revolution of the turntable and the control signals are stored for half a revolution. By utilizing the right and left signals separately, space is provided only for the groove wall that needs it.

When cutting at fine pitch, additional control is required to prevent "wall echo." It is particularly noticeable at the beginning and end of unmodulated passages in the record and sounds like tape print-through. Wall echo usually gets worse during plating and pressing so steps must be taken during mastering to prevent it. This is accomplished by a manual or automatic device which further increases the pitch at the beginning and end of these quiet passages.

The lathe is equipped with timing and switching devices which control lead-in, spiraling, and lead-out. These functions can also be programmed by the use of a photoelectric sensing device on the tape machine which will trigger spiraling and lead-out functions of the lathe when it senses a leader in the tape.

All professional lathes utilize a vacuum to remove the "chip," the thread cut out of the groove, and to hold the blank flat and firm on the turntable. A suitable device for the purpose is a suction unit of the type used to operate a player piano. It is small and almost silent. A Variac in the motor circuit is used to adjust the air flow.

The tape machine must be equipped with an extra playback head and a means of varying the distance between the heads in order to keep the preview time the same regardless of the tape or disc speed. The best machine for this purpose is the Telefunken M-10a which has a special head assembly which allows the preview distance to be varied from 6.4 to 16.5 inches.

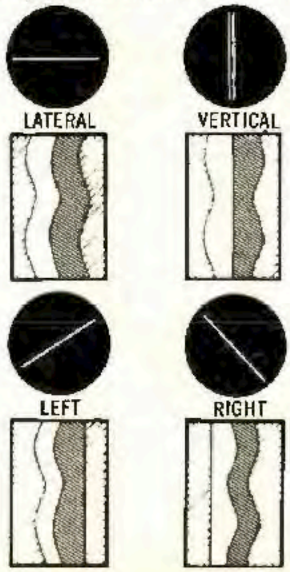
State-of-the-art cutterheads use large amounts of regenerative feedback to achieve a frequency-response characteristic that is virtually flat and with very low distortion. Separation can be better than 35 dB throughout the audio range. To help in dissipating the heat produced by currents in excess of 1.5 amps in each of the cutterhead drive coils, a small amount of helium is fed into the cutterhead at all times. The helium provides a better path than air for the heat to travel from the coils to the magnet structure where it is dissipated. The Neumann system provides a special protection circuit which monitors the temperature of the drive coils and disconnects the cutterhead when a dangerous temperature is reached.

In the channel between the tape machine and the cutter amplifiers are various equalizers, limiters, compressors, and control devices. It is important to remember that any signal processing in the cutting channel must also be done in the preview channel in order to maintain accurate pitch-and-depth control.

Monitoring facilites are important. In addition to a good listening system and standard VU meters, a peak indicator is extremely useful. A light-beam peak-indicating meter shows cutter action more accurately since it reacts to peaks that escape the VU meter. Also, the peak meter has a scale calibrated from +5 to −50 compared to +3 to −20 on the VU meter.

For monitoring phase, two devices are useful. The first is a compatibility meter, which has a scale with zero center. A "0" indication shows no phase relationship between right and left (total separation). Full scale on the + side indicates a completely in-phase signal (mono, lateral, center channel). Full scale on the − side indicates an anti-phase signal—vertical component. Desired readings are in the + direction, indicating a greater degree of lateral stylus motion than vertical. The other device is an X/Y oscilloscope with a matrix network at its inputs or the CRT rotated 45° so that a mono signal produces a horizontal sweep and an anti-phase signal produces a vertical sweep. Left and right form the arms of an X. The display shows lateral/vertical ratio, channel balance, and level. It is also very useful when cutting mono with a stereo system, as small variations from the lateral mode are easily seen. With an equalizer to produce the RIAA cutting curve, the display will show actual stylus motion.

Fig. 1. Oscilloscope display with corresponding groove shown below them.



Since most of the mechanical operations are performed by the machine itself, the cutting engineer is free to concentrate on fine detail and esthetics. In an ideal situation the mastering studio must make a one-to-one transfer from tape to disc. Sometimes adjustments are required and are made at the request of the producer or at the discretion of the mastering engineer. In custom mastering it is important for the producer and the engineer to work together and to understand each other.

When cutting records, one is always faced with the problem of level vs. playing time. The louder the record, the greater the groove excursions, the coarser the pitch must be, so the less time can be recorded on the disc. The most common request is for "more level and more bass." The mastering engineer must please his client with more level and bass but at the same time make a record that doesn't skip or distort, and which conforms to space limitations on the disc. The engineer must use his skills to manipulate and optimize several interdependent variables, such as pitch, depth, level, and bass-and-treble equalization, and have modulation end at the preferred 5.5-in. inside diameter. RIAA specifications allow modulated grooves to a diameter of 4.75 in. and it is often necessary to use the entire allowed space, but due to tracing problems in playback high frequencies fall off seriously and distortion increases significantly past the 5.5-in. mark.

The common level standard or "0" reference level is 7 cm/sec lateral at 1000 Hz. Usual peaks for LP's are 2 or 3-dB above this reference level, and for 45's the average level is +4- or +6-dB peaks. Many records have peaks higher than this and many have much lower average levels. The final level selected is a consideration of length, treble, bass, vertical content, and established levels on a particular label. A limiter is often used to control flash peaks that might make the record mis-track.

Greatest tracking problems are caused by heavy bass, particularly side-channel bass. Corrective measures are equalizing, vertical limiting, or the use of a vertical roll-off network. This last method has the effect of moving bass frequencies to the center. The shift is usually not noticeable since low frequencies are non-directional in most listening situations. High-level 45's should be cut with such a device to assist in tracking on inexpensive players, and the cutting room should be equipped with one of these machines for performing tracking tests.

At the other end of the spectrum, some problems are created by excessive treble. Because of the RIAA pre-emphasis curve used in disc recording, there is always a danger of amplifier overload and high cutterhead currents which can cause cutterhead damage. Very high frequencies at high level often produce groove modulations too small to be traced by the playback stylus and end up only as a source of noise in the pressing. High-frequency problems are corrected by equalizing or treble limiting, or by half-speed cutting. When using this last technique the tape and disc run at half speed, thus cutting all frequencies in half. No response is required above 10 kHz but the system must operate at very low frequencies and corrective equalization must be employed to restore the proper tape and disc curves.

The best solution to most of these problems is to reduce the overall level. Often 1 dB can make a significant difference. Corrective techniques, when properly employed, usually do not result in any aural degradation and in fact will probably enhance the sound.

When tapes of unknown quality come in for mastering it is a good idea at least to spot check them for azimuth, level, equalization, and timing. It is not at all uncommon to be changing equalization, limiting, levels, and even phase between bands on an LP. Careful notes should be made for each master for future reference. If problem areas are encountered it is often helpful to make test cuts for examination and playback. Completed masters should not be played and it is a good idea to cut part of the first band in the test area for playback checking.

The microscope is an invaluable tool in the cutting room. The most useful is about 200× and has a light-projecting lens which surrounds the viewing lens. With the microscope absolutely perpendicular to the disc surface and a strong lighting unit it is possible to look right down into the groove. The land—the area between the grooves—appears black, and each groove appears as three bright lines, indicating the groove bottom and the groove/land intersections. Modulation on the groove walls appears white and black. A reticle in the microscope, calibrated in mils (thousands of an inch) allows the groove to be measured. Minimum groove width should be about 2 mils so that playback stylus is always riding on the walls of the groove. Examination of the groove will show the condition of the cutting stylus, and the effectiveness of stylus heating and chip removal. Problems such as overcutting, excessive treble or bass, or excessive modulation will seen easily. The groove should be bright and shiny and should have no rough or torn parts.

The blank disc used for cutting is made from a flat aluminum plate with a thin coating of cellulose nitrate applied to its surface. The blank should be inspected visually before it is used to make sure that there are no bumps, bubbles, or other flaws. The evenness of the surface can be checked by watching the reflection of a straight edge in the acetate. The blank size for 12-in. records is 14-in., and for 7-in. records a blank with a diameter of 10, 12, or 14 in. is used, depending on the requirements of the plating plant. The extra space is necessary for cutting test grooves and for handling.

The stylus should never be allowed to cut into the aluminum base of the acetate. Since the synthetic sapphire stylus is made from an aluminum oxide crystal, the stylus has an affinity for aluminum and it is practically impossible to remove the metal from the stylus. If the stylus should hit the aluminum it is safer and faster to discard the stylus than to attempt its salvage. The stylus should not be touched with the fingers and should be handled by its heater wires or with non magnetic tweezers. The stylus should be replaced for a variety of faults: when the cut is no longer shiny and smooth, when the tip radius exceeds 0.25 mils (bottom line 0.5 mils), when it becomes chipped, when the noise level is too great or when high-frequency response falls off. The cutting edges will start showing signs of wear after 10 hours of cutting and the tip radius will be too large after about 20 hours.

The stylus is heated to reduce noise level, to improve high-frequency response, and to prolong stylus life. The styli are supplied with several turns of nichrome wire wound around the shank and held by ceramic cement. Silver plating on the leads prevents them from heating and avoids the danger of burning the chip if it should become fouled. The degree of heat is adjusted with a rheostat and heater current is indicated on a meter. Heat is adjusted to the value that will produce the lowest hiss level in an unmodulated groove. It is best to check the noise level at outside and inside diameters and use an average setting. Since more heat is required at smaller diameters due to slower groove speed, it is sometimes helpful, in critical work, to increase heat slightly towards the center of the record. With the microscope described previously it is possible to adjust the heat visually. While watching an unmodulated groove it can be seen that too little heat produces a groove wall with a gray appearance, while too much heat will produce score lines along the wall. The heat setting should be checked with each new stylus or new batch

(continued on page 79)

Disc Mastering

(Continued from page 29)

of acetate, or if suction is changed.

Positioning of the stylus in the cutterhead is very important. A fast and safe method is to use a stand which securely clamps the cutterhead and provides a microscope with a calibrated hair-line reticle. It is a simple matter to rotate the stylus in relation to the hair line to position the cutting edges. The cutterhead is positioned in its suspension by watching reflections of the cutterhead and stylus on an acetate. Another method is to place a small non-metallic block on the turntable under the cutterhead and line up the cutter as it is lowered. The stylus should be perpendicular to the disc surface in all planes. The heater wires should be left slack so that stylus motion is not affected.

The chip pickup tube should be positioned within a quarter of an inch behind the stylus and barely off the acetate surface. The suction should be adjusted to the lowest air flow that will still remove the chip. Excessive air flow can tear the chip out of the groove, or can actually modulate the stylus. In any case the noise it causes makes monitoring difficult. With a low suction it is usually necessary to blow on the stylus as the cutter is lowered to get the chip picked up, but a switching device can be used to increase the vacuum just at the time the cutter is lowered.

The electrical performance of the transfer channel should be checked regularly to make sure it is operating within specifications. Measurements should be made on the whole chain, in addition to individual units. A most important check is an A/B comparison between the master tape and test cuts played on a calibrated turntable.

Mastering is perhaps the most important single step in record production. It is during this process that the product takes its form for the consumer. The most important ingredients are accurate reliable equipment and an engineer with an intimate knowledge of his equipment and the entire process. Æ