Disc Mastering

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The author covers the basic elements—lathes, cutterheads, cutting styli, and instantaneous recording discs, in his discourse on the current state of the art.

In the process of transferring taped material to an acetate record for mastering purposes, the prime consideration is to make certain that none of the high quality of the master tape is lost in the process. To achieve consistent, reliable results with a minimum of service or attention, computer technology is now being utilized to provide complete automation of the entire recording system in performing the functions of switching, timing, counting and programming.

By merely depressing a button, it is possible to initiate a series of events which include dropping the cutterhead, cutting a coarse spiral lead-in groove to a fixed diameter, recording the program material, cutting coarse spirals for banding if necessary, cutting a coarse spiral lead-out groove, and finally lifting the cutterhead at a predetermined diameter. Other functions automatically performed are pitch and depth control and on-off switching of the vacuum, stylus head, and tape machine.

In this article, some of the salient features of recording equipment available in today's market will be discussed, as well as some of the more recent technical improvements.

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Recording Lathes

Generally, the drive mechanism consists of a hysterisis-synchronous motor, utilizing belt coupling for speed selection. Belt-driven units are characterized by extremely low rumble (vertical and lateral) figures, of the order of -70dB below a 5 cm/sec. signal. To minimize belt stretching problems when switching from 33 1/3 to 45 or 78 rpm, a two-speed motor is sometimes employed instead of the usual single-speed units. By this means, the motor pulley sizes are kept dimensionally close to each other, so that changes in motor speed compensate for the otherwise large differences in pulley diameters.

Since low wow and flutter figures (typically .02% peak-to peak) must be maintained, the turntable is designed for maximum flywheel effect and is adequately isolated from the drive mechanism by a mechanical vibration filter assembly. Ideally, the turntable is fabricated of an aluminum casting to eliminate the problem of magnetic attraction between turntable and the cutterhead. Annular rings are machined at various diameters for the purpose of suction holddown, to accommodate record blanks from 7-in. to 16-in. in diameter. Provision is easily made to shut off the holddown action at the outer diameters when not required, thereby eliminating objectionable escaping air noise.

Normally, the turntable drive system is connected by mechanical linkage to the feedscrew assembly via a planetary drive and gear assembly. Some designs, however, incorporate a self-powered feedscrew for guiding the cutterhead carriage, entirely independent of the mechanical linkage from the turntable's drive system. In this arrangement, a separate motor powers the feedscrew, thus eliminating any extra load on the drive system. There are also models in which an auxiliary feedscrew is employed for the inspection microscope, which travels in with the cutter and allows a "standstill" groove effect for easy groove inspection.

Monophonic lateral recordings are commonly mastered with variable groove pitch in order to fully utilize the available recording area. This may be accomplished automatically by a servo-controlled system which derives its feed from an advance playback head reproducing the program material one or two seconds ahead of the cutterhead. The system thus provides a coarser pitch in anticipation of high-amplitude low-frequency passages during the tape-to-disc mastering operation. In some designs, pitch is continuously variable from 32 to 800 lines-per-inch with the ability to manually record over 1000 lines-per-inch if necessary.

Stereo recording, however, involves both lateral and vertical stylus excursions so that in addition to control of groove pitch, control of groove depth is also required. In stereo cutterheads which employ advance-ball suspension, variable depth control may be achieved by operating a solenoid on the advance-ball assembly. This type of suspension, however, is prone to rumble caused by undesirable vertical modulation of the cutterhead, due to any unevenness of the acetate surface. Furthermore, a condition known as "scoring" may occur when a dirt deposit adheres to the sapphire advance ball, plowing through the soft lacquer as the ball rides the acetate blank. To offset these problems, some carriages accommodate a floating- or moving-coil suspension assembly to either replace or work in combination with the advance-ball suspension.

Two typical examples of such sophisticated recording equipment are the Scully Automatic Disc Recording Lathe and the Neumann AM-66 Computer-Controlled Lathe.

Cutterheads

The need for a reliable, rugged cutting head is of major importance if we are to meet the increasing demands for quality disc recording. Particular care must be taken in cutterhead design to achieve stable operation under widely varying environments, without danger of burnout or mechanical damage.

In modern professional cutterheads, the force to actuate the cutting stylus is provided either by a moving coil attached to a fixed armature, or a fixed coil and moving armature, either in a magnetic field. The two types are classified respectively as *dynamic* or *magnetic* transducers. In the dynamic configuration, the mechanical resonant peak lies in the 800 to 1500 Hz range and is effectively removed by *motional feedback*. This arrangement consists of an amplitude-sensitive feedback coil magnetically shielded from the driving coil and placed in close proximity to the stylus chuck. The feedback signal, which is directly proportional to stylus motion, is amplified and fed back (out of phase) to the input of the driving amplifier, thus correcting changes in level and response. An advantage of this technique is that no loading effect is imposed on the driving coil, so that a wide effective range of feedback control is obtained with good linearity throughout the usable frequency range. Harmonic distortion levels with dynamic cutting systems are significantly less than 1%. Dynamic cutters in common industry use are the Westrex 2-B monophonic and the Neumann SX-45 stereo cutting systems.

In *magnetic* cutting systems, the resonant peak generally lies in the 4 to 8 KHz range and may be damped out by silicone damping material in the form of plastic, grease, or fluid, sealed into the gaps between the armature and pole pieces. Cutterhead feedback may be provided by a secondary winding placed closer to the armature than the cutter driving coil. This feedback arrangement is *non-motional* since the secondary winding senses only armature saturation. Any distortion created within the armature due to eddy currents or other magnetic circuit losses is thereby reduced.

Magnetic cutters are somewhat sensitive to the acetate loading effects which increase with decreasing linear velocity, so that the high frequencies are attenuated at the inner diameters of the disc. In some cutterhead designs, this condition is avoided by increasing the stiffness of armature motion so that the resonant frequency is raised to about 10 kHz. Unfortunately, this results in reduced sensitivity so that the power requirements of the driving amplifier are greatly increased. Although magnetic cutting systems are more rugged and considerably less costly than dynamic types, they are less sensitive and display higher harmonic distortion levels (of the order of 2 to 4%). Among the magnetic types commercially available are the Haeco SC-1 and Grampian "D" cutters.

Cutting Styli

Present-day research is being directed toward the development of the perfect recording stylus. Sapphire is still considered to be the most suitable material available for producing a very fine cutting edge. This is mainly due to its crystalline structure, which is characterized by a lack of grain and absence of cleavage planes, thus enabling the material to be ground to a sharply acute angle.

The common hot-stylus technique offers a practical solution to the problems of achieving higher frequency response, longer stylus life, and better signal-to-noise ratio. With this technique, a substantial reduction in surface noise is indeed obtained, particularly at the inner diameters of the recording disc. A further advantage is that it minimizes mechanical loading on the cutterhead, thus increasing the efficiency of the cutting system.

In a more recent development, the conventional flat-faced stylus surface is replaced by a *scooped* stylus, in which the cutting face is ground in a circular arc. The curved surface helps to eliminate some of the errors caused in the vertical radial motion of the stylus by reducing the deviation of the cutting face from the perpendicular to the disc surface.

Discs

Curiously, there has been relatively little change in the basic formulation of instantaneous recording discs over the past thirty years. So-called "acetate" discs, which actually are fabricated of plasticized nitrocellulose lacquer on an aluminum substrate, are still regarded as the best instantaneous recording medium. Major progress, however, has been achieved in recently improved coating techniques leading to flatter, cleaner surfaces. For example, improved drying equipment with rigid control of air flow and temperature, together with improved lacquer filtration methods, have greatly contributed to the fabrication of defect-free discs.

Electronic Elements

Despite the recent trend toward micro-miniaturization and transistor design, some recording systems have retained vacuum tubes and spacious layouts. In any case, the driving system for the cutterhead must provide the necessary power (typically 75 to 100 watts-per-channel) if we are to cut the entire frequency spectrum without clipping. Driving amplifiers are characterized by large open-loop gain, with heavy feedback to insure low dynamic impedance and phase-shift reduction of all stages. A useful innovation is the stylus oscilloscope which instantaneously monitors the output signal and indicates the overload level to which the system can be pushed. RIAA equalization from 30 Hz to 1 kHz and constant-velocity equalization from 1 kHz to 15 kHz is provided by passive networks (usually mounted on a plug-in card) for precise correction of individual cutting systems.

The development of disc recording to its present state-of-the-art has required relatively little electronic sophistication compared to the difficult mechanical and electromechanical problems that have had to be solved. Even with present-day mastering techniques, disc recording technology is continually progressing in a continuing search for superior performance.