AUDIO UPDATE

The history and theory of the dynamic loudspeaker

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ONCE UPON A TIME, MUSIC WAS ALways a "live" experience. Prior to Edison's invention of the phonograph in 1877, there was simply no way to store live sound and reproduce it on demand. Edison's first model used a short mouthpiece horn that terminated in a flexible diaphragm bearing a metal stylus. The free end of the stylus rested on the foil-clad surface of a hand-cranked cylinder. Sounds of sufficient loudness would vibrate the diaphragm, causing the stylus to emboss a track on the rotating foil surface. Playback involved a reversal of the process: The track in the foil would vibrate the stylus and its attached diaphragm and thereby roughly—*very* roughly—recreate the original sound. In truth, Edison's phonograph was simple enough that it could easily have been invented by the ancient Greeks more than two thousand years earlier. In any case, the history of the loudspeaker can be considered as starting in 1877. All subsequent developments essentially reflect the attempt to make it play louder and more accurately.

Early history

I suspect that one of the reasons for Enrico Caruso's popularity as a recording artist was his ability to provide the enormous amounts of acoustic power needed for the "direct-to-disc"—or "direct-to-cylinder"—recordings of his day. Until electricity got into the act, recordings were made by clustering all the performers around a single, huge recording horn and urging them to play or sing as loudly as possible. During playback, the efforts to make the acoustic phonograph louder and more accurate were limited to improving the mechanical pickup head and enlarging its acoustic horn.

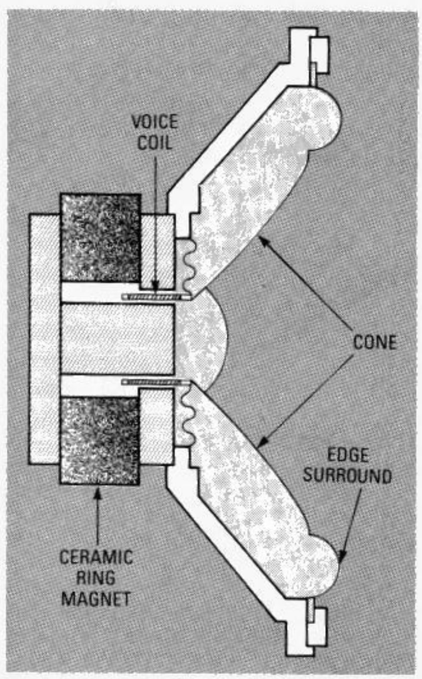

FIG. 1

In the early 1920's, the recording industry was economically jolted by a startling new invention—radio. The annual profits of the Victor Talking Machine Company plummeted from a high of about $23 million to a low of $123,000. However, the good news was that the same technology (electronics) that made radio possible was soon applied to the recording process, with enormous success. Primitive microphones feeding equally primitive vacuum tubes driving electro-magnetic disc cutters achieved a remarkable improvement in recorded fidelity. Unfortunately, the phonophiles of the day had no choice but to play their new "electrical" recordings on purely acoustic phonographs—but that was also about to change.

In the 1920's, radios usually had separate speakers, whose trumpet-like horns emerged from a base that housed a driven stiff-metal diaphragm not unlike those found in the telephone receivers of the day. But a number of researchers were addressing themselves to the dual problems of volume and fidelity. The breakthrough came about in 1925, spearheaded by the work of two General Electric engineers, Chester Rice and Edward Kellogg.

The moving-coil speaker

Rice and Kellogg's description of their work, "Notes on the Development of a New Type of Hornless Loud Speaker," appeared in April 1925 in a leading technical journal. More important, their exposition was shortly backed up by commercial products that were audibly so much better than anything previously available that, within a few years, virtually all other designs were driven from the marketplace. And now, 63 years later, the moving-coil direct-radiator woofer, midranges, and tweeters found in 95% of to-

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...ay's speaker systems do not differ ...ndamentally from the driver described in Rice and Kellogg's seminal paper.

The basic innovation in the new speaker can be described simply: Instead of a small, magnetically driven, metal diaphragm coupled to a horn, it used a large, stiff-paper cone driven at its apex by a "moving coil." There were (and are) significant advantages to such an arrangement. The horn and diaphragm resonances that severely distorted the sound of almost all previous designs were mostly eliminated, and the new configuration could play louder and had a much wider frequency range.

A schematic view of a dynamic speaker is shown in Figure 1. Except for the use of a ceramic ring magnet instead of an electromagnetic field coil, the operating principle is identical to the original Kellogg-Rice design. Cone motion is produced by the interaction of two magnets: One is a heavy *permanent* magnet that is visible as a black ceramic ring at the rear of the speaker; the other is a small cylindrical electromagnetic coil of wire—known as a voice coil—that is suspended within the speaker mechanism. The voice coil is connected by very flexible wires to the driver's input terminals. When the voice coil is fed the amplifier's audio signal it produces a magnetic field that fluctuates in both strength and polarity. That varying magnetic field interacts with the fixed field of the permanent magnet, causing the freely suspended voice coil to shuttle rapidly back and forth within the magnetic gap, carrying the speaker cone along with it. The speaker cone sets up a series of compressions and rarefications (vibrations) in the air that is heard as sound. In short, the voice coil moving in accord with the *electrical* audio signal causes the cone to produce an *acoustic* audio signal.

Back to the present

The original dynamic speakers had a fairly high-compliance soft-leather or chamois ring supporting the outer edges of the cones. Today, a variety of plastic foams and treated rubbers are used. The edge surround not only must support the cone without unduly restricting the long low-frequency excursions, but it also must damp and absorb the higher frequency vibrations traveling through the cone material.

Most midrange units and tweeters operate on the same principles as the larger low-frequency drivers, but their designers must contend with a different assortment of problems. It should be clear that spurious vibrations, floppiness, or cone or dome movements that are not in direct response to voice-coil movements are going to introduce aberrations in the sound produced. And so will any electrical audio signal that is not accurately converted into equivalent voice-coil movement. There are, in fact, so *many* opportunities for the active drive elements in a speaker system to go wrong that it is truly a wonder—and a tribute to Rice and Kellogg's basic design—that most of them work as well as they do. **R-E**