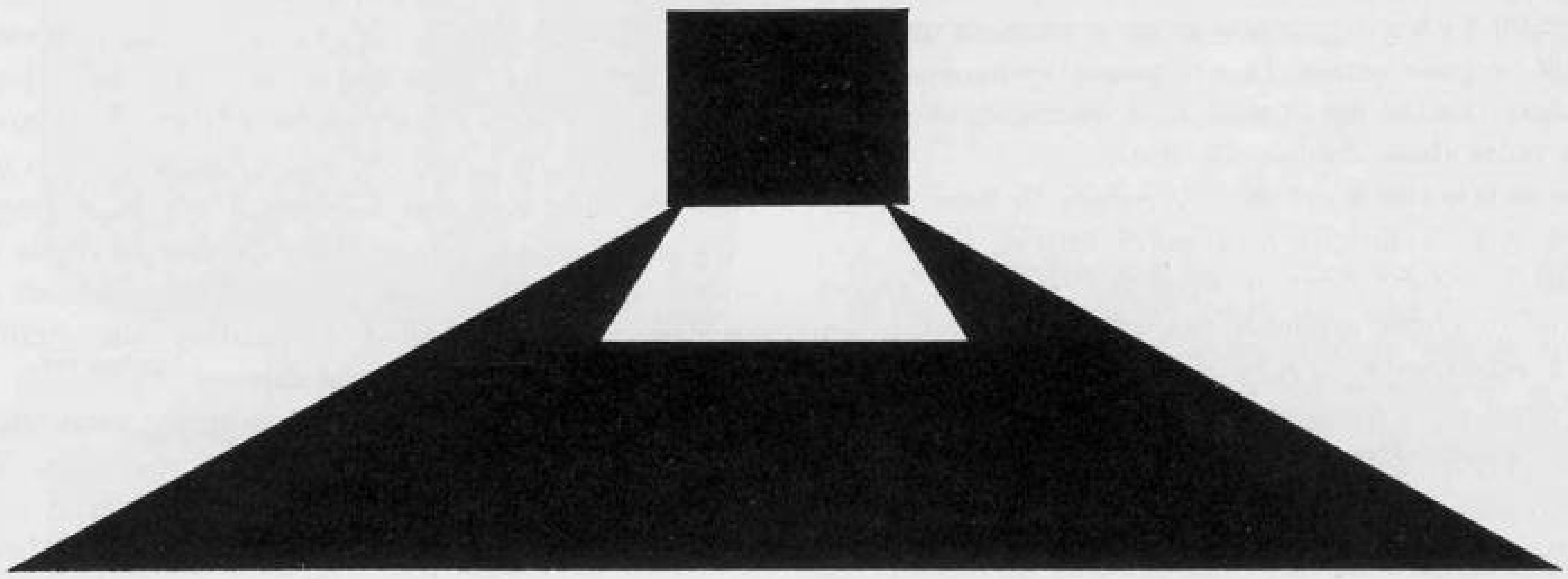
THE MAGNET



HEART OF THE LOUDSPEAKER

IN AN EASY-TO-FOLLOW DISCUSSION
OF PRINCIPLES AND THEORY,
AN AUDIO ENGINEER CLARIFIES SOME OF THE MYSTERY
SURROUNDING THE ELECTROMECHANICAL PROCESSES
THAT MAKE A SPEAKER SPEAK

by George L. Augspurger

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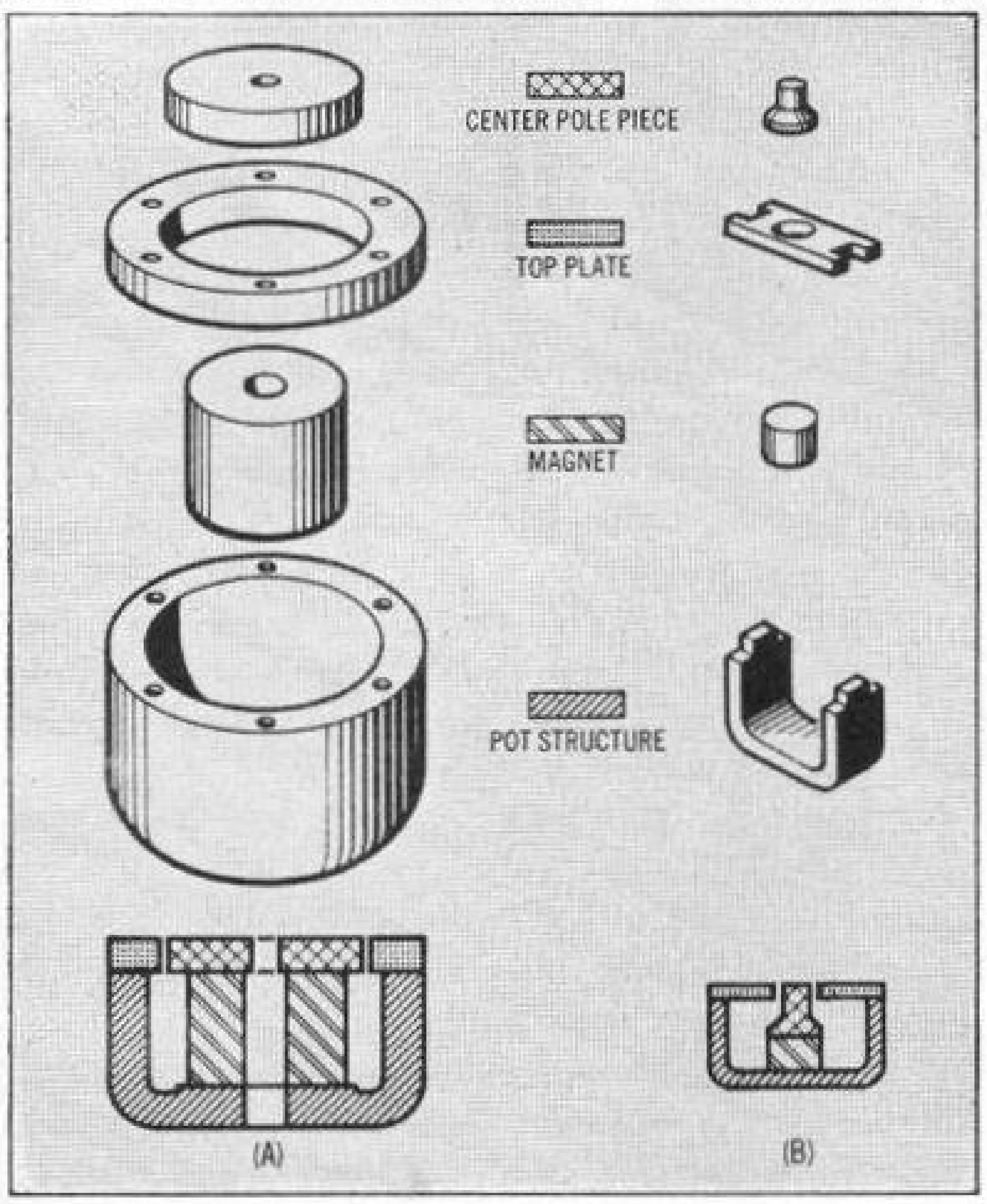
THE MAGNET

WHETHER or not you are a regular reader of loudspeaker specifications, you may have wondered occasionally why manufacturers often specify the weight of the "magnetic assembly" of a given speaker model rather than the weight of the magnet itself. If your speculations have led you to conclude that the main reason for quoting the weight of the complete assembly is to come up with a bigger and more impressive number, you would be quite wrong. In a high-quality loudspeaker, the structure (called the "pot") that surrounds the magnet costs more than the magnet itself.

To appreciate this fact, what it means to loudspeaker designers, and eventually to speaker buyers, let us examine this complex structure in detail. Figure 1 shows the type of magnetic assembly that might be used on an expensive loudspeaker (A), contrasted with the type usually found on a mass-produced speaker designed for use in radio or television receivers (B). Despite their physical differences, the two structures have the same essential parts: a set of concentric pole pieces (formed by the center pole piece and top plate), a magnet, and the additional iron (the pot) needed to carry the magnetism from the magnet to the pole pieces.

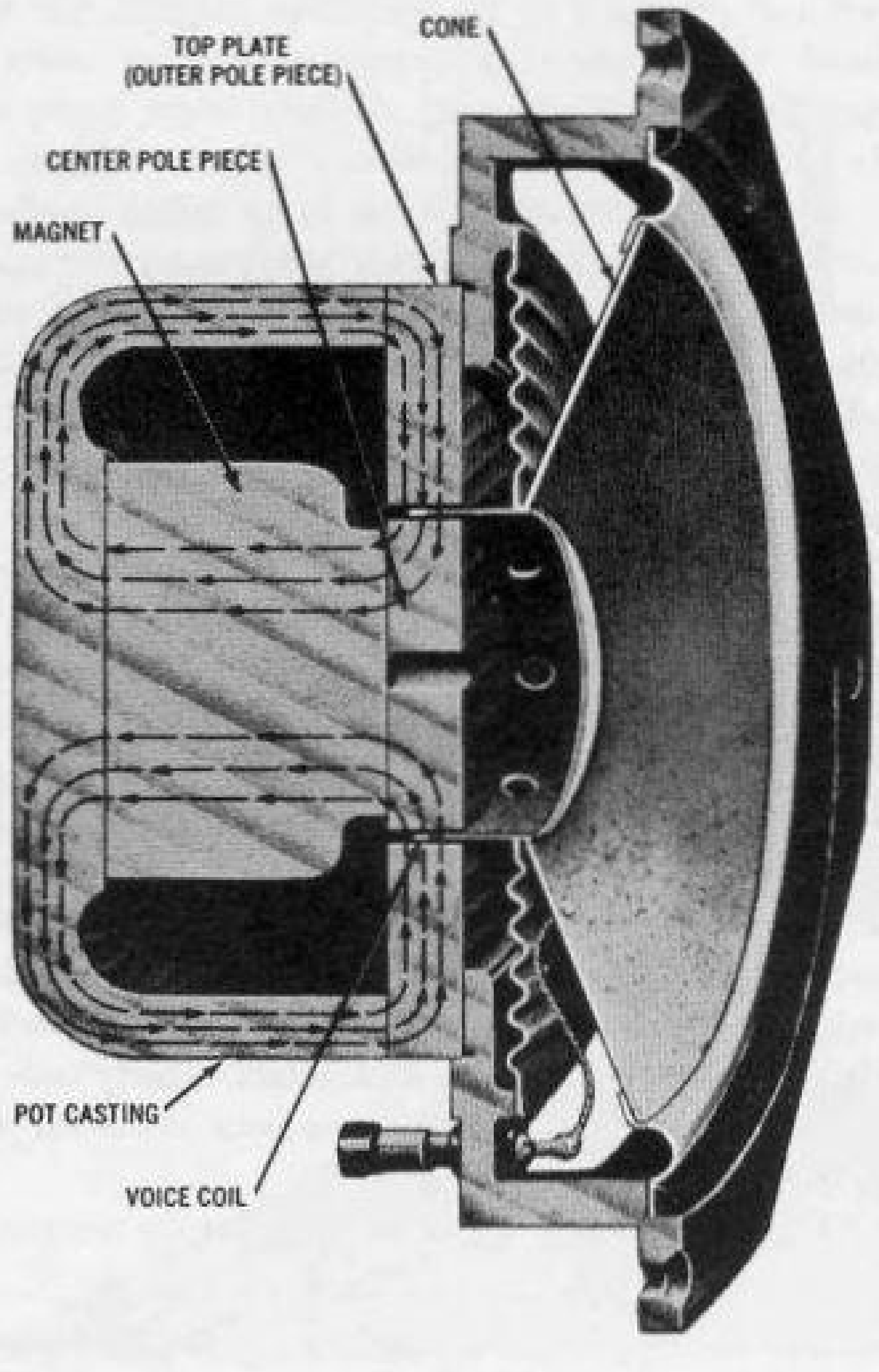
Figure 1. The magnet assembly of an expensive speaker (A) and an inexpensive one (B). Both have essentially the same parts. The better speaker, however, uses heavy cast and machined components: the cheaper one uses stamped, light-weight materials.



The physical size, shape, and arrangement of these various parts will vary, depending upon the overall design of the particular loudspeaker. The magnet may be long and thin or short and squat; it may be a slug, a ring, or even a "W." (Some of the various conformations in common use today are shown in Figure 2.) It is important to remember that the sole purpose of the magnetic assembly is to provide a concentrated magnetic field for the voice coil to operate in. All of the physical parts are selected and assembled to achieve the desired field strength as efficiently as possible.

Some speakers use Alnico magnets, some use ceramic magnets, and some use still other materials. Which is best? As far as the loudspeaker designer is concerned, the choice depends upon a number of complicated and interrelated factors. But as far as the performance of the final design is concerned, the *kind* of magnetic material used has no effect whatever. In setting up his basic design, the design engineer first determines how strong a magnetic field he wants the voice coil to operate in. Whether it takes two pounds of Alnico V or ten pounds of something else to provide this field is of little concern at that point in the design procedure. Perhaps it will help to think of the magnet as a bottle that will hold so much magnetic energy. What the bottle is made of, how brittle it is, how much it weighs—these are not directly related to how much it holds. In working out a magnetic circuit, a "bottle" of a certain capacity is needed, and the designer then tries to make use of all the magnetic potential it can supply.

Obviously, if we are to get full use out of everything in the "bottle," there can't be any leaks in the path from the magnet to the voice-coil gap. If the pole pieces, or any other parts of the circuit, are too thin or are made of inferior material, magnetic potential will be lost—usually leaking away in the form of stray fields. For example, if the back of a loudspeaker strongly attracts a screwdriver, this means that a portion of the magnet's potential is not reaching the voice-coil gap. This is one reason why magnet weight alone is no guarantee of speaker performance. The magnet and the surrounding structure must be designed as a unit for best results.



HOW THE SPEAKER OPERATES

The magnetic field in which the loudspeaker voice coil operates fills the ring-shaped space (the "air gap") between the two pole pieces. The center pole piece is joined directly to one end of the magnet. The magnetic lines of force are carried from the opposite end of the magnet through the heavy pot structure to the outer pole piece. Although the arrows indicate the path of the magnetic lines of force, the magnetic field does not "flow" or fluctuate, but remains constant.

The electrical audio signal from the amplifier is carried to the terminal posts and through the flexible wires to the voice coil, producing a varying current *in* the coil and consequently a varying magnetic field *around* the coil. This varying magnetic field interacts with the fixed field of the magnet, thus causing the entire cone assembly of the speaker to move in and out. Under ideal conditions, the cone movement is an exact replica of the waveform of the electrical signal fed to the voice coil.

The cone assembly can move freely because of its flexible suspension. The voice coil is centered in the air gap by a corrugated "spider," and the outer edge of the cone is joined to the frame by a flexible ring of fabric or rubber. The movement of the cone compresses and rarefies the air next to the cone, thus producing sound.

The most critical element in the design of the magnetic assembly is the voice-coil gap. Magnetic energy finds it very difficult to jump across the gap between the two pole pieces: the wider the gap, the weaker the magnetic field within the gap. Magnetic-field strength is measured in *gauss*. This term can be misleading because it sounds as though it describes the *total amount* of something, but it does not. Rather, it is like saying that there are three dandelions per square foot in my front yard. I don't know the total number of dandelions, but I do know their density. Similarly, gauss is an indication of *flux density*.

Let us assume that we are going to build some loudspeakers and that we have worked out a magnetic assembly which produces 10,000 gauss in the voice-coil gap. A cross-section of the gap is shown in Figure 3(A). It has further been decided that this particular loudspeaker is going to be mass-produced on an assembly line, but for economic reasons we cannot afford to precision-machine the pole pieces for a perfectly concentric gap; nor will it be possible to reject every voice coil that has a slight physical imperfection. However, without close-tolerance components, chances are that most of the speakers we produce this way won't work properly—the voice coils will rub against the pole pieces. The solution is to open up the gap enough to permit wider manufacturing tolerances. The new cross-section of the speaker, with its wider voice-coil gap, is shown in Figure 3(B).

But what has happened to the flux density in the meantime? Increasing the width of the gap decreases the strength of the magnetic field alarmingly. Instead of 10,000 gauss, we may now have only 3,000 gauss in the gap. If we need both the wider gap *and* a high flux density, we will have to use a heavier magnet and a more massive pot structure to get enough "push" to overcome the increased gap width. The heavier magnetic assembly simply compensates for the changes in other factors. Apparently, even the total weight of the magnetic assembly can be misleading. It appears that what we really want to know about any speaker is the strength of the magnetic field in the voice-coil gap. Ten thousand gauss is ten thousand gauss no matter how much iron it takes to put it there.

But even this doesn't tell us the whole story. The amount of push exerted on the speaker cone in response to a given electrical signal in the voice coil depends not only on the flux density in the gap, but on the amount of voice-coil wire that is immersed in the magnetic field. All other things being equal, a voice coil with a diameter of two inches has twice the total conductor length of a oneinch coil. Similarly, a very deep gap will accommodate a longer coil than a shallow one will.

If both the flux density and the dimensions of the voice-coil gap are known, the *total* amount of useful flux can be calculated. To return to the dandelion analogy, if I know the number of dandelions per square foot and the area of my yard, I can calculate the total number of dandelions in it. In magnetic circuits, total flux is given in *maxwells*. If a speaker manufacturer quotes both gauss and maxwells, he is giving you the two basic specifications about his loudspeaker-magnet assemblies. Any further discussion of magnet weight or of material is pointless. As you might expect, the design of a magnetic circuit is much more complicated than these few paragraphs suggest. But the point I am trying to make is an essentially simple—and valid—one: a speaker's magnet weight alone is of practical interest only if you can't find out anything else about it.

From what has been discussed so far, you might assume that the higher the flux density and the greater the total flux, the better the loudspeaker. Unfortunately, it isn't quite that simple. In very general terms, the statement is true: a quality loudspeaker *does* have a heavier magnetic assembly, a stronger magnetic field in the gap, and more total flux than a cheap speaker. But among very good loudspeakers, substantial differences in any of these do not necessarily mean that one unit is better than the other. A compression horn driver (such as is used in some mid-range and public-address loudspeakers), for example, needs a magnetic gap only as long as the voice coil, and the clearance between the coil and the pole pieces can be minute. Such a design can achieve very high flux density without resorting to an enormous magnet. On the other hand, high-power compression drivers designed for greatest possible efficiency *do* have large, heavy magnets. In fact, everything about them is large and heavy.

A woofer intended for use in an infinite-baffle speaker enclosure may not need a very heavy magnetic assembly—too much magnet may result in too little bass in this instance. But a woofer with a very heavy cone and a voice coil designed for long excursions may need a much stronger magnetic field in the gap to insure good transient response.

In short, there are all sorts of corollary factors that the speaker designer has to take into consideration. The fact that he chooses a six-pound magnetic assembly instead of one weighing ten pounds doesn't necessarily mean that he is trying to save money. The six-pound assembly may very well be the best possible choice for a particular loudspeaker in a particular application. So, the next time an audiophile friend asks you how many pounds of magnet are in your favorite woofer, you can be ready for him. You might even practice a condescending half-smile to use on this occasion, the kind of look which clearly indicates that the questioner really doesn't understand the subject at all.

"How many pounds?"

You will placidly reply, "Enough to do the job."

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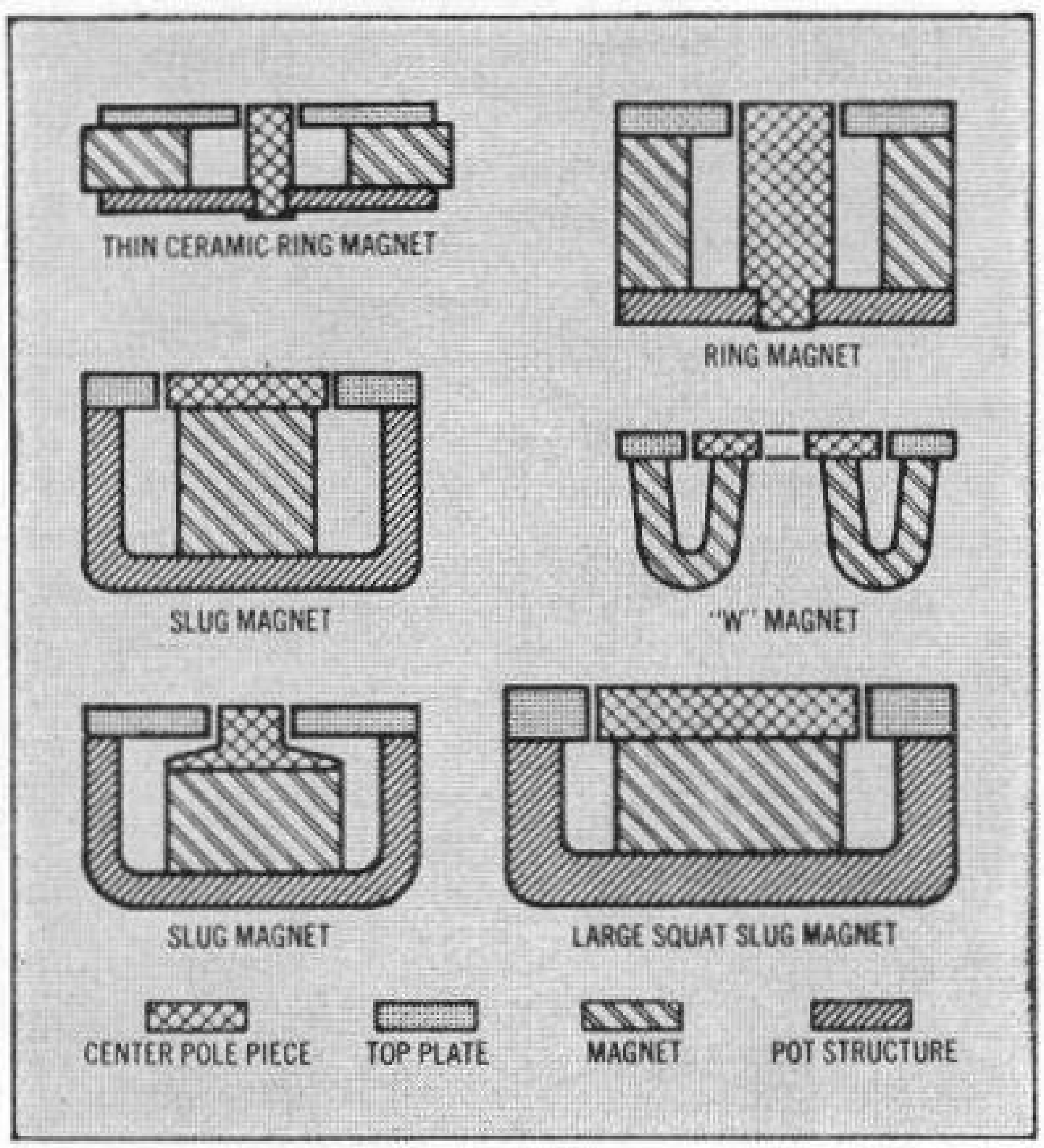

Figure 2. Examples of variations encountered in magnet assemblies. The three basic types are the slug, the ring, and the "W" magnet. The ceramic-ring type is coming into greater use.

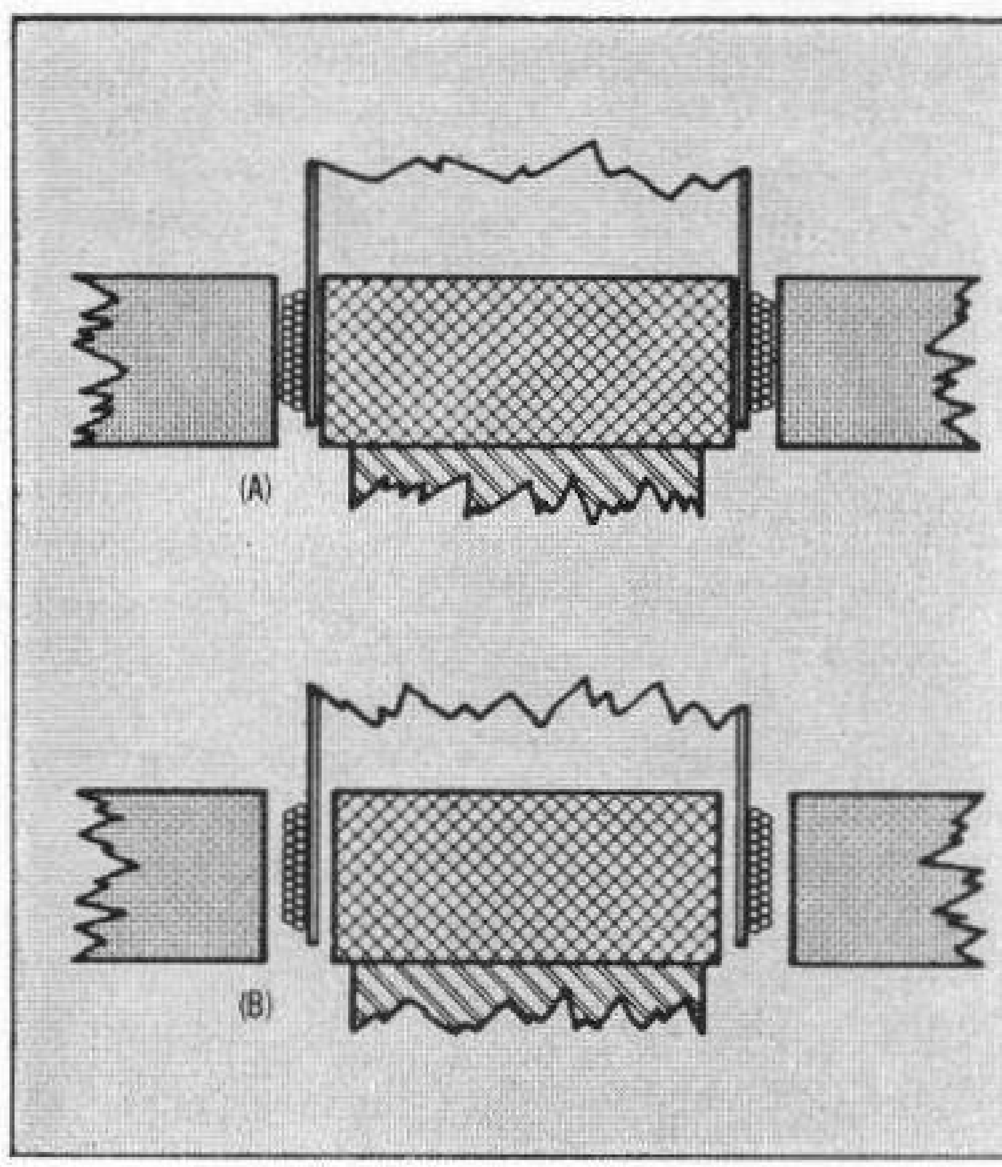

Figure 3. Cross-section of the speaker voice-coil air gap. A close-tolerance gap requiring precision assembly is shown in (A). The wider gap shown at (B) requires less care in its assembly.

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