nish, and later baked to insure a noncompliant assembly. The impedance of the voice coil is nominally 8 ohms. Aluminum ribbon was chosen, rather than copper, because of the selection of unity ratio between the mass of the generator and the effective mass of the radiator plus its air loading at the upper end of the working frequency spectrum. A ratio of unity at about 1,000 cps produces the highest efficiency and best frequency response. This ratio is graphically illustrated in *Fig.* 1, which shows the loss of efficiency in db versus the ratio $M_r/(M_d+M_a)$, where M_r is the mass of the voice coil, M_d is the mass of the effective area of the diaphragm, and M_a is the mass of the air load.

The magnet and pole piece assembly uses an Alnico V permanent magnet weighing 1.8 lbs. which supplies 13,000 gauss to the voice-coil air gap. The structure is conventional in design, consisting of a circular steel back plate, an outside steel spacer ring, a steel front plate having a beveled 3-inch diameter hole that forms one of the pole pieces, and a central pole piece and magnet assembly. The frame, which is a steel die-formed part, completes the low frequency assembly and has the sole purpose to support the component parts rigidly to the baffle.

High-Frequency Unit

The design of the high-frequency unit was based on the space available within the 12-in. low-frequency unit. To minimize interference from the cone and raise the efficiency of the driver, a horn-type radiator was chosen. To maintain the proper phase relation at the crossover region, the driver was located at substantially the same plane as the area of radiation from the effective cone area at the crossover point. The horn length was then fixed at the maximum depth of the cone. From the foregoing dimensions, the crossover frequency was chosen to be 3,000 cps. For ease of manufacture, the high-frequency horn and driver were designed as an integral and independent unit to be mounted directly on the face of the inner pole piece, inside the cone of the low frequency unit. The horn designed is an exponential type with deflection baffles at its mouth. For best distribution angle and minimum interference from reflections of the cone, the flare rate of the horn was chosen to cut off at 1,800 cps. The throat coupling to the diaphragm of the driver was designed to have a cutoff, due to cavity-orifice resonance, at 22,000 cps. This resonance occurs in the cavity between the diaphragm and compliance and the diaphragm dome, coupled to an orifice which is the annular entrance to the horn. The efficiency of the horn was measured to be 9 db. The acoustic loading ratio is 3 : 1.

The cross section of the driver, with its horn and housing, is shown in *Fig.* 2. It is a dynamic moving coil type consisting of a magnet (1), an inner and an outer pole piece (2), (3), a diaphragm and compliance (4), a voice coil (5) attached to the diaphragm, and an acoustic resistance ring (6). A photograph of the driver alone is shown in *Fig.* 3 which clearly shows the diaphragm and its compliance. The dimensions of the unit are approximately 1-3/8 in. diameter and 3/4 in. thick.

To achieve a good response and extend the range to 22,000 cps, particular attention must be placed on the design of the diaphragm. Since it is a mass controlled device, the total mass of the diaphragm and voice coil must be kept extremely small. The material used for the diaphragm is .0005-in. aluminum foil dome shaped to attain rigidity. The compliance is a part of the diaphragm consisting of tangential corrugations flattened at the rim for cementing to the pole plate. The voice coil is edgewise-wound aluminum ribbon made self-supporting by means of a baked insulating varnish. The finished coil is then cemented to the diaphragm dome.

Crossover Network

The crossover network was designed especially for the described low- and high-frequency units. Since the input impedance was chosen to be 8 ohms, which is considered standard for two-way speakers, the network not only has to divide the two frequency ranges, but also match the line impedance to the individual units. The crossover frequency is 3,000 cps.

Because of good phasing characteristics of the combined duplex speaker, the network slope was designed to be 6 db per octave. To match the 8-ohm input impedance to the 30-ohm high-frequency unit, the inductance element was designed as an auto transformer, having a step-up ratio of 1 to 4, with three taps for adjustment of the high-end response in 2 db steps. The schematic is shown in *Fig.* 5 and the measured electrical response is shown in *Fig.* 6. As will be shown later, the actual acoustical crossover slope is considerably more than 6 db per octave. The attenuation is achieved acoustically.

Performance

The actual frequency response of the high- and low-frequency units when assembled together to form a duplex speaker system is shown in *Fig.* 7. This final assembly is shown in *Fig.* 8, which also shows a felt ring cemented between the cone and the base of the high-frequency unit. This felt ring serves two purposes. First, it prevents foreign matter from accumulating in the air gap, which would interfere with the voice-coil motion, and secondly, it acoustically attenuates frequencies above 3,000 cps, which are radiated by the surface of the cone underneath the felt ring. The combined electrical and acoustical attenuation slope above the crossover frequency is 18 db per octave as shown in *Fig.* 7, curve A. The resultant acoustical output of the high-frequency unit is represented by curve B. The slope is 12 db per octave below 3,000 cps, which is the result of the electrical network and the acoustical low-frequency cutoff of the horn. As measured, the total curve is flat within +3 db from 40 to 20,000 cps, with the exception of the region between 50 and 65 cps where it is about 5 db down from the average. The above response was measured in the anechoic chamber and represents the actual response of the speaker system enclosed in the 606A corner type cabinet, which was designed for the new speaker. Since the response was recorded without the benefit of rigid corner walls for which the cabinet was designed, the frequency at 30 cps is considerably lower in amplitude than if the corner walls in a normal room were used. The 30-cps response measured in a typical hard walled room is appreciably improved as shown by the dotted portion of curve A in *Fig.* 7.

As mentioned earlier, the other development is the 602A loudspeaker, which is essentially the same as the 601A, except that a 15-inch cone-and-frame was used. The construction is the same and the performance is superior. The advantage gained in a larger area cone is in the improvement of the extreme low-frequency range. The 602A extends substantially flat to 30 cps and had good efficiency at 20 cps. Since a larger 2.41 pound magnet was used in the 15-in. unit, the over-all efficiency was raised by 2 db. The power handling capacity of both the 601A and 602A is 20 watts, sine wave, continuous radiation. For reproduction of speech and music, however, the peak power rating is 30 watts, at which point non-linearity becomes a limiting factor.

During listening tests, consisting of a variety of material, such as pipe organ selections, speech, percussion, wind and string instruments, vocalists, and full orchestra, exceptional reality and quality are realized. A-B tests were also conducted in competition with various high-quality speaker systems, and the tests confirmed the measurements.

Fig. 8. The Altec Lansing 601A 12-inch duplex loudspeaker.