Technical Notes Volume 1 Number 18

Vented Gap Cooling™ in Low Frequency Transducers

Introduction:

JBL's ongoing research into low frequency transducer design has led to a new, more efficient method for removing heat from the voice coil. It is called Vented Gap Cooling (VGC)'M and its benefits extend over several performance areas:

1. Lower power compression. Since heat IS removed more efficiently than in earlier designs, thermal equilibrium, for a given power input, is reached at lower temperatures and power compression is reduced.

2. Lower distortion. Modifications in the magnetic circuit topology as well as mechanical redesign of suspensions, have resulted in lower values of distortion, as compared to previous JBL models and competitive models.

3. High power handling capability. More efficient heat transfer enables these new transducers to handle substantially more power, and the new 300 mm (12 in), 380 mm (15 in) and 460 mm (18 in) models are now rated at 600 watts.

4. Lower weight. As part of the general redesign of these products, new methods of analysis led to substantial weight reduction in the iron portion of the magnetic structure.

5. Smoother response. New cone and suspension materials, along with improved SFG (Symmetrical Field Geometry), have contributed to significantly flatter response over the normal passbands of the new loudspeakers.

While not every user will require the increase in power handling per se, the improvements in the other areas mentioned above will be beneficial to all users. In this Technical Note, we will cover the new technology in detail.

2. How the goals were accomplished:

Low frequency transducers normally carry two power ratings. One of these is its *thermal rating*, which is dependent on the capability of the device to dissipate heat generated in the voice coil resistance. A loud- speaker voice coil assembly is capable of safely dissipating a fixed amount of power, regardless of the frequency of the input signal.

The *displacement rating* is frequency dependent and relates to voice coil excursion. A loudspeaker voice coil is capable of producing a certain excursion within a specified linearity range; in general, with each halving of frequency, stated linearity performance requires halving of the applied power for safe operation within those mechanical limits.

Proper vented enclosure design minimizes voice coil excursion for a given level of low frequency performance, and the transducer's thermal limit is generally the dominant one. Thus, a transducer which has greater thermal dissipation will benefit the user in terms of greater acoustical output per driver.

The best way to understand the new 600-watt design is to compare it directly with the traditional JBL design. Figure 1 shows a section view of the traditional JBL voice coil-motor structure. In this design, the voice coil is closely placed to both the top plate and the pole piece. Heat is drawn away from the voice coil primarily by radiation to the neighboring metal structures, and the air passage to the back center vent of the motor structure is designed only to relieve internal pressures in the motor structure.

Figure 2 shows details of the new vented gap magnet structure. A section view of the structure is shown at "A:' while a frontal view is shown at "B." In this design, three relatively large openings or vents pass through the back plate, magnet and top plate/pole piece assemblies providing a low resistance path for air flow through the entire magnet structure at three voice coil locations. The cavity under the dust dome, with the resultant air mass, and the dome itself act as a powerful pump which, through cone motion, forces air back and forth through the vent holes and over the voice coil, pro-viding immediate cooling of the coil. There is also normal radiation heat transfer from the voice coil through the magnetic structure.

3. Improvements in manufacturing and assembly:

JBL has taken the occasion of the newly engineered design to reconfigure all aspects of its manufacture. In fact, each step in the engineering of the Vented Gap Cooling series of transducers was carried out in concert with JBL's manufacturing engineering group to ensure that all manufacturing requirements could be met efficiently.

Beginning with redesign of the magnetic structure, finite element analysis of that structure indicated that significantly less iron could be used in the backplate, while maintaining the desired magnetic flux density in the gap. This reduction in material is evident in an examination of the back plate thickness as shown in Figures 1 and 2. Note the thickness of the double crosshatched area. In the case of the 2226H, the weight reduction of the transducer is 1.5 kg (3.25 lb) relative to the 2225H.

A new voice coil winding method was perfected which allows direct winding of each individual voice coil on its former, rather than the older bulk winding of voice coils with their subsequent breakdown and assembly into finished voice coils. The newer method saves time and results in greater manufacturing yield.

The new production line and innovative assembly techniques were developed to reduce sub-assembly steps and to ensure the high accuracy and precision necessary to maintain more stringent performance specifications. The new line has become a model for subsequent improvements in all JBL low-frequency transducer assembly.

Figure 1. **Section view of traditional JBL ferrite SFG structure: 380 mm (15 in) transducer.**

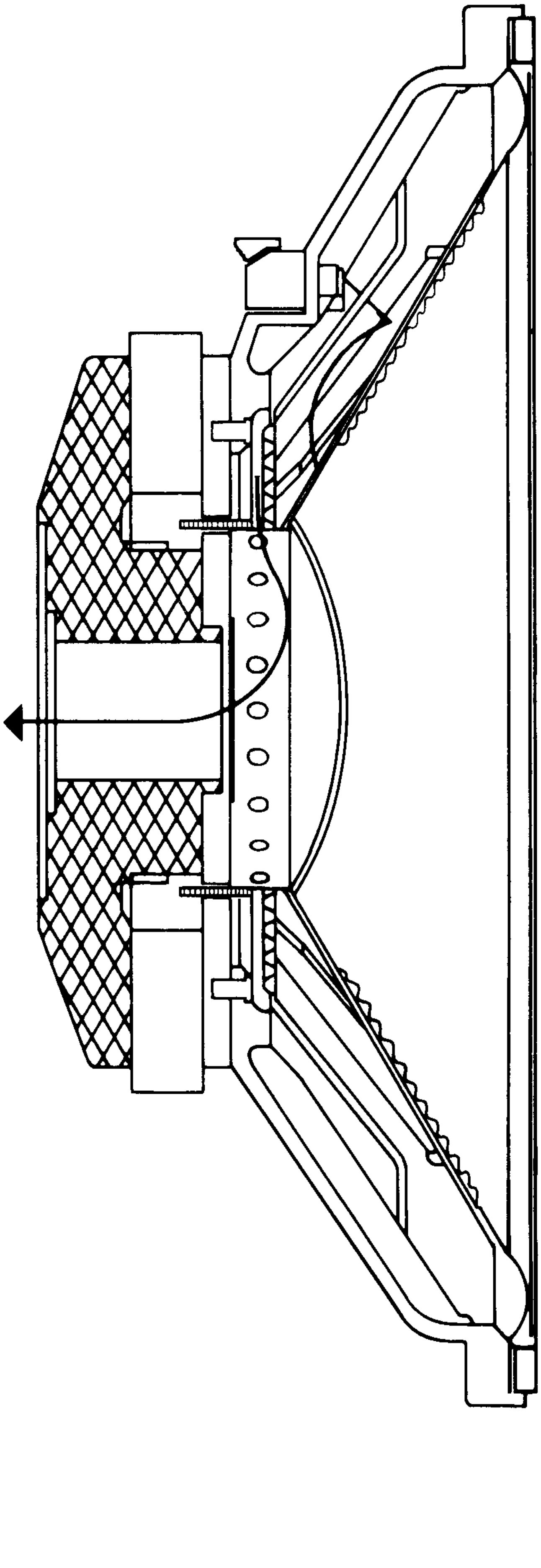


Figure 2. **Views of the new vented gap structure: 300 mm (12 in) transducer**

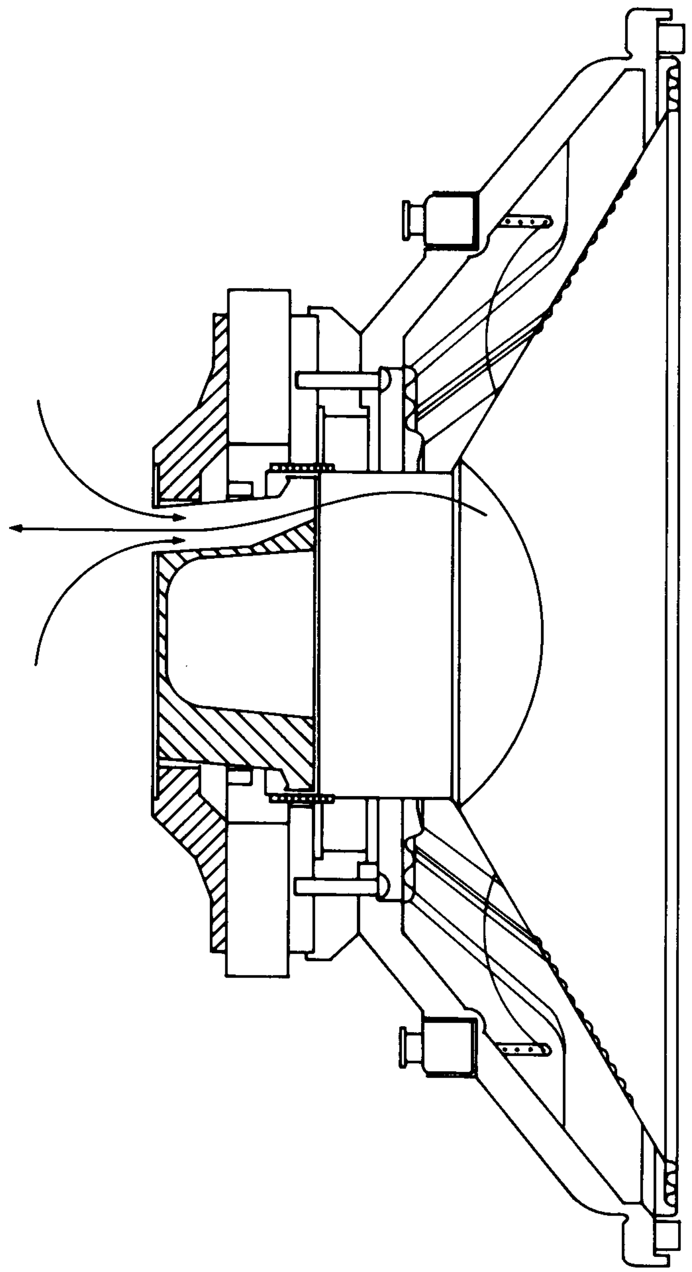


Figure 2 (A) Section view showing air flow

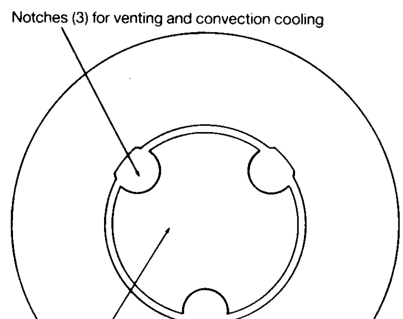
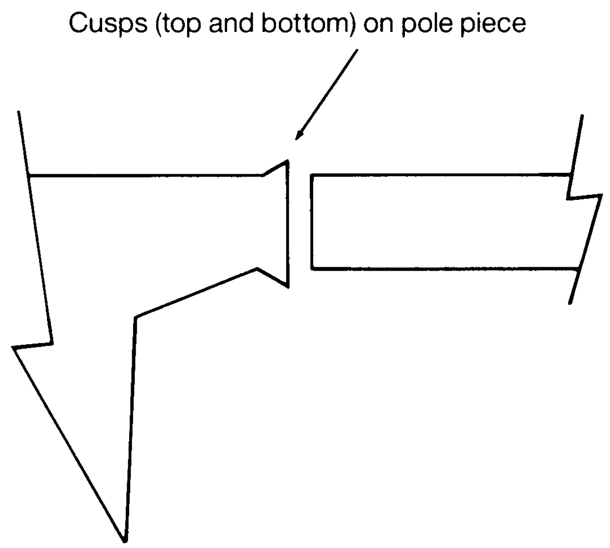


Figure 2 (B) Normal view of top plate, gap, and pole piece

Further performance improvements in the new structure include greater excursion capability (increased X_{max}), and improved SFG. The improvement in voice coil excursion capability results from new inner and outer suspensions for the cone.

The improvement in SFG performance is due to the recontouring of the pole piece cross-section, as shown in Figure 3. Forming the metal into a cusp shape forces it to saturate magnetically, and the increased saturation in the voice coil region reduces the amount of flux modulation in the gap by the counter-flux produced by the voice coil signal.

***Figure 3.* Section view showing reshaping of polepiece.**



4. The proof is in the performance:

Merely increasing the power input capability of a transducer does little for the user, if the device cannot handle that power adequately to produce more useful output. The most immediate improvement in the performance of the JBL's 600-watt transducers is in reduced dynamic compression. Figure 4 demonstrates these improvements. Note what happens in the first four seconds. The JBL drivers and the large voice coil diameter EV driver (EVX-150) show only a maximum of 1 dB of compression. This performance is significant, in that many musical high level peaks are of relatively short duration. The smaller diameter voice coil EV drivers show considerable compression, up to 3 dB, during the first 4 seconds, which would be quite audible on program. In the case of the TAD driver, demagnetization of the motor structure takes place almost immediately, resulting in a final reduction in output of about 7 dB. The JBL 2225H is shown for comparison with the new 2226H. Its performance is typical of standard 100 mm (4 in) voice coil designs with ferrite magnet structures.

In the long term, there is a decided advantage for the JBL VGC products in that the maximum compression does not exceed 2.5 dB, while dynamic compression of the other drivers shown here is greater. It is in the range beyond about 25 seconds where the effects of vented gap cooling are most obvious. Beyond that point, steady state conditions have been reached for the particular input signal, and heat is removed from the transducers at virtually the same rate as it is generated. In this regard, the JBL transducers have an advantage over the EV transducers.

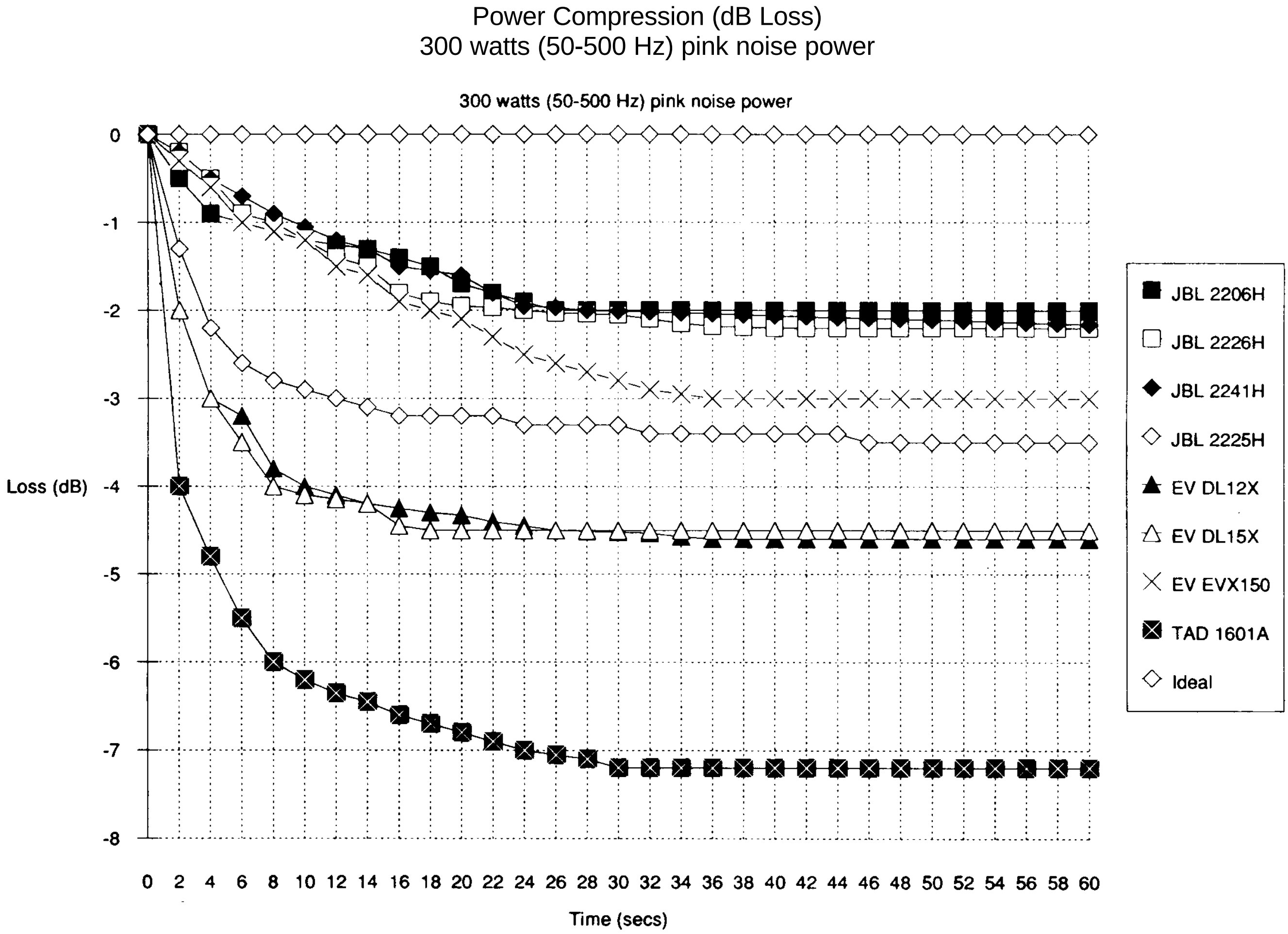
Power compression curves can be used to help predict actual SPL at high power levels. In general, SPL calculations are scaled from a transducer's 1 watt sensitivity. Thus a 2226H would have a calculated sensitivity at 300 watts of:

10 log (power level/1 W) + SPL (1 W) =
10 log (300 W/1 W) + SPL (1 W) =
24.8 + 97 = 121.8 dB at 300 W,1 m

However, the actual sensitivity would be lower by the power compression figure of 2.5 dB, resulting in a true sensitivity of 119.3 dB. This means that real performance is based upon not only sensitivity at 1 watt but on power compression as well and thus a pure specification sheet comparison of sensitivity ratings may not convey the real maximum SPL capabilities. In fact, in some cases a driver with a lower 1 watt sensitivity may actually have a higher equivalent sensitivity at high power. All vented gap transducer specification sheets list power compression at three power levels to help the user in maximum SPL calculations.

This phenomena is further explained and depicted in the following distortion section where a sampling of drivers are run at equal SPL levels.

***Figure 4.* Power Compression in dB versus time for JBL and competitive transducers.**



In terms of distortion, the most direct way to compare transducers is to drive them to the same acoustical output, rather than drive them with the same power input. In Figures 5 through 10 we have plotted the fundamental, second harmonic, and third harmonic outputs of six drivers which were all driven to an output level of 115 dB-SPL in the 100 to 200 Hz range, measured at a distance of one meter.

Figure 5. **JBL 2225H driven to 115 dB-SPL.**

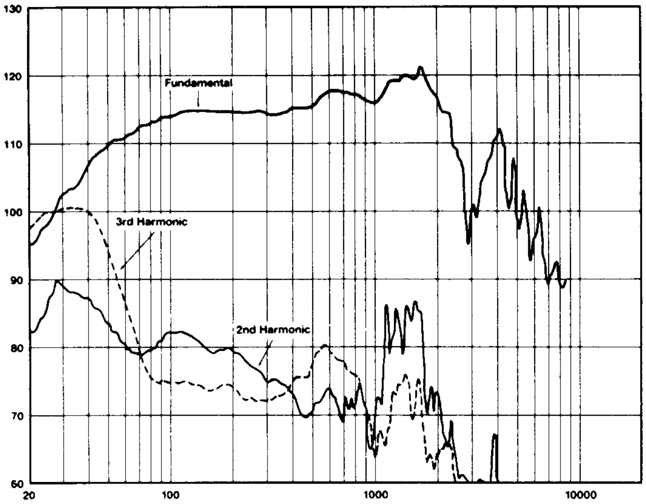


Figure 5 shows the fundamental, second harmonic, and third harmonic distortion of JBL 2225H low frequency transducer driven to produce a mid-band output of 115 dB-SPL at a distance of one meter. Input voltage 30.5 V.

Note that the distortion in the mid-band is 33 to 35 dB lower than the fundamental. The increase in second harmonic distortion in the 1 kHz to 2 kHz range is outside the normal operation passband of the transducer.

Figure 6. **JBL 2226H driven to 115 dB-SPL.**

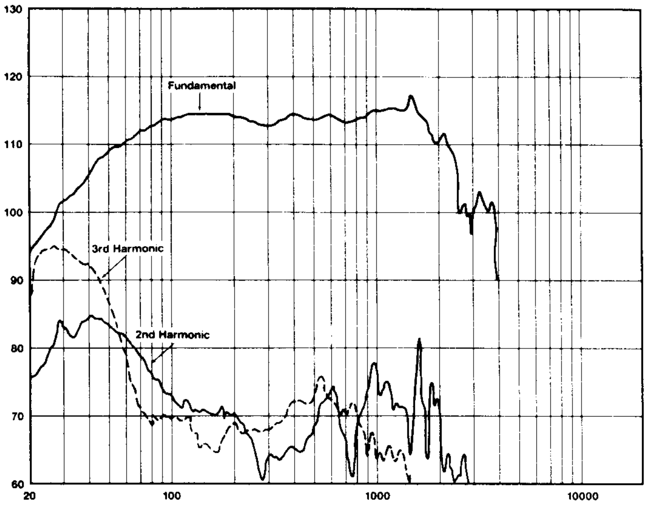


Figure 6 shows the fundamental, second harmonic, and third harmonic distortion of JBL 2226H low frequency transducer driven to produce a mid-band output of 115 dB-SPL at a distance of one meter. Input voltage 24 V.

Note here that mid-band distortion components are better than 40 dB below the fundamental. These improvements have resulted from greater precision in assembly, greater linearity in mechanical suspensions, and more effective use of SFG.

Figure 7. **EV DL15W driven to 115 dB-SPL.**

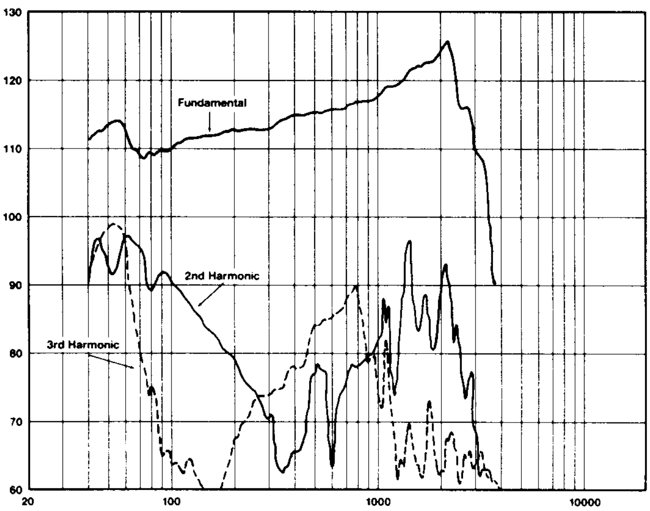


Figure 7 shows the fundamental, second harmonic, and third harmonic distortion of Electro-Voice DL15W driven with 40 volts. Measurement at one meter.

This transducer could not be driven to the targeted output level of 115 dB without danger of burn-out. It could not be driven below 40 Hz without severe bottoming of the voice coil assembly against the back plate.

Figure 8. **EV DL15X driven to 115 dB-SPL.**

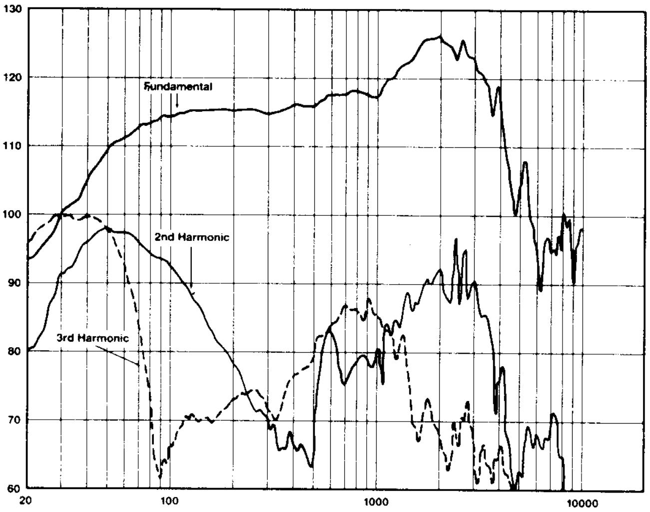


Figure 8 shows the fundamental, second harmonic, and third harmonic distortion of Electro-Voice DL15X low frequency transducer driven to produce a mid-band output of 115 dB-SPL at a distance of one meter. Input voltage 30 V.

The DL15X faired better, in that it could reach the targeted mid-band level of 115 dB. However, note that there is considerable second harmonic distortion in the mid band.

Figure 9. **EV EVX-150 driven to 115 dB-SPL.**

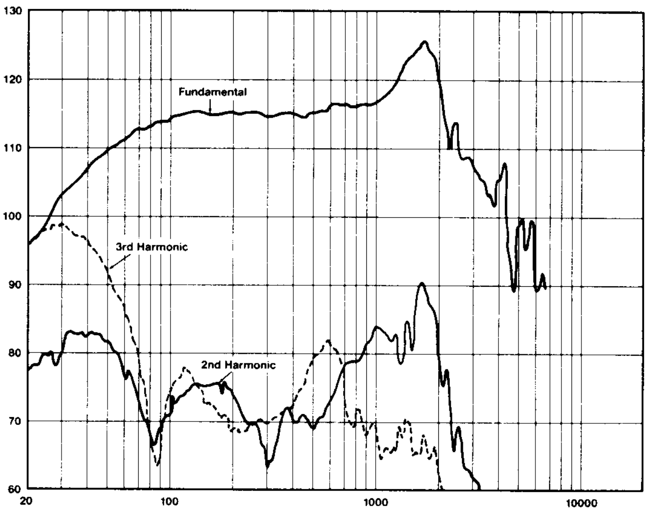


Figure 9 shows the fundamental, second harmonic, and third harmonic distortion of Electro-Voice EVX-150 transducer driven to produce a mid-band output of 115 dB-SPL at a distance of one meter. Input voltage 27 V.

Generally, the performance is good, with distortion components in the 100 Hz to 500 Hz range uniformly 35 dB below the fundamental. However, the fundamental rises 11 dB in the 1-to-2 kHz range, and distortion rises significantly above 500 Hz.

Figure 10. **TAD 1601B driven to 115 dB-SPL.**

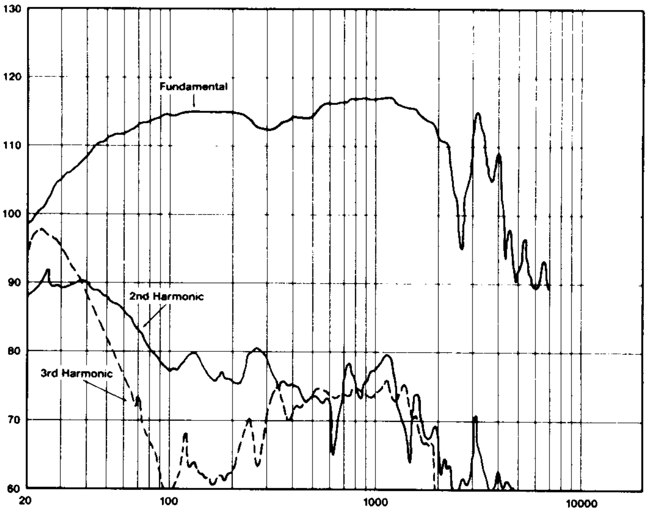


Figure 10 shows the fundamental, second harmonic, and third harmonic distortion of TAD 1601B low frequency transducer driven to produce a mid-band output of 115 dB-SPL at a distance of one meter. Input voltage 33 V.

Generally, the performance is good, with distortion components in the mid-band uniformly 35 dB below the fundamental, similar to the JBL 2225H. However, its lower efficiency and demagnetization characteristics require much greater input power to reach this output level.

5. Summary:

Vented Gap Cooling technology is a clear step for-ward in an art and science which does not often present opportunities for breakthroughs. The essential element of it is the opening of the internal voice coil cavity to the outside by way of multiple air paths which have very low flow resistance, thus enabling significant convection cooling to take place.

The JBL transducers embodying this technology have further been redesigned so that the increased power handling capability can be fully realized. Increased linearity in the moving system and refinement of the magnetic parameters result in lower distortion, and the overall frequency response is smoother than in previous models.

While there are clear advantages for the specialist in high-level music reinforcement, the contractor or consultant who specifies speech reinforcement systems benefits as well from the overall lower distortion and smoother response offered by these transducers.

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