

Technical Notes Volume 1, Number 3

Choosing JBL Low-Frequency Transducers

A. INTRODUCTION

When JBL converted its low-frequency transducers from Alnico-V magnets to SFG ferrite structures in 1978, we took the first steps in simplifying and rationalizing the line by reducing the number of models. There had been needless duplication and functional overlap in the line, and this often served more to confuse the user than help him. The present line-up of products includes models of the important performance classes in each size, and it is the intent of this Technical Note to explain to the professional user how LF transducers are chosen for specific jobs. We will also explain in detail the elements of construction and design of the products which optimize them for their particular jobs.

B. THE BASIC MATRIX

The primary JBL transducers are grouped into a three-way matrix, shown as follows:

TABLE I.

SENSITIVITY:	MEDIUM	HIGH	MAXIMUM
EFFICIENCY:	0.5% - 3%	2% - 6%	4% - 10%
LINEARITY:	HIGH	MEDIUM	LIMITED
460 mm (18")	2245H	2240H	(E155-8)
380 mm (15")	2235H	2225H, J (E140-8)	2220H, J (E130-8)
300 mm (12")	(128H)	2202H	(E120-8)

Those models enclosed in parentheses are not in the normal 2200-series line-up, but they fit structurally into the matrix in the slots indicated. The model 128H is used as the LF driver in the 4411 monitor system.

C. SENSITIVITY VS. EFFICIENCY

It is important to understand the difference between sensitivity and efficiency, and the various methods of rating sensitivity. The reference efficiency is a function of the electro-mechanical parameters of the loudspeaker. It represents the low frequency output within the piston band limit (where sound propagates omnidirectionally), and will usually correlate with the measured output in the 300 Hz to 400 Hz range for 460 mm (18 inch) to 300 mm (12 inch) transducers.

Sensitivity relates to the measured output on-axis for a given input, which may or may not relate to the low-frequency efficiency level. JBL Professional Series low frequency loudspeakers are rated with a 1 watt input averaged from 100 Hz to 500 Hz, which correlates directly with their efficiency ratings. JBL E Series loudspeakers are rated with the same input but averaged from 500 Hz to 2.5 kHz, since they are primarily designed for full range use. If they were rated as the Professional Series are, for low frequency use, their sensitivities would be lower. The reference efficiency percentages give the most consistent method of comparison for E series, Professional Series, and competitive loudspeakers in low-frequency applications. These can be compared by taking 10 log of the efficiency ratio.

D. DETAILED DESCRIPTION OF THE MATRIX

In this section, we will be describing in some detail the internal parts of a loudspeaker. For those who are not familiar with the construction details of a typical JBL LF transducer, we show in Figure 1 a labeled cutaway drawing of a typical JBL Professional series transducer.

1. MEDIUM-SENSITIVITY TRANSDUCERS:

a. Uses:

Primary use is as LF transducers in monitor systems as well as sub-woofer designs for recording studios and motion picture theaters. For these purposes, long travel at low frequencies is essential, as is low distortion. Smooth HF response is also a requirement for proper transition to mid- and high-frequency transducers in the 400-to-1 kHz range.

b. Sensitivity and Power Handling:

TABLE II.

MODEL	RATED SENSITIVITY (1 W, 1m)	CONTINUOUS PROGRAM POWER	REFERENCE EFFICIENCY
2245H	95 dB	600 WATTS	2.1%
2235H	93 dB	300 WATTS	1.3%
128H	91 dB	200 WATTS	0.86%

c. Internal Design and Construction:

VOICE COILS: Flat copper wire (See Table VI), extended over-hanging winding for maximum linearity (See Figure 2A). 100 mm (4") voice coil diameter used in larger models; 75 mm (3") voice coil diameter used in 128H.

VOICE COIL FORMER: Made of aluminum, Kapton polyimide plastic, or a composite for effective heat sinking and mechanical integrity (See Table VII).

SPIDER (Inner Suspension): All models use a special design which reduces dynamic offset and instability at high drive levels, resulting in unusually low distortion and a "tight" transient character.

CONE: Straight-sided and ribbed for stability. Fairly large mass for optimum balance of efficiency and bass output, and low distortion. Aquaplas (TM) coating used on 2245 and 128H to optimize stiffness and mass, mass ring on 2235 for desirable efficiency and bass balance.

SURROUND (Outer Suspension): Half-roll of polyurethane foam for high compliance and long travel (See Figure 3A).

DUST DOME: Made of similar felted material as cone for smoothest HF response.

2. HIGH-SENSITIVITY TRANSDUCERS:

a. Uses:

Primary use is in sound and music reinforcement, mounted in horn and direct radiator reflex-type enclosures. For these purposes, LF cone excursion has been limited and sensitivity increased, relative to the transducers of the medium sensitivity class, in order to get greater output in the 50 or 60 Hz range up to 800 Hz.

b. Sensitivity and Power Handling:

TABLE III.

MODEL	RATED SENSITIVITY (1 W, 1 m)	CONTINUOUS PROGRAM POWER	REFERENCE EFFICIENCY
2240H	98 dB	600 WATTS	5%
2225H,J	97 dB	400 WATTS	3.5%
E140-8	100 dB	400 WATTS	4.9%
2202H	99 dB	300 WATTS	6.0%

c. Internal Design and Construction:

VOICE COILS: Flat copper wire, 100 mm (4") in diameter. Slightly over-hung in the magnetic gap (See Figure 2A) for proper balance of sensitivity and linearity.

VOICE COIL FORMERS: Made of aluminum, Kapton polyimide plastic, or a combination, for effective heat resistance and sinking, and rigidity.

SPIDER (Inner Suspension): All models use a special design which reduces dynamic offset and instability at high drive levels, resulting in unusually low distortion and a “tight” transient character.

CONE: Straight-sided and ribbed for stability; however, total moving mass is less than in the case of medium efficiency transducers, without the added dampening compounds or mass rings.

SURROUND (Outer Suspension): Multiple half-roll (See Figure 3B) provides controlled travel. Stiffness is optimized by depth of rolls, weave of cloth, and damping treatment.

DUST DOME: Made of similar felted material as cone for smoothest HF response.

The E140 is similar to the 2225, but with an aluminum dome and less voice coil overhang for slightly more midrange efficiency, peaked high-frequency output, and a “punchy” sound character.

The E145 and 2234 are specialized transducers that combine high efficiency with high linearity. The E145 has a short copper coil moving in a very deep magnetic gap (Figure 2B) for maximum voice-coil control and excursion linearity. This design also provides maximum low-frequency output from a given enclosure size. The E145 can move as much air as a high efficiency 460 mm (18 inch) transducer.

The 2234 is identical to the 2235 with the deletion of the mass ring. This raises the efficiency (mid-band sensitivity) for multiple woofer applications. The 2234 is used in the 4435 studio monitor.

3. MAXIMUM SENSITIVITY TRANSDUCERS:

a. Uses:

Primarily in music reinforcement for driving LF horn systems. For these applications, the range of linear travel has been restricted in a trade-off for greater sensitivity in the 50 or 60 Hz range up to 1200 Hz.

b. Sensitivity and Power Handling:

TABLE IV

MODEL	RATED SENSITIVITY (1 W, 1 m)	CONTINUOUS PROGRAM POWER	REFERENCE EFFICIENCY
E155-8	100 dB	600 WATTS	4.9%
2220H,J	101 dB	200 WATTS	8.7%
E130-8	105 dB	300 WATTS	8.6%
E120-8	103 dB	300 WATTS	8.6%

c. Internal Design and Construction:

VOICE COILS: Flat copper or aluminum wire, depending on transducer sensitivities. Voice coils either slightly underhang (2220) or overhang (E155) the top plate, or are of equal length (E120, E130) (See Figure 2C). Sensitivity is at a premium and is more important than linearity.

VOICE COIL FORMERS: Aluminum and Kapton polyimide plastic composite, for effective heat sinking and rigidity.

SPIDERS: Stiff, to keep resonance high.

CONE: "Curvilinear" on E120, E130, and 2220 and shown in Figure 4C. Curvilinear cones are thin and exhibit controlled high-frequency break-up for extended output. One piece cone/compliance construction provides increased top-end on E155, while straight sides and deep cone angle give rigidity.

SURROUND (Outer Suspension): Paper, integral with cone on E155. Multiple half-roll on E120, E130, and 2220.

DUST DOMES: Thin paper on 2220, aluminum on E120, E130, and E155 for extended HF response and minimum mass.

The E130 is similar to the 2220, but with an aluminum dome, and an aluminum voice coil equal in length to the magnetic gap, for maximum high-frequency output.

TABLE VI. VOICE COIL WIRE

MATERIAL	CHARACTERISTICS	USED ON
ALUMINUM	FRAGILE — DIFFICULT TO SOLDER LIGHT — HIGHEST EFFICIENCY HIGH RESISTANCE — LOWER INDUCTANCE INCREASES HIGH-FREQUENCY OUTPUT	CONE TRANSDUCERS FOR MAXIMUM EFFICIENCY AND HIGH-FREQUENCY OUTPUT (SENSITIVITY) HORN COMPRESSION DRIVERS
COPPER	RUGGED — HIGHEST POWER HANDLING HEAVY — ADDITIONAL MASS REDUCES EFFICIENCY LOW RESISTANCE — MORE TURNS INCREASES "BI" FACTOR (MOTOR STRENGTH)	LOW FREQUENCY TRANSDUCERS FOR RUGGEDNESS, RESISTANCE TO THERMAL COMPRESSION EFFECTS.
RIBBON WIRE VOICE COILS USE FLAT MILLED WIRE FOR GREATER WIRE DENSITY WITHIN THE AVAILABLE MAGNETIC GAP SPACE, HENCE GREATER EFFICIENCY.		

TABLE VII. VOICE COIL FORM MATERIALS

SUPPORT TUBE, BOBBIN, SUPPORTS VOICE COIL WITHIN MAGNETIC GAP AND CONNECTS COIL TO CONE. MUST MAINTAIN CONCENTRICITY (ROUNDNESS) AND STRENGTH AND AT HIGH TEMPERATURES AND FORCES.		
NAME	TYPE	CHARACTERISTICS
KRAFT PAPER BOND PAPER	WOOD PULP RAG, CLOTH	LOW POWER DESIGNS LIGHT, BUT FRAGILE
NOMEX (DuPONT TM)	HIGH TEMPERATURE NYLON PAPER (POLYAMIDE)	TEMPERATURE RESISTANCE; GOOD ADHESION PROPERTIES FOR BONDING (GLUING)
KAPTON (DuPONT TM)	PLASTIC FILM (POLYIMIDE)	INSULATOR. HIGHER TEMPERATURE THAN NOMEX, HIGH STIFFNESS, DIFFICULT TO GLUE.
ALUMINUM	THIN FOIL FILM. VARIOUS THICKNESSES	STIFF, RIGID. CONDUCTS HEAT FOR ADDITIONAL VOICE COIL HEAT SINKING. CAN ACT AS SHORTED TURN ON MOVING ASSEMBLY, CREATING EDDY CURRENTS WHICH ADD DAMPING TO REDUCE BASS, HIGH END.

FIGURE 1. CUTAWAY DRAWING OF TYPICAL JBL LOW FREQUENCY TRANSDUCER

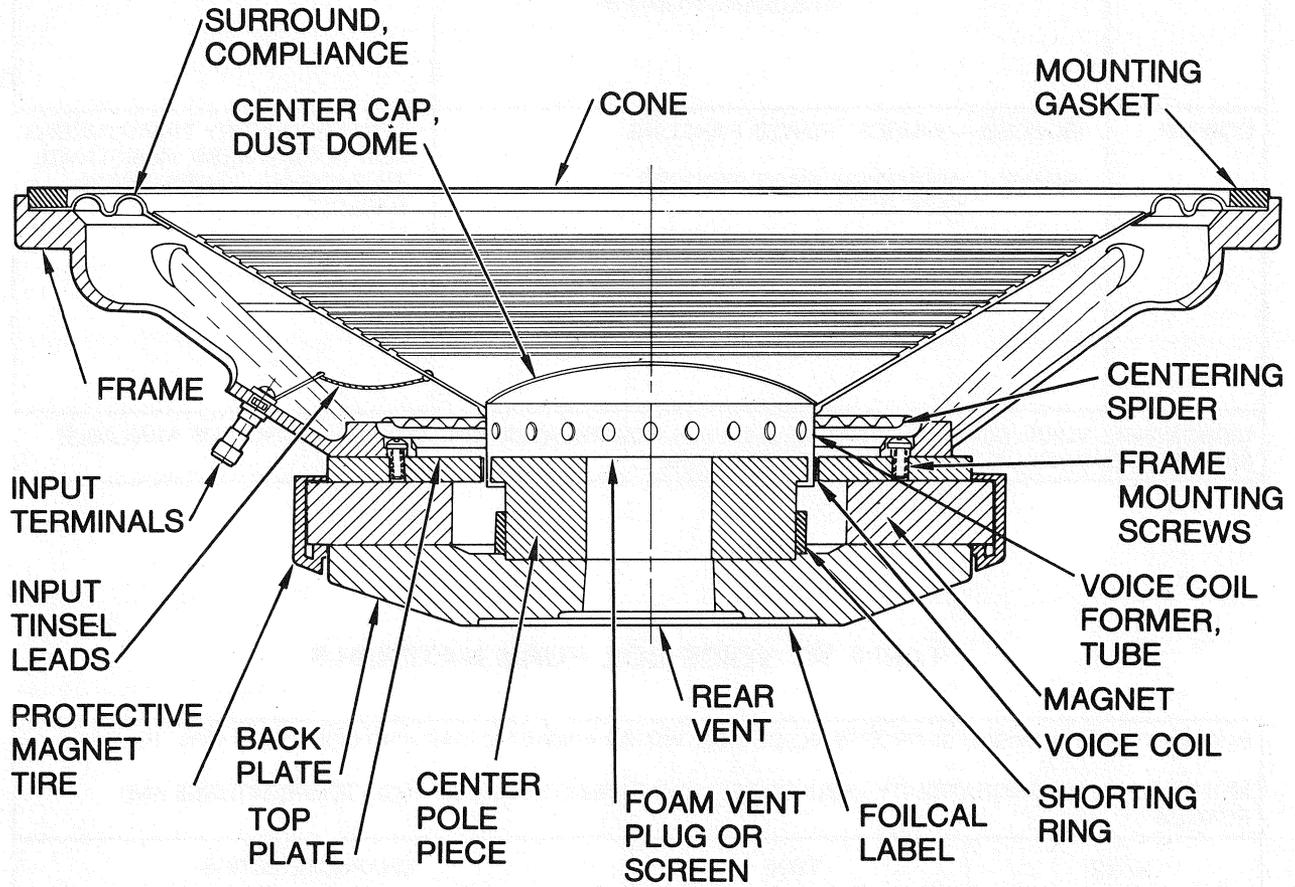
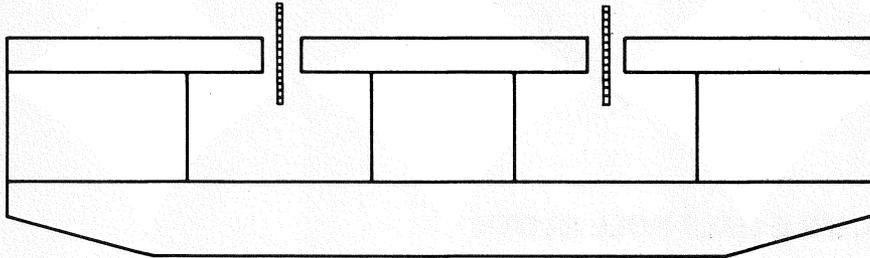


FIGURE 2. THREE VOICE COIL/MAGNETIC GAP TYPES

CROSS-SECTIONAL VIEWS OF LOUDSPEAKER MOTOR VOICE COIL AND MAGNET STRUCTURE

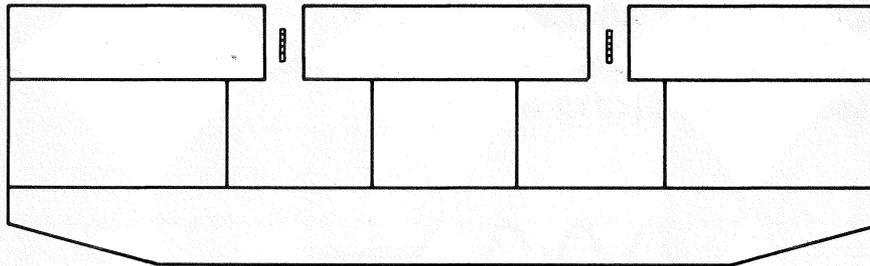
(2A) LONG COIL/SHORT GAP



Coil moves outside magnetic gap, overhang provides linear travel.
Requires precise choice of suspension elements to guarantee linearity.
Both magnetic gap and voice coil depths are scaled up in 460 mm (18 inch) transducers.

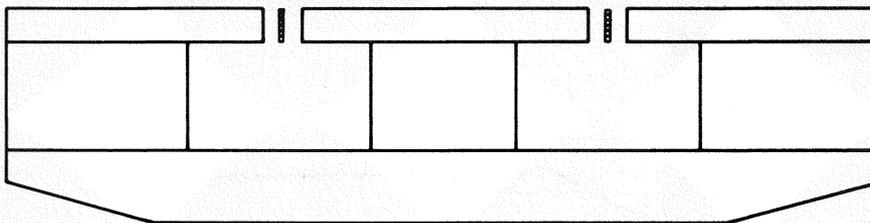
Used on: Slight overhang: 2202, E140
Moderage overhang: 2225, 2240, E155
Large overhang: 2235, 2245, 128H, 2234

(2B) SHORT COIL/DEEP GAP



Coil moves totally within gap for controlled response.
Large heat sink, but expensive due to thick metal, large magnet required.
Used on: 2220, slight gap overhang; E145, very large overhang.

(2C) EQUAL HEIGHT COIL AND GAP



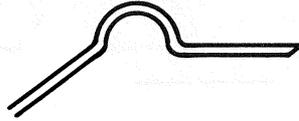
Maximum efficiency; short, light coil completely within maximum flux magnetic gap.
Minimal low-frequency linearity, only what is provided by fringe flux.
Used on: E110, E120, E130.

FIGURE 3. DIFFERENT TYPES OF SURROUNDS/COMPLIANCES

3A. HALF-ROLL OF POLYURETHANE FOAM

Low stiffness (high compliance) for long travel, but requires precise choice of centering spider for controlled linearity.

Used on: 2235, 2245, 128H, 2234



3B. DOUBLE HALF-ROLL CLOTH

Shape of rolls can precisely "tune" stiffness characteristic.

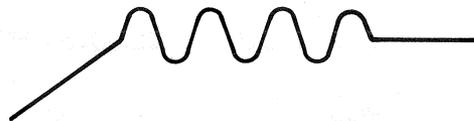
Used on: 2202, 2220, 2225, 2240, E120, E130, E140, E145



3C. MULTIPLE-ROLL ACCORDIAN PLEAT

Long travel, but prone to rim-resonance response dip problems.

Used on: 2213 (4312 woofer)



3D. ONE PIECE CONE/COMPLIANCE WITH TREATED EDGE

Stiff, non-linear suspension, provides HF resonance peak

Used on: E155

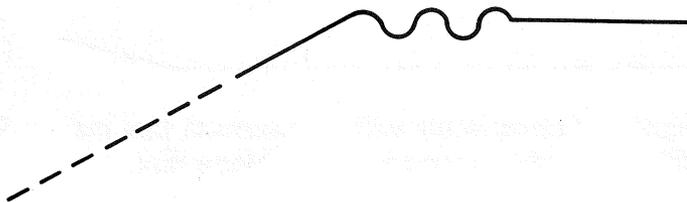
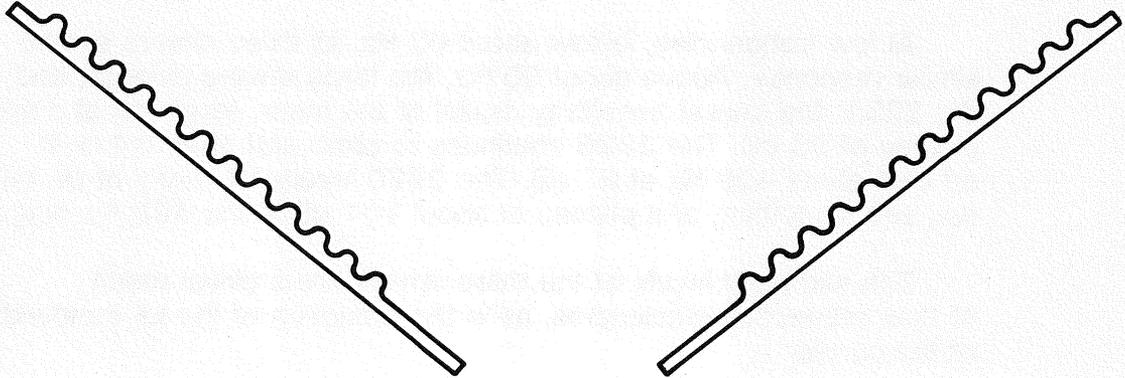


FIGURE 4. DIFFERENT CONE SHAPES

4A. STRAIGHT-SIDED CONE WITH REINFORCING RIBS

Attempts to simulate theoretical piston action

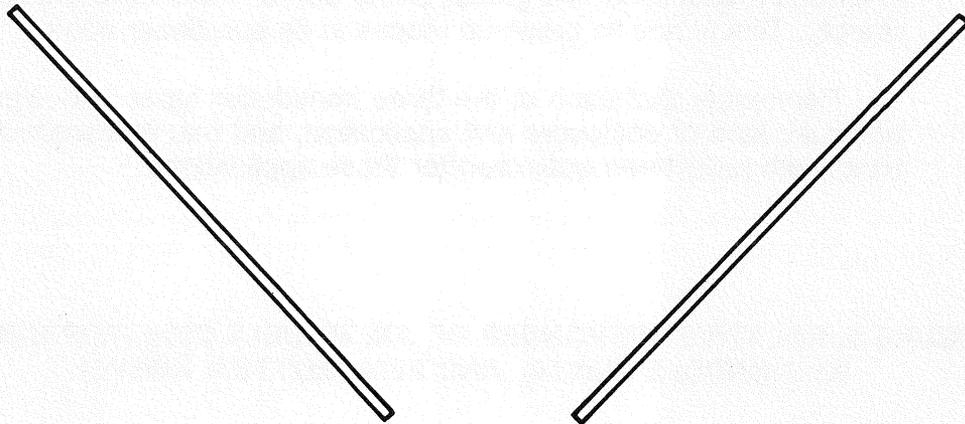
Used on: 2225, 2235, 2240, 2245, 128H, 2234, E140



4B. STRAIGHT-SIDED SMOOTH CONE WITH DEEP CONE ANGLE

Uses deep cone angle to maintain rigidity.

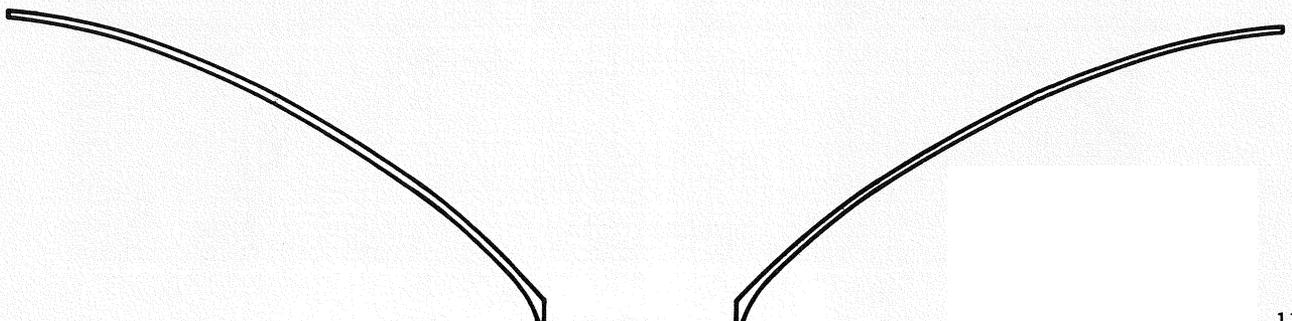
Used on: E145, E155



4C. CURVILINEAR CONE

Cone flexing at mid-points provides greater high-frequency output.

Used on: 2202, 2220, E110, E120, E130



E. COMPARATIVE FREQUENCY RESPONSE:

The three families of LF devices are normally mounted in different enclosure types; however, it is instructive to look at the frequency response of the three types mounted under similar conditions. Figure 5 shows the 2235, 2225, and 2220 mounted in a 280 liter (10 cubic foot) sealed enclosure. The curves were run in half space; that is, the enclosure front was flush with a large baffle surface.

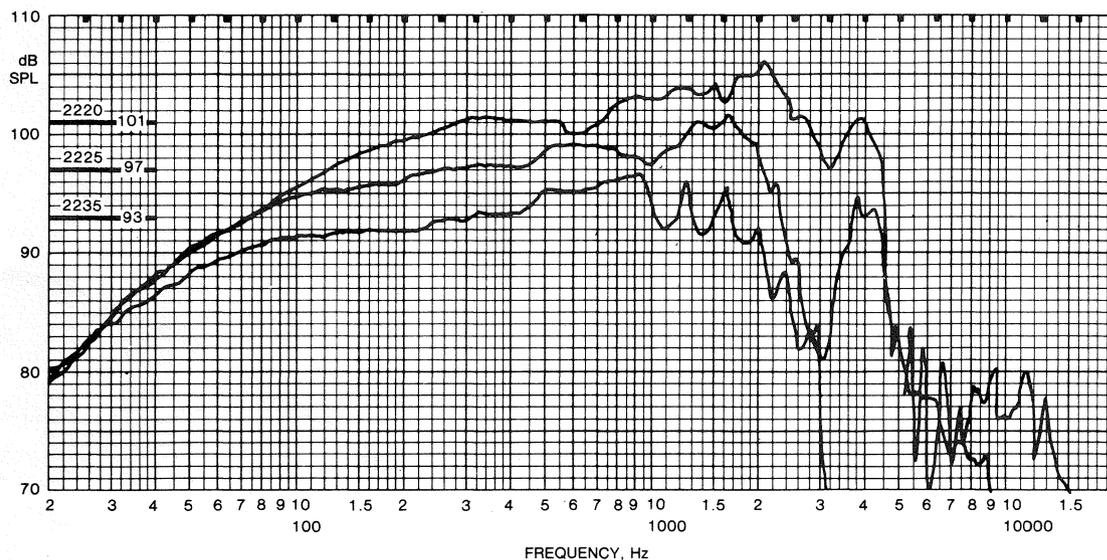
At low frequencies, below about 60 Hz, all three drivers exhibit similar response. Above about 80 Hz, the three drivers diverge, and the 2235, the lowest sensitivity model of the three, levels off at a mid-band plateau of 93 dB. The 2225 continues to climb and does not level off until about 400 Hz at 97 dB. The 2220 levels off hardly at all, but we can see something of a plateau at about 101 dB in the 400 Hz range.

The mid-band levels of the three drivers are a direct result of their respective efficiencies, as is the reduction of the LF bandwidth of the curves.

Note the HF response of the three drivers. The 2235 begins to roll off at 1 kHz, and the slight peaks and dips in its roll-off characteristics are due to resonances in the polyurethane surround. Because of its lower mass, the 2225 reaches about 1600 Hz before it begins to roll off, and it exhibits the smoothest roll-off characteristic of the group, due to its straight, ribbed cone and stiff, multiple half-roll surround. The 2220 exhibits the most extended response of the group, going out to 4 kHz before it rolls off sharply. This is due to break-up modes in its curvilinear cone.

Remember that each of the three transducer types is designed for a particular kind of enclosure and application, and that its sensitivity and bandwidth have been optimized for those applications.

FIGURE 5. RELATIVE RESPONSES OF JBL MODELS 2220 (TOP CURVE), 2225 (MIDDLE CURVE), AND 2235 (BOTTOM CURVE)

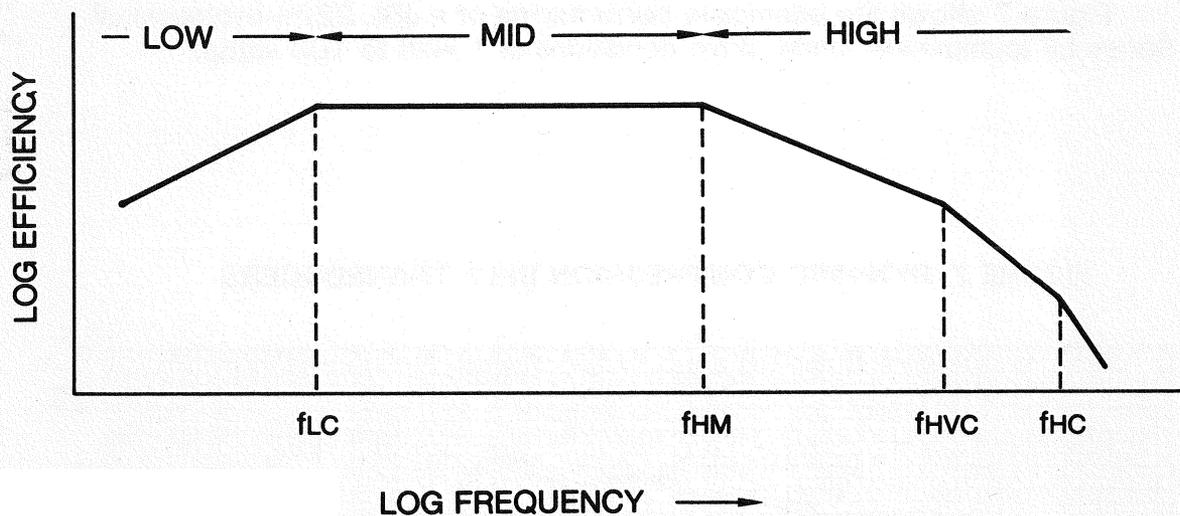


F. THIELE-SMALL PARAMETERS

While the high-frequency performance of a LF transducer is often unpredictable due to break-up modes and surround resonances, the precise nature of LF response can usually be accurately plotted beforehand through the use of the Thiele-Small parameters. All JBL ported enclosures have been designed using these parameters and, where possible, it is recommended that sound contractors use them. For the convenience of those who have a need for designing special systems, we present here a tabulation of the Thiele-Small parameters for all JBL 2220-series and E-series products (See Table V). References which will be useful in Thiele-Small simulations are given at the end of this Technical Note (1,2).

Work done by D. B. Keele (3) has extended the usefulness of the Thiele/Small parameters to LF horn systems. Some details of this are shown in Figure 6, where both LF and HF roll-off frequencies have been related to specific Thiele/Small parameters. The high frequency mass roll-off of the driver in horn loaded use, f_{HM} , can be easily computed from the Thiele-Small parameters, and used as a strong indicator of how high in frequency a horn/driver system can be expected to produce power-flat output.

FIGURE 6. USE OF THIELE-SMALL PARAMETERS IN DETERMINING LF HORN RESPONSE



$$f_{LC} = Q_{TS} f_s / 2$$

$$f_{HM} = \frac{2 f_s}{Q_{TS}}$$

$$f_{HVC} = \frac{R_E}{\pi L_E}$$

$$f_{HC} = 2 Q_{TS} f_s \left(\frac{V_{AS}}{V_{FC}} \right)$$

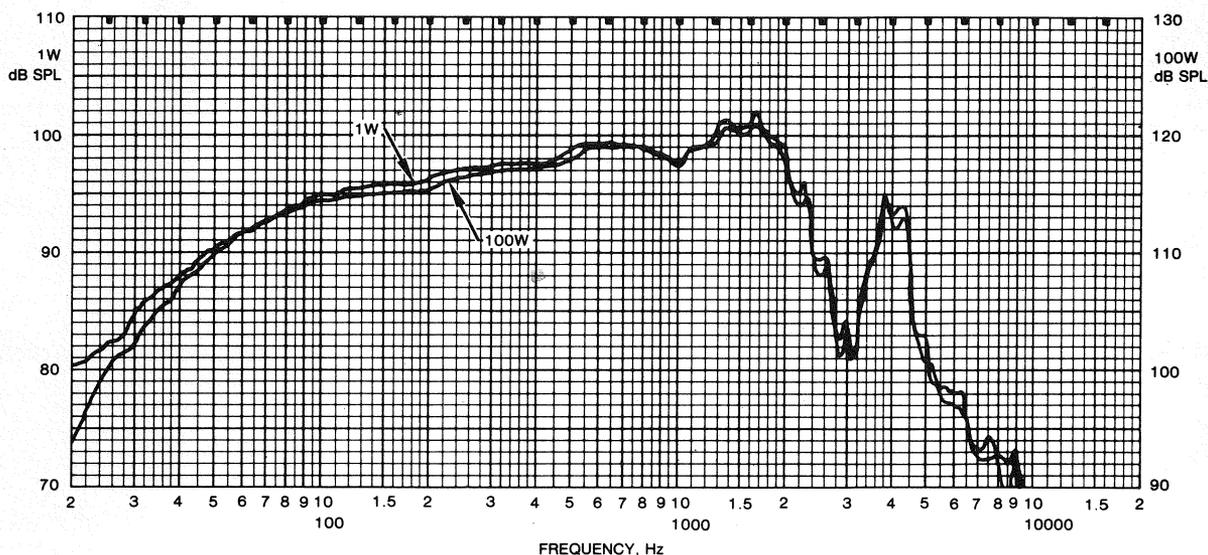
G. DYNAMIC COMPRESSION IN LF TRANSDUCERS

A loudspeaker should theoretically respond with the same frequency response with an input of 100 watts as with an input of 1 watt. There should only be a 20-dB difference in level. In reality, considerable thermal and mechanical stresses are placed on a loudspeaker with high power inputs. Typically, they reduce its efficiency and alter its response. The change in performance from low to high power inputs is an important indicator of its behavior in many musical applications. Power linearity does correlate with power handling, but distortion mechanisms and mechanical characteristics also play a part.

A high-accuracy loudspeaker should show no more than 1 dB compression between power inputs of 1 watt and 100 watts; that is, for the 20 dB increase in power input, at least 19 dB level increase should be observed acoustically. An average loudspeaker will show 1-to-2 dB compression, and it is not uncommon to find otherwise highly regarded loudspeakers to exhibit 3 dB or more compression. This correlates with the subjective impression of "folding up" or sounding "squashed" under high-power transient inputs. The dominant factor in compression at high drive levels at mid- and high-frequencies is the increase in resistance of the voice coil due to heating. In this regard, JBL loudspeakers, with their large voice coils, do not heat up as readily as do loudspeakers with smaller voice coils, and our products typically exhibit less compression.

Figure 7 shows the exemplary performance of a JBL 2225 Professional Series LF loudspeaker under drive conditions of 1 watt to 100 watts.

FIGURE 7. DYNAMIC COMPRESSION IN LF TRANSDUCERS



H. HARMONIC DISTORTION IN LF LOUDSPEAKERS

1. MOTIONAL NON-LINEARITIES:

The voice coil length and top plate thickness can only indicate the potential excursion linearity of a loudspeaker (4). Unless the suspension elements are carefully matched to the motor structure, distortion and limited excursion will result. As the ends of the coil move outside the magnetic gap, at each position the motor strength is different from that observed when the voice coil is centered in its rest position. Under transient conditions the coil can actually jump forward, trying to move out of the gap. This is known as magnetic rectification, or DC offset, and it causes a high level of 2nd harmonic distortion to be generated as part of the transient signal. This effect is common to many long coil loudspeakers. By carefully choosing the stiffness characteristics of the outer suspension and spider, this offset can be eliminated and the linearity of the loudspeaker improved. JBL loudspeakers have inner suspensions which eliminate, or substantially reduce, DC offset. In some cases, this offset may be allowed to occur to a certain degree, to provide a desired musical effect. An example is the E140 bass instrument 380 mm (15") loudspeaker, where LF offset actually provides a "punchy" sound character.

Care must be taken that the suspension is not too stiff, or excursion will be limited. Also, if the suspension has a bias which prefers one direction of motion over the other, it can itself generate 2nd harmonic distortion as the voice coil tries to move against the bias. The E155 460 mm (18") bass instrument loudspeaker exhibits this suspension bias effect, giving it its distinctive low-frequency sound character.

2. HARMONIC DISTORTION CHARACTERISTICS

The 2nd and 3rd harmonic distortion components generated by a loudspeaker at various operating levels create a signature by which, together with its fundamental output, one can often readily identify not only what performance characteristics are present, but also what the subjective character of the loudspeaker's sound will be. Higher harmonics are also present, but their amplitude and character are usually subordinate to the 2nd and 3rd.

Second harmonic distortion is caused by single-ended non-linearities, those preferring one direction of motion over the other. A non-linear bias in a suspension, improper centering of the rest position of the voice coil, and voice coil offsets will all cause 2nd harmonic generation. Flux modulation within the magnetic structure and simple cone break-up also generate 2nd harmonic distortion. In musical terms, the 2nd harmonic is the octave above the fundamental, and a consistently present 2nd harmonic, such as a flux modulation effect, adds a thick, muddy quality to the sound. Second harmonic effects which are a function of transient signals, such as DC offset or cone break-up, can be used to impart desirable sound characteristics to a loudspeaker's signature.

JBL's Symmetrical Field Geometry (SFG) magnetic structures significantly reduce flux modulation, as well as providing equal flux lines above and below the top plate. Through the action of SFG, both 2nd and 3rd harmonic distortion are greatly reduced.

Third harmonic distortion is caused by balanced non-linearities, those which are equally non-linear in both directions of motion. Third harmonic distortion rises with decreasing frequency below 100 Hz as the voice coil motion exceeds the limits of the magnetic gap with increasing excursion. A suspension which restricts coil travel equally in both directions may cause this low-frequency 3rd harmonic rise to occur sooner. Or, if it is precisely matched to the coil motion, it may actually improve coil linearity and reduce distortion.

High 3rd harmonic distortion in the mid-band region can indicate magnetic gap magnetization effects or improper venting of the magnetic structure. The 3rd harmonic is the musical fifth above the octave, and it is generally not as tolerable to the ear as is 2nd harmonic distortion. It tends to add a harsh character to the sound. A square wave, for example, consists entirely of odd harmonics.

I. SOUND PRODUCERS VS. SOUND REPRODUCERS

Another way of categorizing loudspeakers is to view them either as producers of sound or reproducers of sound. For the most part, JBL's E-series loudspeakers are intended as producers of sound, while the 2200-series products are reproducers of sound. As we have seen, there is a slight overlap of these functions in our basic matrix.

The following table summarizes the differences between the two types:

PRODUCERS	REPRODUCERS
<u>E-SERIES</u>	<u>PRO-SERIES</u>
RISING HF	FLAT RESPONSE
DYNAMIC NON-LINEARITIES	LINEAR
HF PEAKS	SMOOTH ROLL-OFF
FULL-RANGE USE	MF OR LF USE
SENSITIVITY:	SENSITIVITY:
500 - 2500 Hz, AVERAGED	100 - 500 Hz, AVERAGED
MODELS:	MODELS:
E110	2122
E120	2202
E130	2220
E140	2225
E145	2234
E155	2240

REFERENCES:

1. G. Margolis and R. Small, "Personal Calculator Programs for Approximate Vented-box and Closed-Box Loudspeaker System Design," Jour. Audio Eng. Soc., Vol. 29, No. 8, (June 1981)
2. J. Young and G. Margolis, "A Personal Calculator Program for Low-Frequency Horn Design Using Thiele-Small Driver Parameters," Preprint 1433. 62nd Convention of the AES (March 1979)
3. D. B. Keele, "Low-frequency Horn Design Using Thiele-Small Driver Parameters," Preprint 1250. 57th Convention of the AES (May 1977)
4. M. R. Gander, "Loudspeaker Topology as an Indicator of Linear Excursion Capability," Jour. Audio Eng. Soc., Vol. 29, No. 11, (Jan, Feb 1981)

TABLE V. THIELE-SMALL PARAMETERS FOR JBL CONE TRANSDUCERS

	SMALL SIGNAL									LARGE SIGNAL				
	MODEL	Re ohms	Fs Hz	Qts	Qms	Qes	Vas L cu. ft.		RefEFF %	Sd m ² /in ²	xMAX mm/in	Vd cm ³ /in ³	PeMAX Watts	Le mH
125 mm: (5") 200 mm: (8")	2105H	6.1	200	.53	3.0	.65	.85	.035	1.2	.0062/9.6	1.5/0.06	9.2/6	25	0.25
	2118H	5.5	85	.35	2.4	.40	14	.5	2.1	.0218/33.8	3.0/12	65/4	100	.06
	2118J	10.3	85	.35	2.4	.40	14	.5	2.1	.0218/33.8	3.0/12	65/4	100	0.85
	LE8T-H	5.5	45	.56	4.0	.65	35	1.2	.5	.018/28	5.5/22	99/6	25	0.3
250 mm: (10")	2123H	4.2	75	.27	4.0	.29	26	0.9	3.5	.033/51	2.5/10	83/5.1	250	0.4
	E110-8	6.0	65	.36	4.0	.40	45	1.6	3.0	.031/48	2.5/0.1	78/4.8	75	0.4
300 mm: (12")	2202H	5.5	50	.16	3.5	.17	89	3.1	6.0	.053/82.5	3.5/14	185.5/11.4	150	1.1
	2204H	6.2	45	.35	1.7	.44	89	3.1	1.8	.054/83	6.9/27	370/22.4	350	0.7
	2213H	4.4	25	.49	8.5	.52	235	8.3	0.68	.049/76	8.0/31	392/23.7	75	0.6
	2214H	5.6	23	.24	10.5	.25	224	7.9	1.1	.053/82	6.6/26	353/21.3	200	1.3
	128H	5.7	20	.24	7.0	.25	280	9.9	0.86	.053/82	8.0/31	424/25.6	100	0.6
	E120-8	6.3	60	.17	1.8	.19	80	2.8	8.6	.053/82	2.5/0.1	133/8	150	0.4
	E120-16	13.0	60	.17	1.8	.19	80	2.8	8.6	.053/82	2.5/0.1	133/8	150	1.1
380 mm: (15")	2220H	5.7	37	.17	5.0	.18	300	10.5	8.7	.089/138	3.0/12	267/16.3	100	1.0
	2220J	13.2	37	.17	5.0	.18	300	10.5	8.7	.089/138	3.0/12	267/16.3	100	2.0
	2225H	6.3	40	.28	2.5	.31	175	6.25	3.5	.089/138	5.0/2	445/27	200	1.1
	2225J	12.9	40	.28	2.5	.31	175	6.25	3.5	.089/138	5.0/2	445/27	200	2.2
	2234H	6.0	23	.22	2.0	.25	460	16.2	2.1	.089/138	8.5/33	757/46	150	1.2
	2235H	6.0	20	.25	2.5	.28	460	16.2	1.3	.089/138	8.5/33	757/46	150	1.2
	E130-8	6.3	40	.19	1.8	.21	300	10.5	8.6	.089/138	2.5/1	233/13.6	150	0.4
	E140-8	5.5	32	.17	5.0	.19	300	10.5	4.9	.089/138	3.5/14	312/19	200	1.1
	E145-8	5.7	35	.25	6.0	.26	275	9.7	4.3	.089/138	7.0/28	623/38	150	1.6
460 mm: (18")	2240G	2.5	30	.23	2.2	.25	480	17	5.0	.130/200	5.5/22	720/44	300	0.7
	2240H	6.0	30	.23	2.2	.25	480	17	5.0	.130/200	5.5/22	720/44	300	1.4
	2245H	5.8	20	.27	2.2	.27	820	29	2.1	.130/200	9.5/375	1230/75	300	1.4
	E155-4	2.5	30	.20	2.2	.22	425	15	4.9	.115/177	5.0/0.2	575/35	300	0.7
	E155-8	6.0	30	.20	2.2	.22	425	15	4.9	.115/177	5.0/0.2	575/35	300	1.4

