Test Bench

By Vance Dickason

Pro Sound

Samples for this month's Test Bench review are both pro sound products. From Faital Pro I received a 6.5″ pro sound woofer (the 6FE100) and from Eminence, a new lightweight neodymium motor 15″ woofer (the 3015LF).

The 6FE100 (***Photo 1***) is intended for use as either a small monitor product or as a midrange in a larger multi-way system. Features include a glass fiber cone, 2.75″ diameter coated cloth inverted dustcap, NBR rubber surround, 8 "window" stamped frame, 90 × 17mm ferrite magnet, shaped rear plate with bump out, 32mm (1.25″) diameter Kapton former wound with round copper wire, 3.25″ cloth spider, and standard solderable terminals.

PHOTO 1: Faital 6FE100.

I began analysis of the 6FE100 employing the LinearX LMS analyzer and VIBox to generate both voltage and admittance (current) curves with the driver clamped to a rigid test fixture in free-air at 0.3V, 1V, 3V, 6V, and 10V. As has become the established protocol for Test Bench testing, I no longer use a single added mass measurement and instead used actual measured mass. This requires 50% of the surround, spider, and voice coil leads removed before putting the entire cone assembly (including the voice coil) on a digital scale. However, in this case, the data was supplied by Faital Pro using the laser method with the company's Klippel analyzer, which is acceptably accurate.

Next, I post-processed the ten 550 point stepped sine wave sweeps for each 6FE100 sample and divided the voltage curves by the current curves (admittance) to derive impedance curves, phase added by the LMS calculation method, and along with the accompanying voltage curves, imported to the LEAP 5 Enclosure Shop program. Because most Thiele/Small data provided by OEM manufacturers is being produced using either a standard method or the LEAP 4 TSL model, I also generated a LEAP 4 TSL parameter set using the 1V free-air curves. I selected the complete data set, the multiple voltage impedance curves for the LTD model (see ***Fig. 1*** for the 1V free-air impedance curve) and the 1V impedance curves for the TSL model in the transducer derivation menu in LEAP 5 and the parameters produced for the computer box simulations. ***Table 1*** compares the LEAP 5 LTD and TSL data and factory parameters for both Faital samples.

Table 1: Faital 6FE100 Woofer.

	TSL model		LTD model		Factory
	sample 1	sample 2	sample 1	sample 2	
F_S	53.9Hz	53.3Hz	51.1Hz	50.82Hz	61Hz
R_{EVC}	5.37	5.42	5.37	5.42	5.4
Sd	0.0143	0.0143	0.0143	0.0143	0.0137
Q_{MS}	4.81	4.67	4.40	4.61	4.58
Q_{ES}	0.59	0.56	0.59	0.58	0.61
Q_{TS}	0.53	0.50	0.52	0.51	0.54
V_{AS}	17.9 ltr	18.3 ltr	20.1 ltr	20.3 ltr	13.0 ltr
SPL 2.83V	88.6dB	88.8dB	88.4dB	88.5dB	91.0dB
X_{MAX}	3.25mm	3.25mm	3.25mm	3.25mm	3.25mm

LEAP parameter calculation results for the 6FE100 were reasonably close to the factory data, with the exception of the lower V_{AS} for the factory data compared to the LTD model, and a roughly 2dB lower SPL. Despite the variance, I began setting up computer enclosure simulations using the LEAP LTD parameters for Sample 1. I produced two box simulations, both sealed. This consisted of a 0.75ft^3 sealed box with 50% fiberglass fill material, and a 0.23ft^3 sealed box with 50% fiberglass fill material.

Figure 2 displays the results for the 6FE100 in both sealed boxes at 2.83V and at a voltage level high enough to increase cone excursion to Xmax + 15% (3.75mm). The resulting F3 frequency was 65Hz with a box/driver Qtc of 0.70 for the 0.75ft^3 sealed enclosure and -3dB of 89Hz with a box/driver Qtc of 0.95 for the 0.23ft^3 box. Increasing the voltage input to the simulations until the maximum linear cone excursion was reached produced 101dB at 11V for the larger sealed enclosure simulation and 106.5dB with an 17.5V input level for the smaller sealed box (see ***Figs. 3*** and ***4*** for the 2.83V group delay curves and the 11/17.5V excursion curves).

Klippel analysis for the 6FE100 (our analyzer is provided courtesy of Klippel GmbH), which was performed by

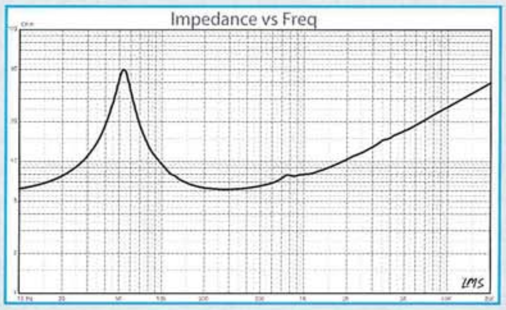

FIGURE 1: Faital 6FE100 woofer free-air impedance plot.

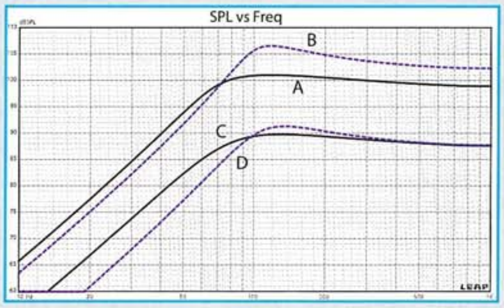

FIGURE 2: 6FE100 computer box simulations (A = sealed 1 at 2.83V; B = sealed 2 at 2.83V; C = sealed 1 at 11V; D = sealed at 17.5V).

Pat Turnmire, Red Rock Acoustics (author of the SpeaD and RevSpeaD software), produced the Bl(X), Kms(X), Bl, and Kms symmetry range plots given in ***Figs. 5-8***. Red Rock Acoustics can provide Klippel analysis of most any driver for a nominal fee of $100 per unit (www.redrockacoustics.com).

The Bl(X) curve (***Fig. 5***) is very symmetrical and shaped about like what you would expect for a 3mm

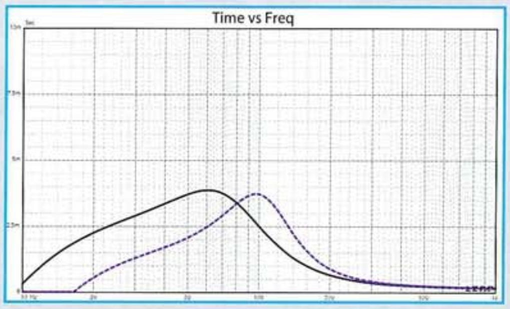

FIGURE 3: Group delay curves for the 2.83V curves in *Fig. 2*.

FIGURE 4: Cone excursion curves for the 11/17.5V curves in *Fig. 2*.

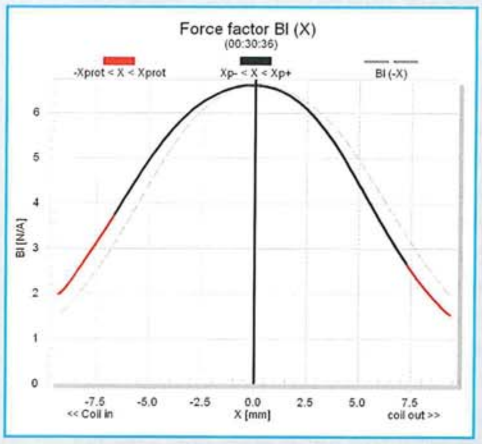

FIGURE 5: Klippel Analyzer Bl (X) curve for the Faital 6FE100.

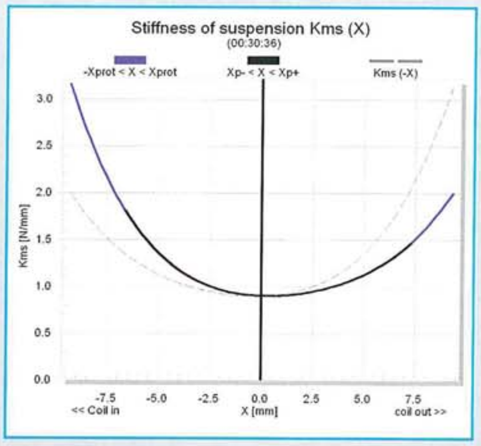

FIGURE 7: Klippel Analyzer mechanical stiffness of suspension Kms (X) curve for the Faital 6FE100.

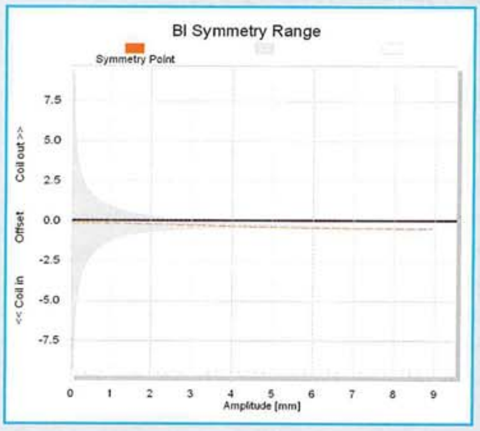

FIGURE 6: Klippel Analyzer Bl symmetry range curve for the 6FE100.

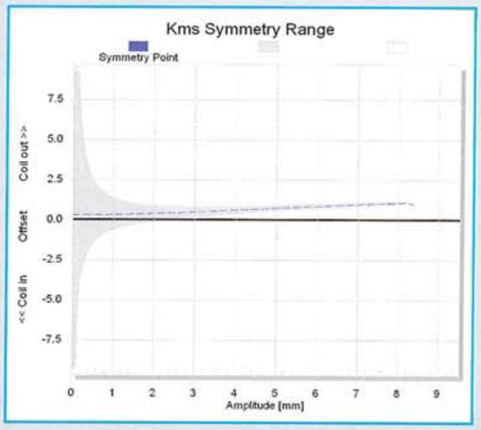

FIGURE 8: Klippel Analyzer Kms symmetry range curve for the 6FE100.

Xmax 6.5″ woofer. In the Bl symmetry plot (***Fig. 6***), this curve stays almost constant throughout the operating range of the driver with a minor rearward (coil-in) offset of 0.5mm at double the Xmax of the driver! ***Figures 7*** and ***8*** show the Kms(X) and Kms symmetry range curves. The Kms(X) curve has some minor asymmetry in both directions, with a coil-out offset of about 0.25mm at the rest position increasing to coil-out 0.5mm at the physical Xmax position; however, these are still rather small offsets. Displacement limiting numbers calculated by the Klippel analyzer were XBl at 82%, Bl was 3.7mm, and for XC at 75% Cms minimum was 4.2mm, which means that the Bl is the most limiting factor at the prescribed distortion level of 10%, but both numbers were beyond the physical Xmax of the driver.

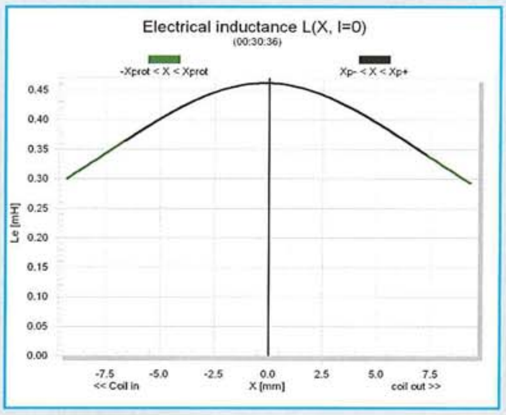

FIGURE 9: Klippel Analyzer Le(X) curve for the Faital 6FE100.

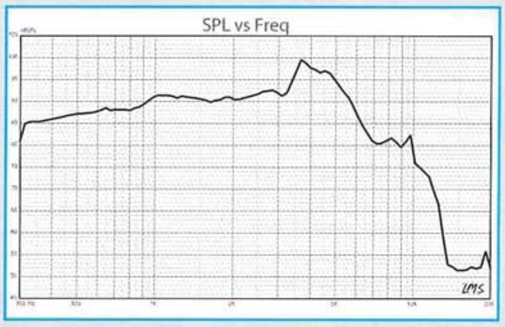

FIGURE 10: Faital 6FE100 on-axis frequency response.

Figure 9 gives the inductance curves Le(X). Inductance will typically increase in the rear direction from the zero rest position as the voice coil covers more pole area, but the slope of this curve decreases in the rear direction, which is normally a result of the copper shorting ring or copper cap on the pole piece. This was not mentioned in the Faital literature.

Next I mounted the 6FE100 in an enclosure which had a 17″ × 8″ baffle and was filled with damping material (foam) and then measured the driver on- and off-axis from 300Hz to 20kHz frequency response at 2.83V/1m using a 100-point gated sine wave technique. ***Figure 10*** gives the on-axis response showing a smooth rising response to about 3kHz, with a 6dB peak at 3.7kHz. ***Figure 11*** illustrates the off-axis frequency response at 0, 15, 30, and 45°. -3dB at 30° with respect to the on-axis curve occurs at 2.7kHz, so like most 6.5″ drivers, a crosspoint in the vicinity of 3kHz would be appropriate. And finally, ***Fig. 12*** gives the two-sample SPL comparisons, showing a very close matchup throughout the operating range.

For the remaining group of tests, I used the Listen Inc. SoundCheck analyzer (courtesy of Listen Inc.) to measure distortion and generate time frequency plots. For the distortion measurement, I mounted the woofer rigidly in free-air, and set the SPL to 94dB at 1m using a noise stimulus, and then measured the distortion with the Listen Inc. microphone placed 10cm from the dust cap. This produced the distortion curves shown in ***Fig. 13***. I then used SoundCheck to get a 2.83V/1m impulse response for this driver and imported the data into Listen Inc.'s SoundMap software. The resulting CSD (cumulative spectral decay) waterfall plot is given in ***Fig. 14*** and the Wigner-Ville (for its better low-frequency performance) plot in ***Fig. 15***. For more information, visit www.faitalpro.com.

Eminence sent a new 15″ from their lightweight Professional Neodymium Series, the Kappalite 3015LF (***Photo 2***). Kappalite is the next generation of Eminence's successful Deltalite series (previously featured in *Voice Coil* January and February 2006) that are neo versions derivative of the Kappa ferrite series. Features include a lightweight curved profile uncoated paper cone, a 5″ diameter uncoated solid composition paper dust cap, and a die-cast aluminum frame with small cooling vanes around the periphery below the spider mounting shelf. Additional cooling is provided by a 0.75″ (19mm) pole type vent. Compliance is provided by a two-roll pleated coated cloth surround and by a 5.75″ diameter coated cloth spider.

The motor assembly is powered by a neodymium ring magnet with metal return cup, making this a very lightweight 8.6 lb. 15″ woofer. Driving the cone assembly is a voice coil assembly that consists of a 63.4mm (3″) diameter polyimide (Kapton) former wound with round copper wire. Voice coil tinsel lead wires terminate to color-coded chrome-plated multi-way binding posts.

Starting up the test sequence, I clamped the driver to a rigid test fixture in free-air, and then generated both voltage and admittance (current) curves at 1V, 3V, 6V, 10V, 15V, 20V, and 30V. I post-processed all 14 10Hz-20kHz 550-point stepped sine wave curve pairs for each driver and divided the voltage curves by the current curves to produce the seven impedance curves. The impedance curves each had phase calculation applied and, along with the voltage curve for each sweep, imported to the LEAP 5 Enclosure Shop CAD program.

Because most T/S data provided by OEM manufacturers is produced using either a standard method or the

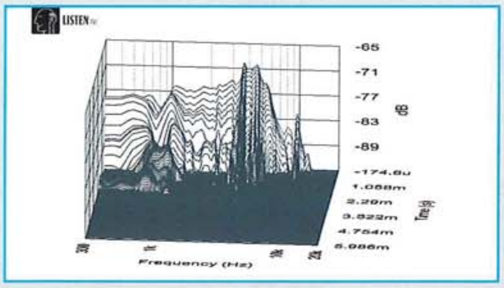

FIGURE 14: Faital 6FE100 SoundCheck CSD waterfall plot.

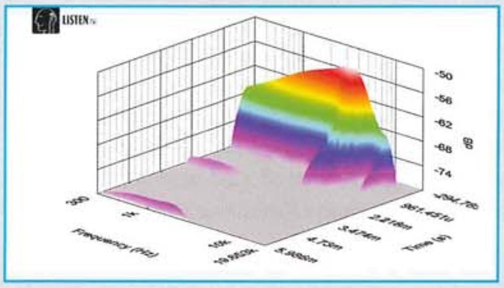

FIGURE 15: Faital 6FE100 SoundCheck Wigner-Ville plot.

FIGURE 11: Faital 6FE100 on- and off-axis frequency response.

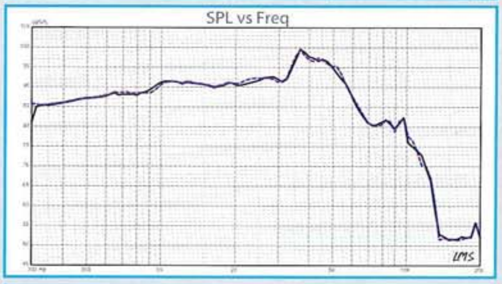

FIGURE 12: Faital 6FE100 two-sample SPL comparison.

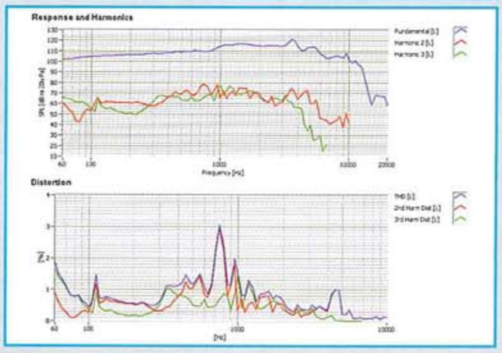

FIGURE 13: Faital 6FE100 SoundCheck distortion plots.

PHOTO 2: Eminence 3015LF.

LEAP 4 TSL model, I additionally produced a LEAP 4 TSL model using the 1V free-air curves. I selected the complete curve set, the multiple voltage impedance curves for the LTD model (see ***Fig. 16*** for the 1V free-air impedance curve), and the 1V impedance curves for the TSL model in the transducer derivation menu in LEAP 5 and produced the parameters for the computer box simulations. ***Table 2*** compares the LEAP 5 LTD and TSL data and factory parameters for both 3015LF samples.

FIGURE 16: Eminence 3015LF free-air impedance plot.

Table 2: Eminence Kappalite 3015LF Woofer.

	TSL model sample 1	sample 2	LTD model sample 1	sample 2	Factory
F_S	43.0Hz	42.8Hz	42.4Hz	42.0Hz	42Hz
R_{EVC}	5.37	5.36	5.37	5.36	5.31
Sd	0.0871	0.0871	0.0871	0.0871	0.0881
Q_{MS}	8.40	8.91	7.28	7.97	6.82
Q_{ES}	0.54	0.50	0.50	0.47	0.41
Q_{TS}	0.51	0.47	0.47	0.44	0.39
V_{AS}	146.1 ltr	147.7 ltr	151.8 ltr	155.1 ltr	158.8 ltr
SPL 2.83V	95.2dB	95.5dB	95.5dB	95.7dB	99.8dB
X_{MAX}	8.1mm	8.1mm	8.1mm	8.1mm	8.1mm

Thiele/Small parameter results were not as close to the factory data as I am used to with Eminence samples. However, simulations I did using cabinet volumes and tunings from the Eminence website turned out very close to the results that were published on the Eminence website, so I am not as concerned with the relatively small variation in parameters. However, the calculated SPL from LEAP 5 had a nearly 4dB difference from the factory SPL rating, which is a lot. Eminence sensitivities are expressed as the average output across the usable frequency when applying 1W/1m into the nominal impedance, i.e., 2.83V/8Ω, 4V/16Ω. LEAP 5 calculates the theoretical sensitivity in dBSPL using 1W based on the R_{EVC} at 1m and is relative to half-space radiation. Eminence has as fine an engineering department as any OEM I have ever worked with, so after I discuss this issue, I will report back in a future Test Bench column.

Following my usual test protocol, I programmed computer enclosure simulations using the LEAP LTD parameters for Sample 1 using the vented enclosure size and tuning listed for this driver on the Eminence website. This included a 5.1ft^3 ported box with 15% fiberglass fill material tuned to 44Hz, and a 4.1ft^3 vented box alignment with 15% fiberglass fill material and tuned to 50Hz.

Figure 17 depicts the results for the 3015LF in the two vented boxes at 2.83V and at a voltage level high enough to increase cone excursion to Xmax + 15% (9.3mm). This produced a F3 frequency of 44Hz for the 5.1ft^3 vented enclosure and –3dB = 50Hz for the 4.1ft^3 vented box simulation. Increasing the voltage input to both simulations until the maximum linear cone excursion was reached resulted in 126dB at 90V for the larger vented enclosure and 126.5dB with an 97V input level for the smaller vented box (see ***Figs. 18*** and ***19*** for the 2.83V group delay curves and the 90/97V excursion curves).

Klippel analysis for the 3015LF produced the Bl(X), Kms(X), Bl, and Kms symmetry range plots given in ***Figs. 20-23***. The Bl(X) curve (***Fig. 20***) is moderately broad, but as you would expect for a moderately long Xmax pro driver and is very symmetrical with a small degree of coil-out offset. The curve in the Bl symmetry plot (***Fig. 21***) is nearly centered at the rest position gradually rising to a 1.75mm forward offset physical Xmax of the driver. ***Figures 22*** and ***23*** give the Kms(X) and Kms symmetry range curves. The Kms(X) curve shows a small amount of asymmetry and has a 2mm forward offset at rest that decreases to about 1mm at the physical Xmax of the driver. Displacement limiting numbers calculated by the Klippel analyzer for the 3015LF were XBl at 82% Bl =

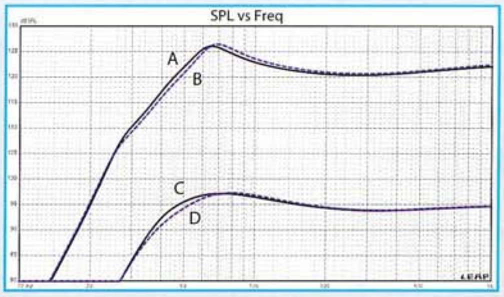

FIGURE 17: Eminence 3015LF computer box simulations (A = vented at 2.83V; B = vented at 2.83V; C = vented at 90V; D = vented at 97V).

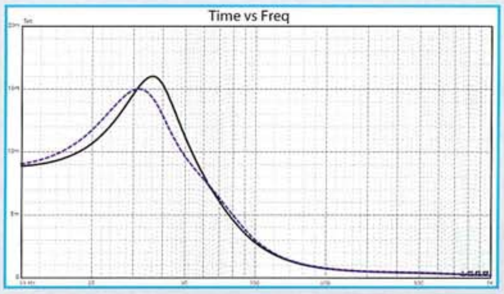

FIGURE 18: Group delay curves for the 2.83V curves in *Fig. 17*.

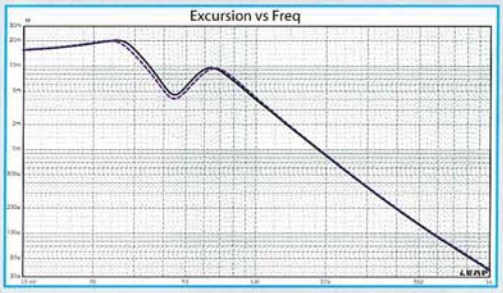

FIGURE 19: Cone excursion curves for the 90/97V curves in *Fig. 17*.

6.7mm and for XC at 75%, Cms minimum was 4.1mm, which means that for the 3015LF, the compliance is the most limiting factor at the prescribed distortion level of 10%.

Figure 24 gives the inductance curves Le(X). Inductance will typically increase in the rear direction from the zero rest position as the voice coil covers more pole area, which is what you see with the 3015LF.

Next I fired up the Listen Inc. SoundCheck analyzer again and set it up for distortion measurements. The SPL at 1m with the 15″ Eminence woofer mounted in free-air using pink noise was set to 104dB, my standard for pro sound products. The 3015LF produced the distortion curves shown in ***Fig. 25***. Following the distortion measurements, I mounted the 3015LF on an enclosure with an 18″ × 18″ baffle and made the impulse measurement. I imported this into Listen Inc.'s SoundMap software, windowed to remove the room reflection and produced the CSD waterfall plot in ***Fig. 26*** and the Wigner-Ville plot in ***Fig. 27***.

For the remaining series of SPL measurements, using the same enclosure as with the impulse response, I then measured the driver frequency response both on- and off-axis from 300Hz to 20kHz with a 100-point resolution at 2.83V/1m using a gated sine wave technique. ***Figure 28*** depicts the 3015LF on-axis response, yielding a smooth rising response out to 1kHz and with about 5dB of peaking before rolloff at 2kHz.

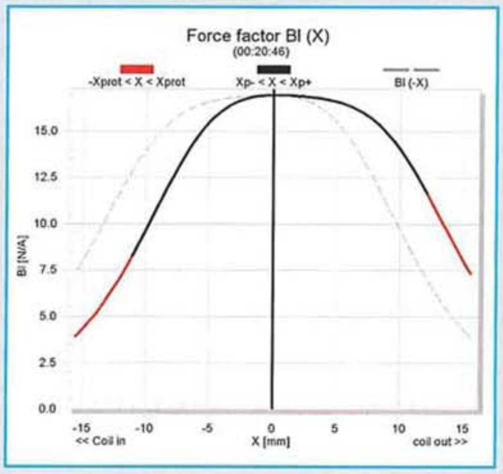

FIGURE 20: Klippel Analyzer Bl (X) curve for the Eminence 3015LF.

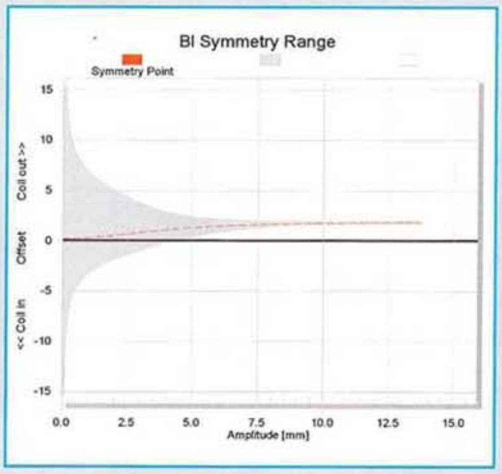

FIGURE 21: Klippel Analyzer Bl symmetry range curve for the 3015LF.

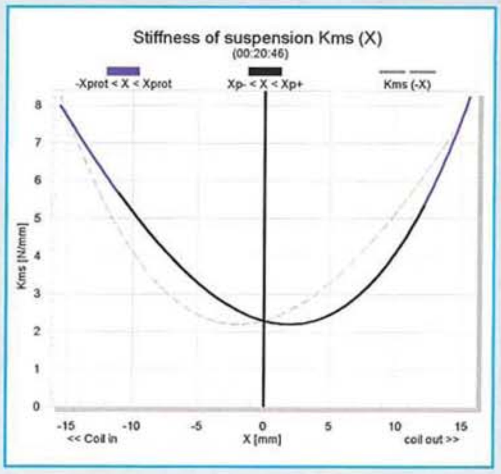

FIGURE 22: Klippel Analyzer mechanical stiffness of suspension Kms (X) curve for the Eminence 3015LF.

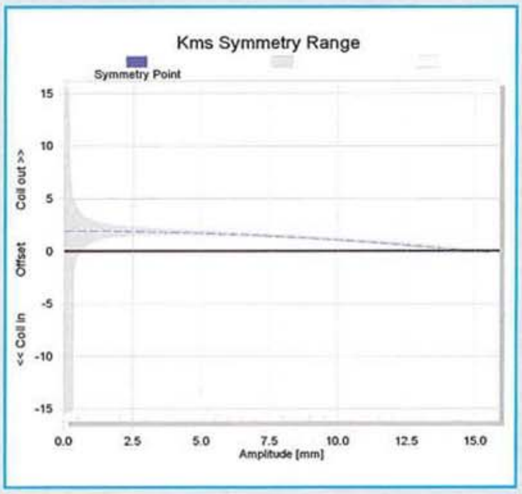

FIGURE 23: Klippel Analyzer Kms symmetry range curve for the 3015LF.

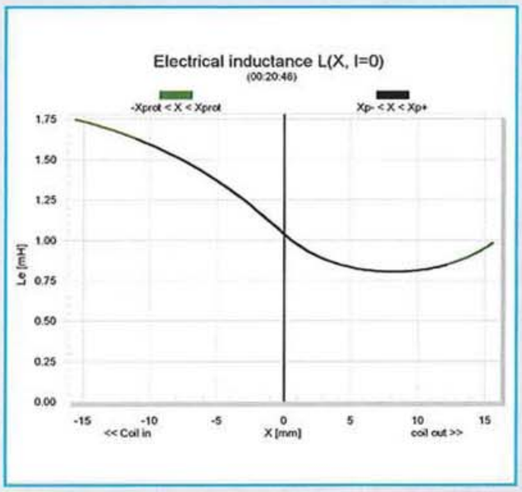

FIGURE 24: Klippel Analyzer Le(X) curve for the Eminence 3015LF.

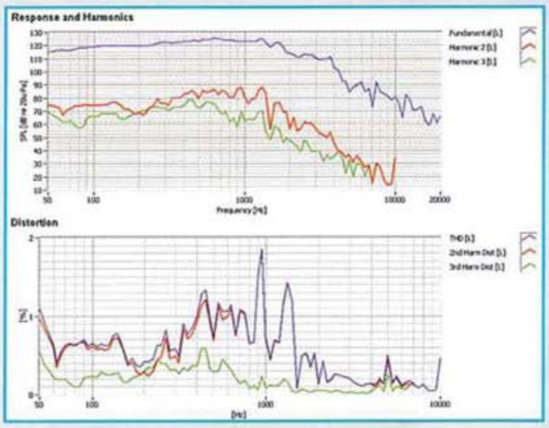

FIGURE 25: Eminence 3015LF SoundCheck distortion plots.