EQUIPMENT PROFILE

LEGACY CONVERGENCE LOUDSPEAKER

The Convergence, a large floor-standing three-way tower, is next to the top of Legacy's lineup of loudspeaker systems and subwoofers. The Legacy line is made and distributed by Reel to Real Designs. Bill Dudleston, one of Reel to Real Designs' founders (in 1983), is the chief architect of the Legacy line and brings to the company a rich background in engineering, math, and chemistry. Reel to Real Designs is known for exotic and elaborate cabinet construction, and the Legacy line is available in many woods and finishes, from teak to ribbon mahogany (the systems I reviewed were supplied in this wood).

Dudleston's primary goals in designing the Convergence were uniform lateral coverage, wide bandwidth, high efficiency (sensitivity), and low distortion. When optimizing the crossover and driver-to-driver relationships, he considers overall power response to be just as important as on-axis response. After all, he states, "Our ears are mounted on the *sides* of our heads, right?" After much experimentation with driver spacings, tweeter offsets, and polar patterns, he ended up with a tweeter halfway between two identical vertically stacked midranges, similar to the D'Appolito configuration (named after Joseph D'Appolito, a contributing editor of *Speaker Builder*, who first gave a detailed description of it). The major benefits of this configuration include higher vertical directivity (which reduces floor and ceiling reflections), symmetrical up/down polar response, greater acoustic output capability, and lower distortion. Because his implementation of this configuration does not follow some of D'Appolito's guidelines, such as odd-order Butterworth slopes and driver spacing less than one wavelength at crossover, Dudleston prefers not to call his a D'Appolito configuration but rather names his technique Field Optimized Convergent Source technology. The output of the system is optimized for seated listeners.

In addition to the front-mounted midranges and tweeter, the Convergence has

SPECS

System Type: Three-way, floor-standing, vented box.

Drivers: Two 12-in. cone woofers, two 6½-in. cone midranges, and two 1-in. aluminum-dome Ferrofluid-cooled tweeters.

Frequency Response: 21 Hz to 20 kHz, ±3 dB.

Sensitivity: 98 dB at 1 meter with 2.83 V rms applied.

Crossover Frequencies and Filter Slopes: 180 Hz (second-order high-pass, third-order low-pass) and 4 kHz (second-order high-pass and low-pass); both crossovers yield third-order slopes, acoustically.

Impedance: Nominal, 4 ohms; minimum, 2.6 ohms; maximum, 18 ohms.

Dimensions: 51 in. H × 15⅞ in. W × 13¾ in. D (129.5 cm × 40.3 cm × 34.9 cm).

Weight: 150.3 lbs. (68.2 kg) each.

Price: $3,400 per pair; optional bass-alignment filter, $450; available in walnut, oak, cherry, mahogany, teak, rosewood, or black finish with black, brown, gray, tan, maroon, or off-white grille fabric.

Company Address: c/o Reel to Real Designs, 3021 Sangamon Ave., Springfield, Ill. 62702.

For literature, circle No. 91

two husky, low-resonance 12-inch woofers with rubber surrounds, in a rear-ported vented box. The four ports are in a two-by-two array on the top rear of the cabinet. Dual woofers were chosen to increase maximum acoustic output capabilities and to lower distortion. An optional high-pass bass-alignment filter/equalizer further extends response and decreases distortion due to elimination of below-band energy in the program material.

The French-built Focal midranges have cast frames, polyglass cones, and a stationary bullet-shaped diffuser (or phase plug) in the center that is said to improve off-axis response. The front-mounted Ferrofluid-cooled dome tweeter, sourced from Vifa of Denmark, is recessed by about ¼ inch. According to Dudleston, this creates a quasi-horn-loaded configuration that smoothes off-axis response, increases output above 5 kHz, and simplifies crossover design. An additional, switch-selected tweeter is on the top rear of the cabinet. It provides additional energy to fill out the system's high-frequency power response, compensating for the way the front tweeter's coverage narrows with rising frequency.

The overall impedance of the Convergence is deliberately on the low side to take advantage of the high current capability typical of high-end amplifiers. This lets the audiophile tap into some of the unused capability of these amplifiers that sometimes goes to waste on higher impedance systems. However, Dudleston points out that, because the Convergence speakers have a relatively high sensitivity, they actually require substantially less current for a given sound pressure level than most systems, which have lower sensitivity.

The woofers of the Convergence operate up to 180 Hz, where the midranges start operating. The midranges are used up to about 4 kHz, where the tweeter takes over. The crossover of the Convergence contains 11 resistors, nine inductors, and six capacitors, not counting paralleled units. Three rear-mounted switches control the midrange and front tweeter levels and also defeat the rear tweeter. High-quality parts are used throughout, including audiophile-type wire. The crossover is hand-wired on two hard-board panels mounted behind the woofers. Two pairs of gold-plated Tiffany double-banana binding posts on the rear panel provide for straight or bi-wire operation.

Most of the cabinet is constructed of medium-density fiberboard, 1 inch thick. The inside of the cabinet is strengthened quite well, with braces running up the sides and rear of the enclosure and two internal cross partitions (called Q-braces by the manufacturer). Tubes of PVC, 6 inches in diameter, form sub-enclosures for the midranges and connect the front and rear of the cabinet. White polyester fiber is used for internal damping.

Measurements

The on-axis and 20° horizontal off-axis anechoic frequency responses of the Convergence are shown in Fig. 1, taken without the bass-alignment filter and with all the rear switches in their normal (up) position. Measurements were taken 2 meters from the cabinet's front, at the height of the tweeter. A voltage of 5.66 V rms was applied and the measurement referenced back to 1 meter. The response below 1 kHz was derived from 2-meter ground-plane measurements, and the input was reduced to 2.83 V rms to compensate for the ground plane's 6-dB boost. The 20° off-axis response corresponds approximately to what a centrally located listener would hear with the systems pointed straight ahead, as the manufacturer recommends, rather than toed in at him.

THE SENSITIVITY OF THE CONVERGENCE IS THE SECOND HIGHEST I HAVE MEASURED.

Although somewhat rough overall, the response fits a fairly tight window of 6 dB between 40 Hz and 20 kHz. Above 2 kHz, the response is significantly smoother at 20° off axis but rolls off somewhat at higher frequencies. Above 20 kHz (data not shown), the response had a high-Q dip of 20 dB at 24.2 kHz followed by a sharp 6-dB peak at 25.5 kHz, presumably due to the tweeter's metal-dome resonance. The response rolled off very rapidly above 30 kHz. Separate measurements (not shown) revealed that the unmarked rear-panel switches controlling the midrange and front-tweeter levels attenuated their respective drivers' output by about 1.5 dB each.

Averaging the response over the range from 250 Hz to 4 kHz yielded a sensitivity figure of 92 dB, significantly less than the manufacturer's rating of 98 dB but still the second highest I have measured, surpassed only by the KEF 105/3 (reviewed in the June 1991 issue).

The Convergence's grille caused fairly severe interference effects (not shown) in the on-axis response above 1 kHz, with irregularities of up to +2 and –4 dB. I suggest leaving the grille off for serious listening; the speaker looks quite good without it. Above 100 Hz, the right and left systems matched within a close ±1 dB, which ensures stable lateral imaging.

A conspicuous aspect of the bass response, seen in Fig. 1, is an octave-wide

peak at 62 Hz, followed by a depression between 85 and 170 Hz. This trough coincides with the crossover between the woofers and the midranges. Separate ground-plane measurements of the woofer and mid/high sections, with the bi-wire straps removed, revealed that the two sections were slightly out of phase in this trough region and thus summed to a lower level. Connected separately, the woofer response peaked at 62 Hz and then rolled off at higher frequencies, although it did so quite slowly from 200 Hz to 1 kHz.

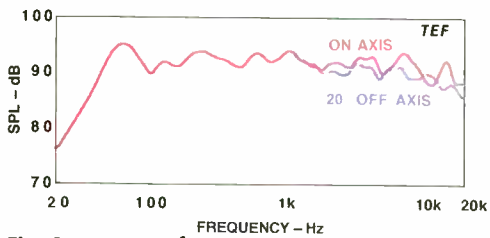

Fig. 1—On-axis frequency response.

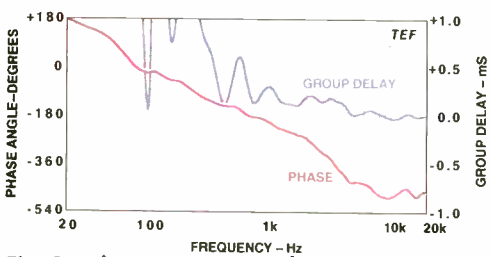

Fig. 2—Phase response and group delay.

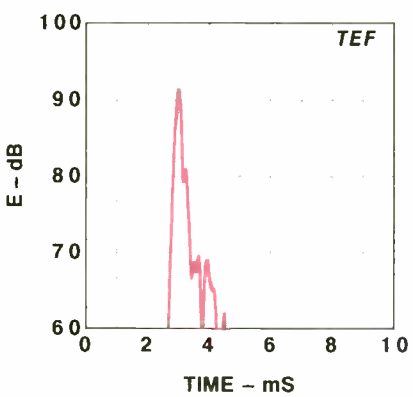

Fig. 3—Energy/time response.

Reversing the polarity of the mid/high section raised the level between 80 and 180 Hz by about 2 dB but decreased the level by about the same amount in a broad range from 180 Hz to 1 kHz. The reversed mid/high connection also added an extra 180° to the overall phase response. Clearly, the normal polarity connection is preferable. The moderate changes in response with normal and reversed mid/high polarity indicate that the two sections are approximately 90° out of phase with each other through the lower crossover range.

The bass-alignment filter provided a standard second-order high-pass response at 21 Hz with a peak of 5.4 dB at 24 Hz (response not shown). The filter changed the system's overall low-frequency response from a vented-box fourth-order high-pass into a sixth-order high-pass. This was accomplished by the filter's boosting of the response at and above the box resonance frequency, where the power handling is high, and rapidly rolling off the response at lower frequencies, where the power handling capability is much lower.

The sixth-order loudspeaker alignment provides a good combination of high acoustic output and resistance to potential intermodulation from below-band power in the program material. It was first described by A. N. Thiele in his pioneering paper "Loudspeakers in Vented Boxes, Parts 1 and 2" (*Journal of the Audio Engineering Society*, May and June 1971, also reprinted in *Loudspeakers*, the first of two anthologies of speaker articles from the *JAES*. Incidentally, I recommend these anthologies highly.)

I also investigated the phase relationships between the tweeter and midranges by reversing the tweeter's polarity (measurements not shown). The output actually went up by about 2 dB between 1.5 and 3.2 kHz but decreased by about 5 dB between 3.5 and 4.7 kHz. These level changes confirm that the tweeter and midranges are neither in phase nor completely out of phase through the crossover region, but are halfway between, about 90° out of phase. This does not, however, increase the speaker's lobing, because the D'Appolito configuration minimizes this problem.

Figure 2 shows the phase and group-delay responses of the Convergence, referenced to the tweeter's arrival time. Between 1 and 20 kHz, the phase curve rotates a significant 280°, due to a combination of the crossover's design and the offset between the acoustic centers of the tweeter and midranges. Between 1.2 and 4 kHz, the midrange output lags the tweeter by about 0.23 mS. The dips in the group delay at 100 and 170 Hz coincide with dips in the axial response at the same frequencies, which indicates a possible minimum-phase aberration. If the response were equalized flat in this region, the phase and group delay response would also be much smoother.

The Convergence's energy/time response is shown in Fig. 3. The test parameters were chosen to accentuate the system's response from 1 to 10 kHz, which includes the upper crossover region. Except for a slight perturbation about 10 dB down from the peak, the response decay is well behaved. Lower level delayed reactions, some 24 dB down from the peak, are exhibited.

THE CONVERGENCE'S BASS OUTPUT EXCEEDS THAT OF ANY SPEAKER —OR SUBWOOFER— I HAVE TESTED.

Figure 4 shows the horizontal off-axis responses of the Convergence. The bold curve at the rear of the graph is the on-axis response. The horizontal coverage is quite good, because the on-axis response aberrations are carried over quite appropriately into the off-axis curves. The output of the rear-mounted tweeter shows up in the 180° curve at the front of the display. The rear tweeter operates above 10 kHz, at about the same level as the front tweeter.

In Fig. 5, the vertical off-axis responses, the bold curve in the center of the graph (front to rear) is on axis (at a right angle to the front of the cabinet). Not clearly seen in the graph is the fact that only the –5° to +5° curves are reasonably flat. The response at higher and lower angles exhibits dips in the crossover region from 3 to 6 kHz. This means that to hear the flattest response, the listener should be sitting down; a standing listener is about 10° to 14° above the axis. The relatively high vertical directivity of the Convergence is due to its use of two comparatively wide-spaced midranges, coupled

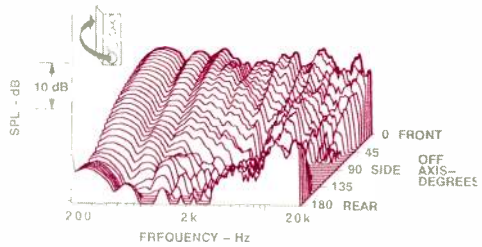

Fig. 4—Horizontal off-axis responses.

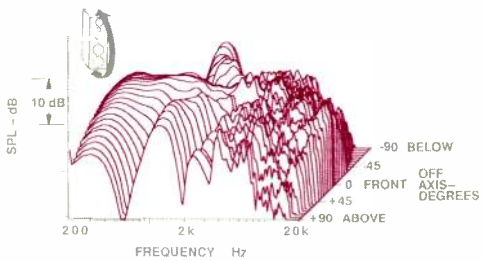

Fig. 5—Vertical off-axis responses.

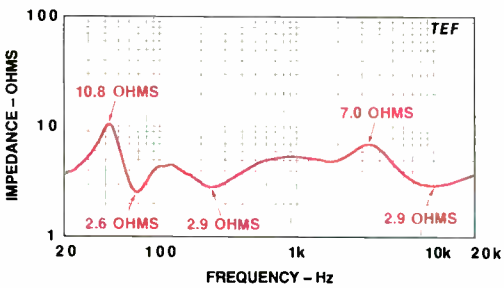

Fig. 6—Impedance.

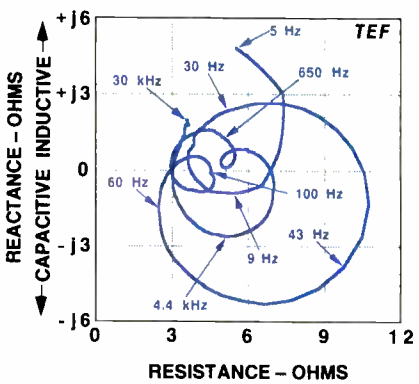

Fig. 7—Complex impedance.

with its relatively high, 4-kHz crossover frequency. The vertical off-axis curves exhibit up/down symmetry that is an inherent characteristic of the D'Appolito configuration.

The Convergence's impedance magnitude is shown in Fig. 6. A minimum impedance of 2.6 ohms occurs at 65 Hz and a maximum of 10.8 ohms at 42 Hz. Below 20 Hz, a minimum impedance of 3.7 ohms was reached at 18 Hz (near the vented-box tuning frequency), and the maximum was 8 ohms at 6 Hz (the lower anti-resonance impedance peak of the vented-box system). The curve in Fig. 6 has a pass-band max/min variation of about 4.2 to 1, so the Convergence will be somewhat sensitive to cable resistance. Cable series resistance should be limited to a maximum of about 0.04 ohm to keep cable-drop effects from causing response peaks and dips greater than 0.1 dB. For a typical run of about 10 feet, 14-gauge (or larger) low-inductance wire should be used. Smaller diameter wire can be used but will result in higher peak-to-dip variations in reponse.

Figure 7 shows the complex impedance of the Convergence, plotted over the range from 5 Hz to 30 kHz. The large circle in the plot is the upper vented-box impedance peak. The overall curve is quite energetic and exhibits five complete clockwise loops as frequency increases! The passband impedance phase (not shown) reached a maximum angle of +25° (inductive) at 30 Hz and a minimum of –50° (capacitive) at 54 Hz. Although the phase angles are not excessive, the low minimum impedance of the Convergence (2.6 ohms) requires that an amplifier with low output impedance and high current capability be used.

When the speaker was subjected to a high-level low-frequency sine-wave sweep, no significant cabinet resonances were evident. The ports reduced the woofer excursion over a broad range from 19 to 35 Hz, with a minimum excursion at 23 Hz, the system's vented-box tuning. (I would have preferred to have the effective box tuning at the minimum excursion point for large signals, rather than at 18 Hz, the impedance minimum for small signals, where the designer put it.) The vent reduced the excursion to about 50% of its maximum excursion above box resonance, which occurred at 54 Hz. Even at levels above 20 V rms near box resonance, the port turbulence was quite low. On high-level low-frequency sine waves, the Convergence always sounded very clean and effortless.

The maximum excursion of the woofers was a healthy 0.7 inch, peak to peak, with a linear excursion of about 0.5 inch, peak to peak. The woofers overloaded very gracefully and exhibited no dynamic offset problems. The speaker could handle levels up to 30 V rms (225 watts into 4 ohms) at frequencies all the way down to 10 Hz without making any bad noises whatsoever (although my whole lab was shaking above 18 Hz)! This is the highest sine-wave power handling in the low-frequency range that I have measured on any system.

DISTORTION WAS VERY LOW AND OUTPUT VERY HIGH, A DYNAMITE COMBINATION.

Figure 8, the 3-meter room response of the Convergence, includes curves for both raw and sixth-octave smoothed data. The speaker was in the right-hand stereo position, aimed straight ahead (not at the listening position), and the test microphone was at ear height (38 inches), at the listener's position on the sofa. The system was driven with a swept sine-wave signal of 2.83 V rms (corresponding to 2 watts into the rated 4-ohm load). The direct sound and 13 mS of the room's reverberation are included. Above 1 kHz, the curve is fairly smooth but exhibits roll-off above 7 kHz. Repeating the test with the speaker aimed at the microphone revealed less roll-off but much less smoothness. Excluding the room-effect dip at 400 Hz and the 600-Hz peak, the averaged curve fits a window of 8 dB (±4 dB) from 100 Hz to 13 kHz.

The spectra of single-frequency harmonic distortion versus power for the musical notes of E_1 (41.2 Hz) and A_2 (110 Hz) are shown in Figs. 9 and 10. As with most large speakers I've tested lately, distortion for the 440-Hz tone was too low to present, only about 0.5% second harmonic rising above the floor of my measurement gear at full power. The power levels were computed using the rated system impedance of 4 ohms. A high maximum power level of 200 watts was set as the upper limit, the highest I have ever used for these tests. Even with this power level, the Convergence always sounded quite clean.

The E_1 (41.2-Hz) harmonic distortion data is shown in Fig. 9. At maximum (200-watt) power level, the distortion only reaches 6% second harmonic and 3.4% third. The higher harmonics were mostly below the floor of my measuring gear. At 200 watts, the system generates a very loud 100 dB sound pressure level at 1 meter at 41.2 Hz.

Figure 10 shows the harmonic data for A_2 (110 Hz). The second harmonic reaches only 3% at 200 watts, and the third harmonic reaches 4.9%. Higher harmonics are very low. At 110 Hz with an input of 200 watts, the Convergence generates a very loud 113 dB SPL at 1 meter.

Figure 11 displays the IM distortion created by tones of 440 Hz (A_4) and 41.2 Hz (E_1) of equal input power. The IM distortion rises only to the low value of 4% at full power. The Convergence's lower crossover, at 180 Hz, separates the two IM test tones and thus minimizes the distortion.

Figure 12 shows the speaker's short-term peak-power input and output capabilities, measured using a 6.5-cycle tone burst with third-octave bandwidth. Due to the high input and output capabilities of the Convergence, the scales for this graph were increased by one division, so that the top of the SPL scale is 140 dB (rather than 130 dB, as in previous reviews) and the input power starts at 10 watts (rather than 1 watt). The peak input power was calculated by assuming that the measured peak voltage was applied across the rated 4-ohm impedance.

The input power starts very high, at about 1 kW at 20 Hz (the highest I have measured in the range from 20 to 70 Hz!), and then fluctuates as frequency increases. Between 63 and 100 Hz, the input was limited because the output waveshape changed to a triangle, presumably due to crossover-inductor saturation. A power limitation occurs between 170 and 400 Hz, where the wave became quite rounded and sounded hollow at higher levels. A maximum peak input of 10 kW (200 V!) is reached between 1 and 5 kHz. The reduction of input power above 6 kHz was not caused by the Convergence, but by my test amplifier running out of gas due to the speaker's low impedance in this range!

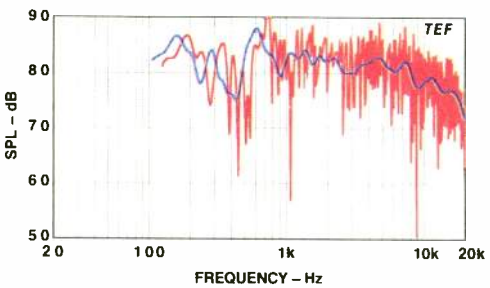

Fig. 8—Three-meter room response.

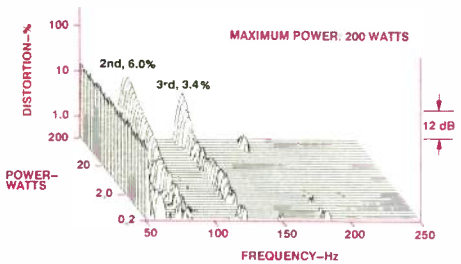

Fig. 9—Harmonic distortion products for E_1 (41.2 Hz).

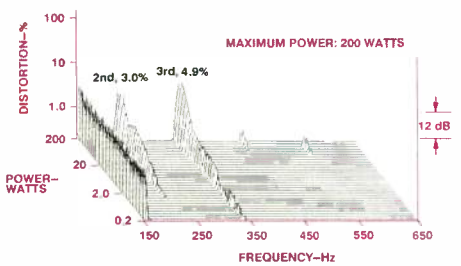

Fig. 10—Harmonic distortion products for A_2 (110 Hz).

The upper curve in Fig. 12 shows the maximum peak sound pressure levels the system can generate, at 1 meter on axis, for the input levels shown in the lower curve. Also shown is the "room gain" of a typical listening room at low frequencies, which adds about 3 dB to the response at 80 Hz and 9 dB at 20 Hz.

The peak acoustic output rises with frequency up to 55 Hz, then flattens out, and continues to rise above 400 Hz. Between 800 Hz and 8 kHz, the level actually exceeds an ear-shattering 130 dB! These levels are high enough to keep up with the peak SPLs of live percussion instruments. With room gain, the maximum output exceeds 110 dB above 18 Hz and 120 dB above 30 Hz, the lowest frequencies I have measured for these SPL points! The Convergence's low-frequency maximum output exceeds any of the systems I have tested for *Audio*, including the four subwoofers I measured for the November 1992 issue—and this for a single system! A stereo pair of Convergence speakers can reach even higher low-frequency levels with bass material common to both channels.

Use and Listening Tests

The appearance and the fit and finish of the Convergence are superlative. As stated before, the finish of my review samples was ribbon mahogany, which reminded me of majestic old-time console radios. These speakers are large and heavy (150 pounds apiece), and one person can only move them by walking them with a side-to-side rocking motion. The speakers are supplied with molded plastic rails that are screwed to the bottom of the cabinet for stability. Cone spikes are also supplied. Connections are made through heavy-duty double-banana jacks on the cabinet's bottom rear. Each speaker is supplied with two short cables with spade lugs to be used as jumpers when the speaker is under normal (not bi-wired) operation.

ON SOFT AND DELICATE CHAMBER MUSIC, THE CONVERGENCE SOUNDED SMOOTH, DETAILED, AND NEUTRAL.

The thorough 10-page instruction manual covers such topics as speaker placement, connections and cabling, fine tuning (with the systems' level-adjustment switches), amplifier and power requirements, and bi-wiring and biamplification. Additionally, Reel to Real Designs will even supply custom passive resonance-trap filters to use with the bass section. These may help solve some typically troublesome room and placement problems.

As discussed previously, Legacy states that the optimal listener position is actually 20° off the horizontal axis and recommends that the speakers fire straight into the room rather than being toed in. For best results, the listener's ear should be at the same height as the tweeter. All my listening was done with the speakers facing straight ahead and not aimed at my listening position. I placed them 8 feet apart, 10 feet from my sofa, and about 5 feet from the wall behind them.

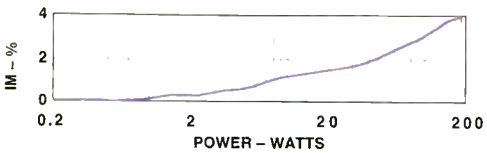

Fig. 11—IM distortion for 440 Hz (A_4) and 41.2 Hz (E_1).

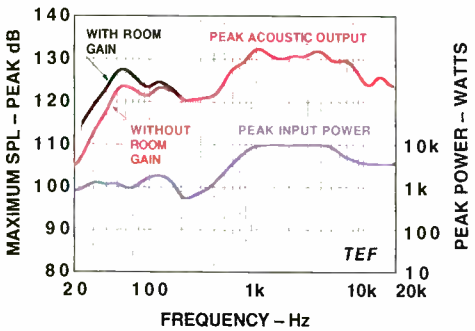

Fig. 12—Maximum peak input power and sound output.

I used an Onkyo CD player driving the Bryston 0.4B preamp, coupled with balanced Straight Wire cables to the Crown Macro Reference power amplifier. Straight Wire Maestro speaker cables were used to connect the Convergence systems to the amps. About half my listening was done with the Legacy's optional bass-alignment filter inserted in the tape loop of the preamp. When the bass filter was used, I also used it when listening to my reference B & W 801 Matrix Series 2 speakers because of its close similarity to the filter supplied with the 801s.

First listening disclosed that the Convergence has considerable bass impact, very wide dynamic range, and a clean and open sound. No matter how loud I played these speakers with demanding bass material, they always sounded quite clean and effortless. At seated listening positions, the tonal balance and overall sound were quite close to my reference speakers'. Only when I stood up did the Legacy systems differ tonally in the upper midrange from the references. When I was standing, the tonal differences often sounded like a general reduction in level rather than a spectral aberration.

Some one-note bass character was noted on acoustic bass lines. Subsequent speaker and room measurements revealed that the 60-Hz bass hump of the Convergence coincided with a 60-Hz mode in my listening room, thus emphasizing notes in this range. My reference speakers also excite this room mode, but the Convergence systems were consistently louder when a bass note fell in this range.

On third-octave, band-limited pink noise, the Convergence's low-frequency maximum output significantly exceeded my reference systems' in the bands from 20 to 40 Hz. Particularly impressive was the output in the 20- and 25-Hz bands, which made everything in the room vibrate! The high sensitivity of the Convergences enabled them to play significantly louder and cleaner than my references when turned up to the point where the power amplifier occasionally clipped. (The Crown amp has very useful LED level and overload indicators.) The bass drum at 1:08, 1:10, and 1:31 on track 1 of *Winds of War and Peace* by the National Symphonic Winds (Wilson Audio WCD-8823) was truly awesome when played at high level.

Of course, I had to get out my assortment of sound-effect CDs to try, including the jets and steam locomotives on *Sonic Booms* (Bainbridge BCD6276). The Convergences didn't even whimper when subjected to this material played through the very powerful Crown amplifier, the same amp I use in my peak power tests! These speakers also did considerable justice to various rock 'n' roll tracks, easily creating full concert levels, including bass.

When Bach's *The Art of the Fugue* by the Juilliard String Quartet (Sony Classical S2K 45937) was played, the Convergences demonstrated a fine capability to re-create soft and delicate chamber music with smoothness, a detailed and neutral sound, and good instrument placement and stereo focus. Male speaking voices sounded natural and well controlled. Compared to my references, the Legacy systems had a more forward sound that was less influenced by my listening room. I attribute this to the Convergence's greater directivity in the important mid-frequency range. Tambourines, cymbals, and other high-frequency percussion exhibited a crisp and well-balanced sound with extended response.

Overall the Convergences did a commendable job on most program material. Only rarely were the speaker's limits reached, and even then it overloaded quite gracefully. Particularly impressive were its wide dynamic range capability, high sensitivity, powerful bass response, and very high power-handling capabilities. Its smoothness, frequency range, and imaging capabilities were also first-rate. No subwoofers are required with this system! If you are prepared to part with about $3,500, the Convergence would be a very good choice. *D. B. Keele, Jr.*

STEAM LOCOMOTIVES? JETS? THE LEGACY CONVERGENCE DIDN'T EVEN WHIMPER.