11.8.2 Comparison of various enclosure-materials

An often-asked question: what is the contribution that the type of wood used for the enclosure makes to the sound (i.e. to the transmission function) of the loudspeaker? Dealers point to historic models, and attribute to the wood a significance similar to that it would have for Italian master-built violins – and the musician believes it and shells out the money. To go beyond assumptions and obtain some objective data, we analyzed a number of cabinets of identical dimensions but made out of different woods: pinewood (18 mm), poplar (14 mm), and medium-density fiberboard (MDF, 14 mm). The enclosures were carefully assembled by Tube-Town (www.Tube-Town.de) and were measured with the same loudspeaker installed (Eminence MOD-12). The external dimensions were 50 cm x 41 cm x 30 cm. The *sealed enclosures* were closed off to the rear with a non-reinforced panel while the *open cabinets* featured two boards to the rear that had a gap of 13 cm between them.

All measurements were done in the anechoic chamber at 3 m distance on axis. The speaker was fed from a stiff voltage-source (2.83 V at first, later more); a B&K 4190 served as measurement microphone,. The resulting frequency responses of the SPL (recalculated for 1 m distance) are shown in **Fig. 11.93**. There are visible differences between the wood-types, but they are so small that they will be insignificant for everyday stage-use. In fact, our hearing does not recognize such small sound differences in music performances. Moreover, production tolerances will have a similar magnitude. However, the differences caused by changing the back panel (open vs. closed) are of significance – the sound does change.

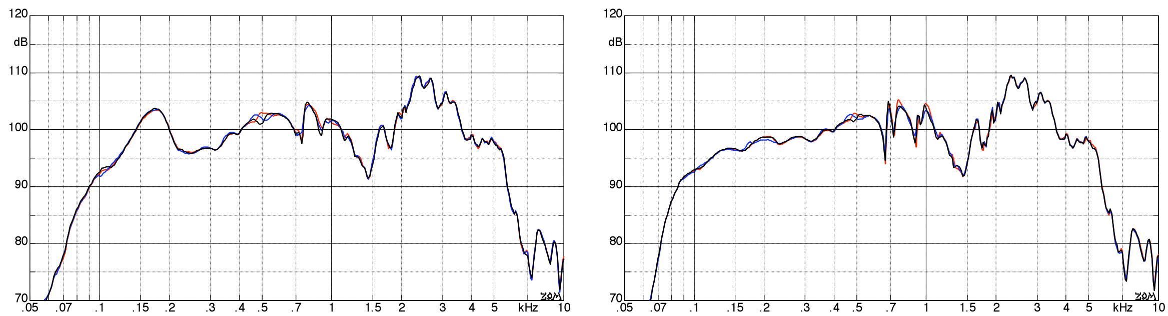

Fig. 11.93: SPL (1W/1m); enclosures: pine (black), poplar (red), MDF (blue).
Left: open rear-panel (gap of 13 cm). Right: closed rear-panel.

Fig. 11.94 shows the corresponding frequency responses of the impedance; again there are no peculiarities. The pronounced similarities guarantee practically the same behavior when driving the speaker from a high-impedance source (tube amplifier) – independent of the wood type. However, the changes in the rear-wall have in a particularly strong effect for operation from a high-impedance amp because transmission behavior <u>and</u> voltage at the speaker change.

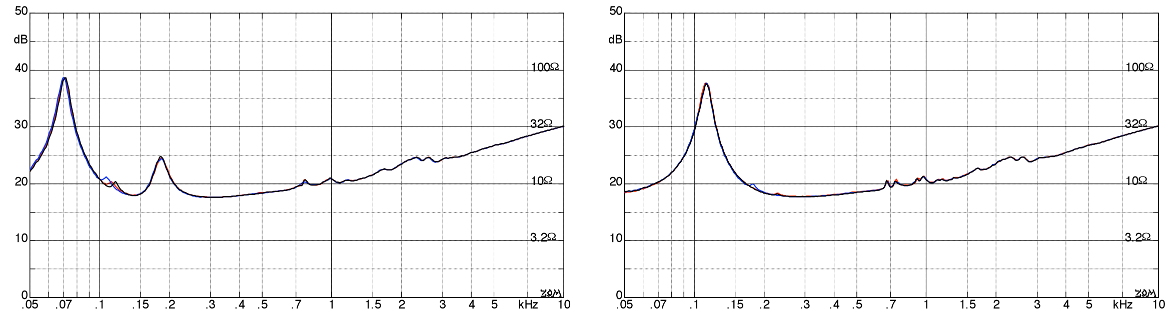

Abb. 11.94: Frequency responses of the impedance, loudspeaker and enclosure as in Fig. 11.93.

In **Fig. 11.95** we find supplementary measurements with pinewood-enclosures that either had no back-panel at all, or a partial one consisting of one board of a given size, or a partial one consisting of two boards of the same (given) size each (i.e. the latter corresponded to the *open cabinet* of the previous measurement). Again, there are no unexpected peculiarities.

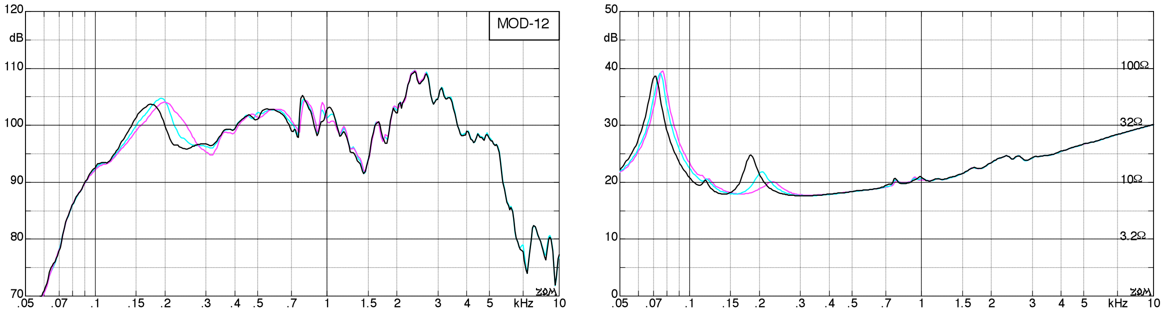

Fig. 11.95: SPL and impedance; completely w/out back panel (magenta), 1 board (cyan), 2 boards (black).

The operation with 2.83 V (resulting in 1 W at 8 Ω) is typical for loudspeaker measurements but does not correspond to customary power loading. As long as the speaker works in a reasonably linear fashion, the transfer function may be taken at any voltage. However, since loudspeakers can generate significant non-linear distortion, we opted to include measurements at a higher power level: at 2.83 V, 8.94 V, and 17.9 V, corresponding (at the nominal 8-Ω-impedance) to a **power of 1 W, 10 W, and 40 W**, respectively. Upping the power from 1 W to 10 W and 40 W, the level rises by 10 and 16 dB, respectively. This is shown in **Fig. 11.96** – merely in the bass-range we see deviations due to very strong distortion. To facilitate comparing the curves, **Fig. 11.97** depicts a representation normalized to 1 W: the 10-W-curves was lowered by 10 dB, and the 40-W-curve was lowered by 16 dB. Overall, the 40-W-curve is low visibly at too low a level; this is, however, not wood-specific, but simply caused by the heating up of the voice coil (all measurements were done with stiff *voltage*-source).

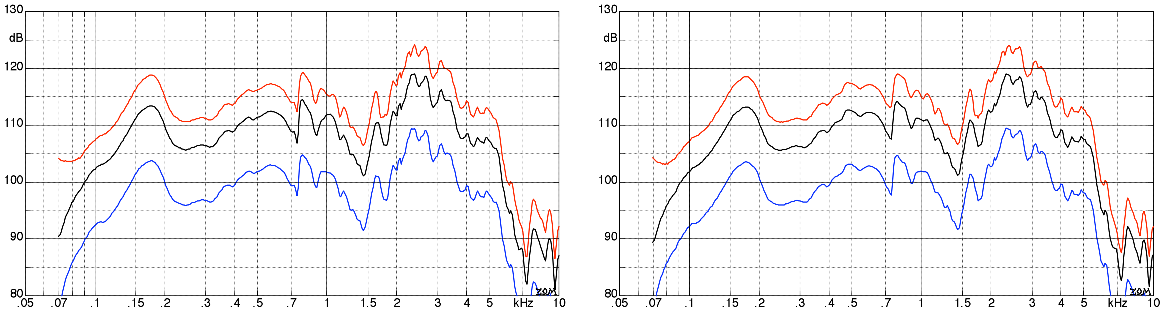

Fig. 11.96: SPL at 1 W (blue), 10 W (black), 40 W (red). Enclosures: pine (left), poplar (right).

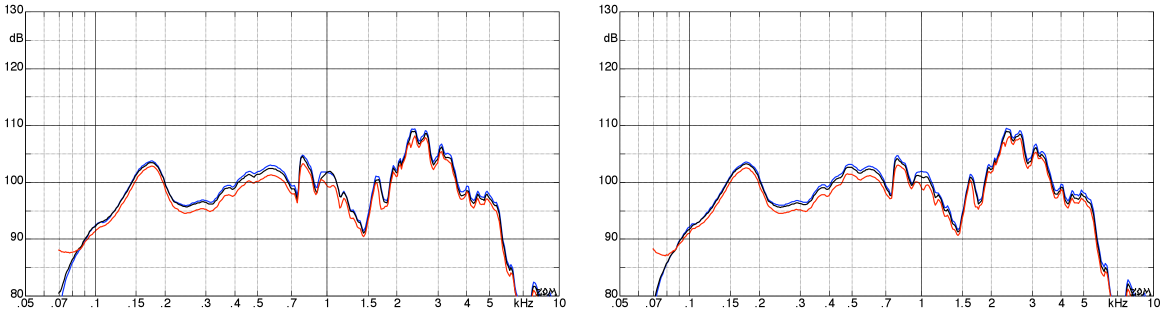

Fig. 11.97: as in Fig. 11.96 but representation normalized to 1 W.

The wood of the enclosure might influence the transmission function in two ways: via changes in the mechanical impedance of the bearing of the loudspeaker, and via sound radiation of co-vibrating enclosure walls. In order to obtain quantitative data relating to **enclosure vibrations**, we carried out measurements with a **laser-vibrometer** (Polytec). The loudspeaker was again fed from a stiff voltage source (2.83 V, 8.94 V, and 17.9 V). The laser-vibrometer measures the velocity; from this the displacement can be derived via integration, and the acceleration via differentiation. For the *ideal* loudspeaker (given a stiff current source) the acceleration is imprinted at $f > f_{Res}$; in the *real* speaker, resonances of the membrane cause selective frequency dependencies. Acceleration values corresponding to up to the 100-fold of the gravitational acceleration may be expected: 30 N at 0.03 kg yields 102 g (1 g = 9.81 m/s^2). Only the membrane experiences such strong acceleration, however; the side-panel vibrations are markedly weaker relative to the membrane-vibrations (**Fig. 11.98**).

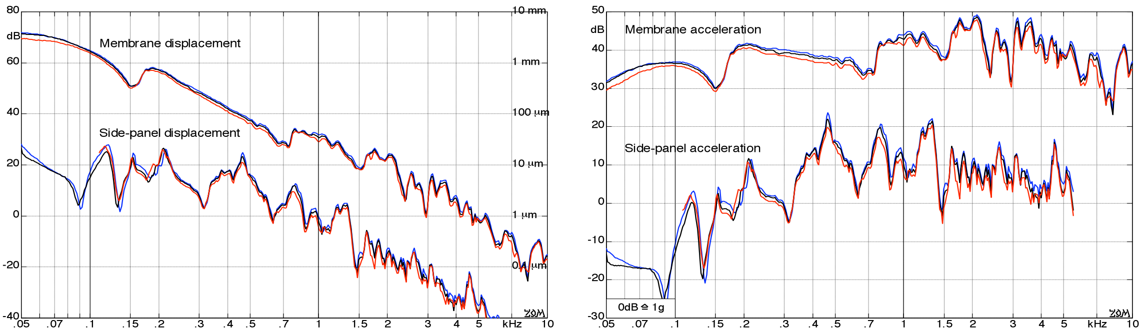

Abb. 11.98: Displacement (left) and acceleration (right) of the middle of the side panel; poplar; 1 W, 10 W, 40 W. Curves were normalized to 17.9 V (40 W), i.e. the 1-W-curve was elevated by 16 dB.

As is well known, the radiated sound power depends on the *square* of the velocity, on the size of the vibrating area, and on the radiation impedance [3]. The latter, and the effectively radiating area as well, can only be determined with much effort; therefore here just an approximate estimate: if the velocity of the membrane is, at 460 Hz, about 7 times as high as the velocity of the side panel (ΔL = 17 dB), the membrane will radiate about the 49-fold sound power at this frequency compared to the side panel. The other 'round: the side-panel contributes merely 2% to the sound radiation. Even if it were 5%: that's still rather insignificant. The contribution of the baffle is similarly small; only the **back-panel** weighs in with two relatively strong vibration-maxima (**Fig. 11.99**).

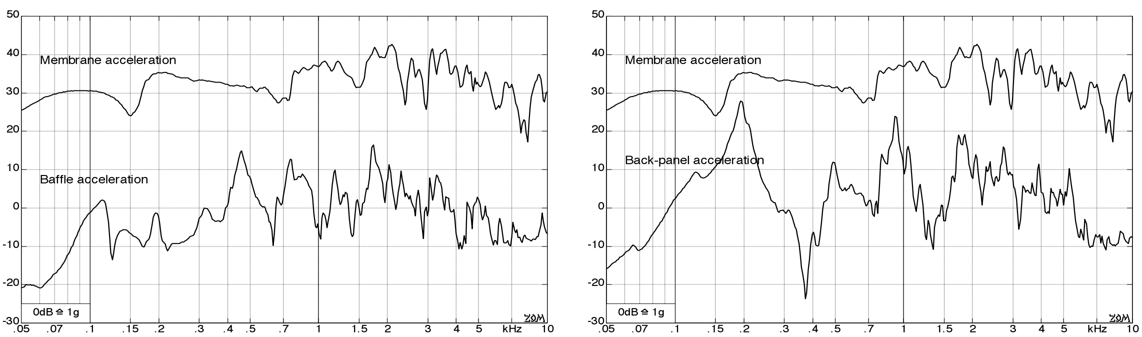

Abb. 11.99: Acceleration, poplar-enclosure, P = 10 W. Left: baffle, right: edge of back-panel.

Each of the two rear-panels is bolted on only three of its sides so it's understandable that larger vibration amplitudes are possible. Of course, the one-point-measurements presented here cannot provide exact data of the sound radiation – due to the lack of a scanning vibrometer, an exact sampling of all enclosure surfaces was not possible, and the selected measuring points can only give a first impression. The comparison of the three enclosures shows that all their walls vibrate in a similar manner (**Fig. 11.100**). The maxima of the rear-panel vibrations are a bit stronger in the poplar-made cabinet. For the sidewalls and the baffle, we see clear differences in the resonance frequencies but the maximum levels are similar. There are several reasons why the measured enclosure vibrations contribute so little to the SPL. The vibration amplitude of the cabinet walls, for example, is never larger than that of the **membrane vibration**. At low frequencies, the whole **membrane surface** vibrates with the same amplitude, which is not possible for a board bolted down at its rims even at its resonance. As regards the **radiation impedance**: the rear panel vibrates (at 200 Hz) strongest with its free rim, similar to a **dipole**. With an outward movement, the outer surface of the rear-panel generates excess pressure while the inner surface generates low pressure – both balance themselves out momentarily around the rim of the panel. Regarding the sound radiation, this is a most inefficient movement that is termed "operation with acoustical shortcut". At higher frequencies, lines of nodes appear in all enclosure walls, separating areas of the panels that vibrate in opposite phase: as one point of the panel moves outward, a neighboring point moves inward at the same moment. With the two movements being in opposite phase, only little sound is radiated. In Fig. 11.100, the SPL-measurement is again included for comparison: as different as the enclosure vibrations may be, they all have very little bearing on the sound pressure level.

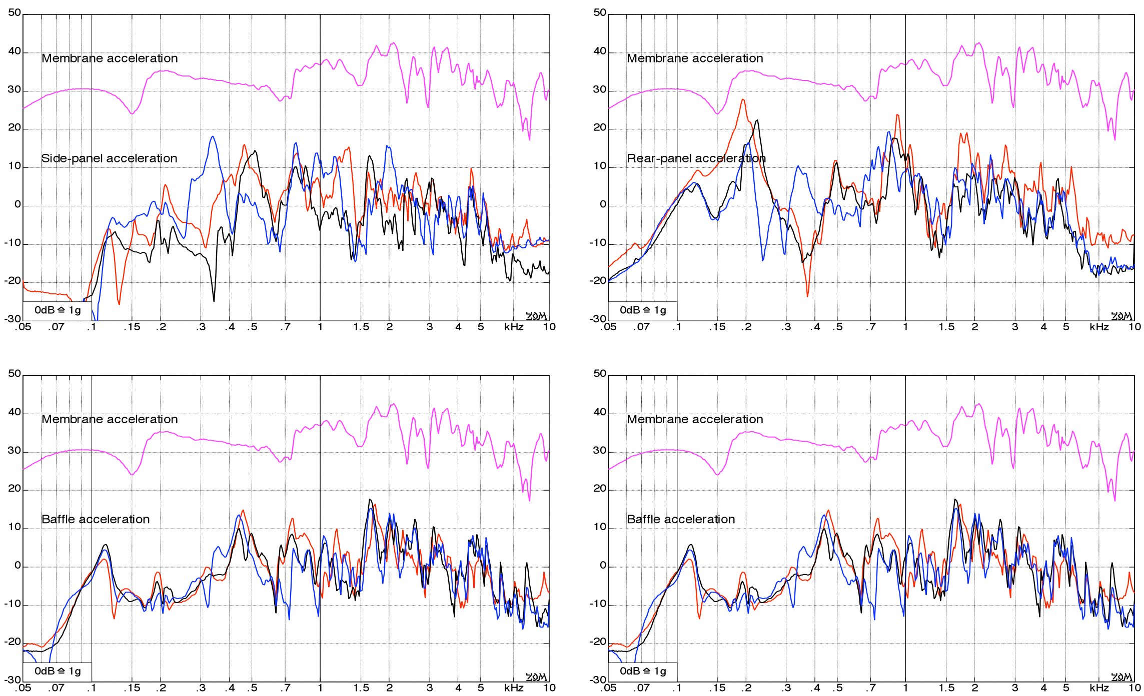

Abb. 11.100: Left: acceleration of the enclosure wall. P = 10 W; poplar (red), pine (black), MDF (blue). Right: SPL-measurement axially, 3 m in front of the enclosure, P = 1 W; color-coding as above.

Abb. 11.100 depicts the frequency response of the SPL in front of the membrane; however the loudspeaker radiates in all directions. **Fig. 11.101** shows the SPL frequency-responses for two further measuring points: 3 m behind the enclosure and 0.5 m above it.

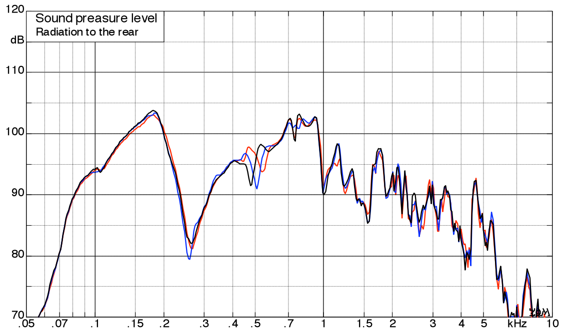

Fig. 11.101: Left: SPL 3 m behind the enclosure, P = 1 W; poplar (red), pine (black), MDF (blue). Right: SPL 0.5 m above the leading edge of the enclosure, P = 1 W; color-coding as above.

All SPL- and vibration measurements were done with one and the same loudspeaker, an Eminence MOD-12. To mount it, the rear panels had to be disassembled and reassembled each time. Repeat-measurements carried out to investigate the reproducibility showed SPL-differences that can be traced to the mounting of the rear panels (**Fig. 11.102**). Measuring the rear-panel acceleration showed a very strong dependency on the torque with which the mounting screws were tightened. This torque had not been checked when re-mounting the loudspeaker♣; consequently it can be assumed that enclosure-specific differences found in the SPL are in part due to differences in the attachment of the rear panel. **Therefore the differences purely due to the wood turn out to be even smaller.**

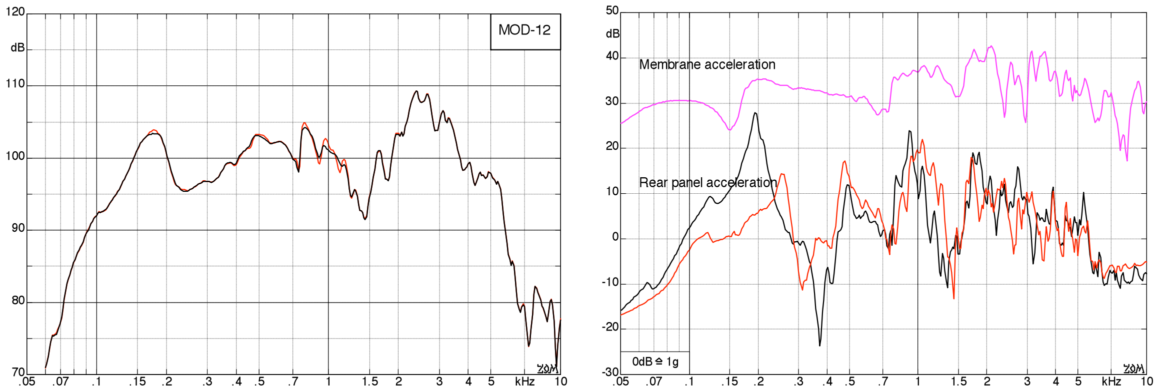

Fig. 11.102: Rear-panel screws tightened with different torque. Left: SPL; right: rear panel acceleration

Given these measurement results, the question poses itself why the dealers put so much emphasis on the wood used for the construction of instrument-loudspeaker cabinets, i.e. why it is imperative that the guitar box is made of "Baltic birch" or "solid pine". Simple answer: because it has always been that way – there's no connection to vibration-engineering. You can't build a Fender "Woody" using MDF-panels, because you will want to see only the most

♣ The screws fastening the rear-panels had been tightened „strongly" by hand each time.

strikingly beautiful wood grain. With a Tweed Deluxe, you could use MDF – as long as nobody looks inside. Leaving aside cosmetics, we have sound, weight, and durability remaining. Without further testimony, let's believe in the higher on-the-road resilience of the precise finger-joint construction. The question regarding the maximum weight we shall delegate to those tattooed knights-of-the-long-braid who will willingly schlep all that stuff back and forth every night. That leaves us with the sound. Is the wood in fact supposed to vibrate or not? Fortunately, our much-shepherded problem-child cannot be bothered about that question and just vibrates, as soon as it receives the invitation to do so from the membrane – irrespective of whether it is pine, poplar, birch, particle-board or MDF. Not in the identical manner for each of those materials, but so little that any influence on the sound radiated by the membrane remains marginal. We would not be adverse to the wood contributing some resonances (this being a sharp contrast to the world of HiFi) since the electric guitar has to offer little in that area. However, such contributions would have to be product-specific, and that would require a disproportionate effort – in a number of ways, not just in the tightening-torque for the mounting-bolts. The dimensions are crucial, as well: if the rear-panel rests on a slightly convex bar, it will vibrate differently compared to it sitting on a concave bar. Minute tolerances would be of importance here – one reason why acoustic guitars are not bolted together from planks. Speaker boxes, on the other hand, receive just that treatment – there appear to be differences to your D-28 or J-200, after all.

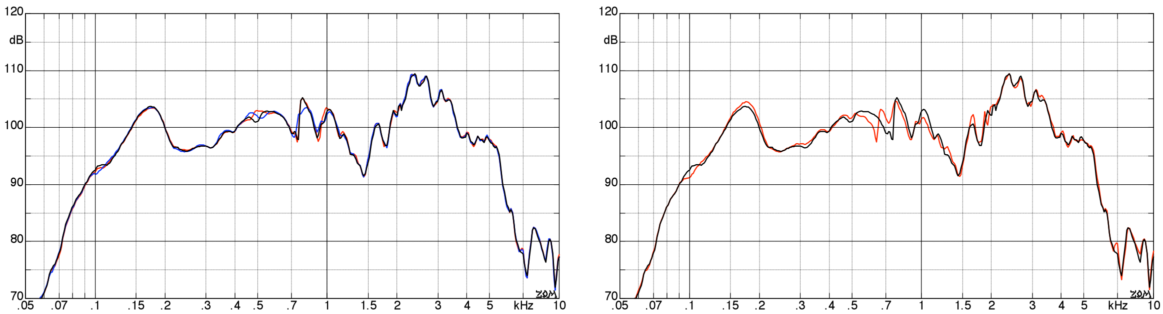

Fig. 11.103: Left: SPL (1W/1m), cabinets made of pine (black), poplar (red), MDF (blue).
Right: SPL (1W/1m), pine cabinet; 60x40x29 cm^3 (red), 50x41x30 cm^3 (black).

In **Fig. 11.103**, the differences caused by the type of wood are contrasted with those caused by changing the enclosure dimensions. The latter are varied by only a few centimeters – but hat is enough to result in greater differences that swapping poplar for pine.

Whether the loudspeaker is **front- or rear-mounted** onto the baffle-board also makes for small differences in the frequency response: The rear-mounting results in slight advantages: a gain of 1 – 2 dB in the range between 0.2 and 1 kHz, and a loss of about 2 dB around 3 kHz. The exact values depend on the given chassis and the dimensions of the enclosure.

The **speaker-cloth on the baffle** can have a two-fold effect: comb-filtering because sound is reflected back to the membrane, and – in particular at high frequencies – absorption. Some cloths, for example the material used in Fenders "Silverface"-amps, have next to no effect at all. Others, such as e.g. the thick material used by Marshall, cause an attenuation of about 1 dB at 1 to 5 kHz … which can certainly be measured but will be audible only when listening VERY closely.