B&W Bowers & Wilkins

Development of the PV1

The Problem

The holy grail of subwoofer design is deep and clean bass from a near-invisible box. The immediate problem that arises is that reduced box size both curtails bass extension and increases pressure on the enclosure wall and driver diaphragm.

Many small subwoofers are unable to reproduce sufficiently extended bass and suffer from considerable cabinet coloration, often resulting in bass that is uneven and dissociated from the midrange and treble.

Some existing designs have tried to address this problem by using complex, rugged drive units and very large amplifiers in small boxes, but have neglected to give sufficient consideration to the design of the enclosure. Typically, the huge backpressures and mechanical reaction forces generated by the heavy driver tend to deform the cabinet walls, which then resonate and distort the sound, particularly in relation to pitch definition.

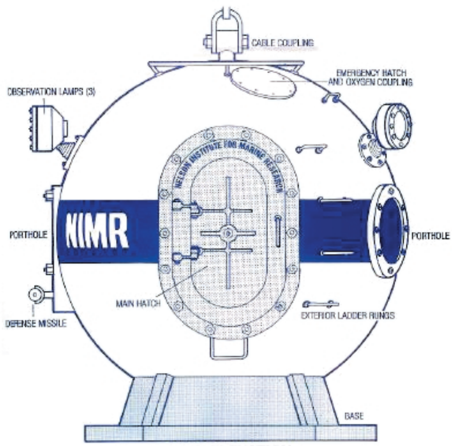
Bracing the cabinet extensively certainly helps but to satisfactorily solve the problem, you have to change the design approach.

Pressure Vessel Concept

It is often the case that effective solutions to problems in one scientific discipline may be derived from work done in another. An example of that within B&W is the derivation of our dimpled Flowport design from the aerodynamics of a golf ball.

The Pressure Vessel takes its inspiration from deep-sea diving bells. Their characteristic curved form resists the pressure differences on each side of the walls to a much greater degree than flatter panels, however well braced they may be.

The trick is to change the way forces are distributed in the structure, from bending (i.e. at right angles to the panel) to being in the plane of the panel. After all, it's much harder to squash or stretch a panel along its length or width than to bend it.



To illustrate this, there are two analogies that we can apply. The first is the soap bubble. An undisturbed bubble assumes a spherical shape because the pressure difference inside and out is perfectly balanced by the only force the bubble can sustain - surface tension that is entirely in the curved plane of the skin.

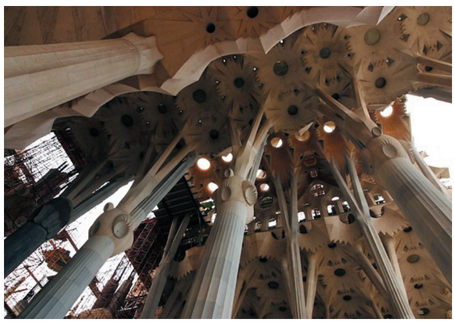
The second important analogy is found in the architecture of Antonio Gaudi. For our subwoofer, not only do we have to consider pressure changes in the enclosed volume of air, we must also deal with mechanical reaction forces generated in the magnet system of the driver and transmitted to the enclosure walls via the driver's chassis.

The delicate and almost skeletal structure of the temple of the Sagrada Familia in Barcelona was derived from a novel simulation of the structure using string and weights. Tension in the string of the inverted structure is analogous to compression in the arches and pillars. The string naturally assumes a shape where the only force is tension along its length. It cannot support any other. There are therefore no bending forces. The resulting arches and pillars built following these natural forms suffer only compression along their length, so they are very strong yet slender compared to traditional designs.

Gaudi's inverse force model.

B&W Pressure Vessel prototype

The principle of restricting forces to compression or tension in the plane of a structure was applied to a subwoofer enclosure in order to minimise sound radiation caused by flexing of its walls.



Support pillars in the temple of the Sagrada Familia, Barcelona

Early prototypes used a single drive unit mounted in a large spherical enclosure. This worked very well at ultra low frequencies, as the conditions approached those of the static analogies discussed above. However, as the frequency increased, it was found that internal pressure changes due to movement of the driver diaphragm did not transmit instantaneously throughout the whole of the internal volume. Neither were the mechanical reaction forces from the driver chassis transmitted instantaneously throughout the structure of the enclosure.

These effects are related to the ratio of the sound wavelength to the dimensions of the enclosure. The resulting pressure and force gradients allowed the reintroduction of bending forces on the walls of the sphere, which raised the level of radiated sound and coloration. Going back to our soap bubble analogy it could be likened to the way a bubble flexes as it moves through the air.

The obvious course to ameliorate this effect was to add a second driver to power the enclosure from the opposite end. Because of symmetry, this effectively halved the volume loading each driver and doubled the frequency at which these two effects began to cause a problem. The second prototype, shown here, used two 380mm (15 in) diameter drivers, one mounted at each end of a steel marine floatation device. This prototype was capable of producing prodigious levels of clean, articulate bass, but was hardly a viable commercial proposition. Furthermore, the resonances were still only just outside the effective bandwidth of the device, due to its large dimensions. However, the stage had been reached where a more compact and visually appealing product could be developed.

PV1 - Concept

The PV1, launched in June 2004, was developed directly from this prototype. From a sphere that comfortably passes through a basketball hoop, it creates truly extended bass that defies its diminutive and gorgeous exterior in both quality and quantity.

Although the Pressure Vessel concept was proven in very large enclosure, it was obvious that its prime technical merit of reducing cabinet stress was always going to find a particular relevance with a smaller product. Indeed, the PV1 represents a joyous meeting of minds for both engineer and industrial designer.

The problems inherent to small subwoofers are often compounded further by the industrial designer's desire to shave off centimetres here and there. The beauty of the PV1 is precisely that its non-bending cabinet design permits the use of a relatively thin aluminium shell, maximising the internal volume and therefore minimising the amount of equalisation required from the amplifier.

Early pressure vessel prototype

A secondary consequence of the use of twin opposing drivers is the inherently balanced kinetic nature of the device. It is well known that the reproduction of bass with correct dynamics requires a firm, solid foundation – sometimes referred to as a mechanical ground. It is the reason that speakers stand on spikes. A practical downside is that some vibrational energy is transmitted to the floor, with the potential of radiating sound into a room below the listening room. This can be a particular problem in apartments. With the PV1, there is no rocking motion generated and the device is inherently stable. The subwoofer therefore rests on a circular rubber base that mechanically isolates it from the floor, yet it retains an effective foundation.

A simple, yet effective demonstration of the inertness of the enclosure is to touch it while the subwoofer is playing loudly. There is virtually no discernable movement.

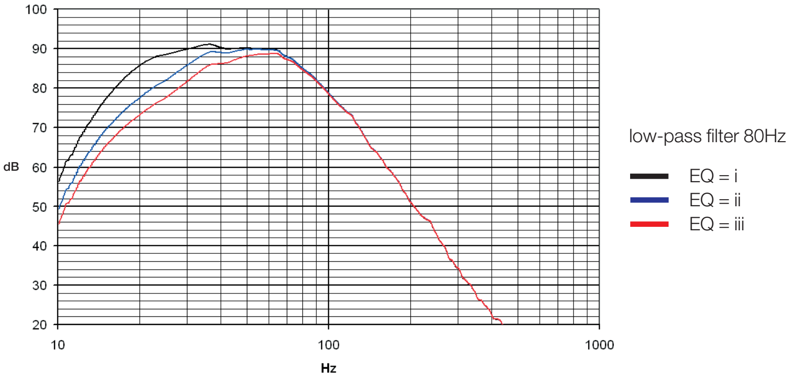
PV1 – Technical information

The listening experience reveals a subwoofer with incredible transient response and pitch definition. However, the enclosure design is not the only reason for this. The driver diaphragms themselves also have to be stiff enough to resist any tendency to deform when subjected to the pressures generated inside the enclosure and the forces from the voice coil. A very rigid sandwich construction is therefore employed, with a concave aluminium outer layer, a mica cone at the back and an expanded polystyrene core.

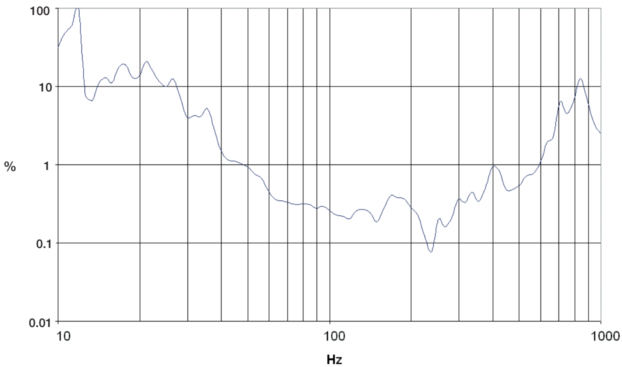
Any compact subwoofer will require substantial equalisation in order to have an extended low-frequency response and this implies a high-power amplifier. The PV1 utilises a 500W ICEpower® module, which allows considerable output levels to be generated without audible distortion. The aluminium enclosure acts as the heat sink.

Naturally, the driver must be capable of handling this power. The large magnet structure aids control of the motion of the diaphragm and forms an effective heat sink for the voice coil, which, at 30mm long, allows sufficient linear movement. A double rear suspension ensures that the coil remains in line throughout the large excursion.

PV1 section

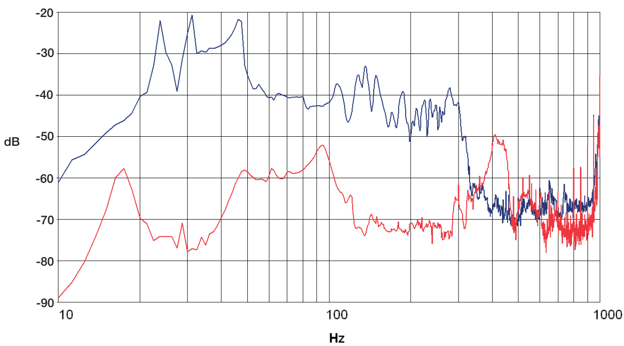


PV1 - frequency response



Bandpass output level 90dB at 1m

PV1 - total harmonic distortion



The vibration levels of the PV1 (red) are compared with those of a conventional subwoofer (blue) of similar bandwidth, output capability and drive unit radiating area, but using a single 250mm driver in a heavily braced wooden cabinet. Measurements were made by scanning the enclosure surfaces with a laser beam and summing over the total area in each case.

Sound output due to cabinet vibration

Technical features	Pressure vessel enclosure 500W ICEpower® amplifier Switch mode power supply
Description	Active closed-box subwoofer system
Drive unit	2x 200mm (8 in) dia mica / aluminium diaphragm long-throw
Frequency range	-6dB at 18Hz and 40/140Hz adjustable (EQ at i)
Frequency response	±3dB 21Hz – 31/110Hz adjustable (EQ at i)
Amplifier	Power output: 500W Rated power consumption: 110W (105W - 100V version) Input impedance: 100kohms Signal / noise: >90dB Functions: Volume level; Low-pass filter frequency; Bass roll-off alignment; Auto sense on/standby; Phase switch Inputs: Line In (RCA Phono); Speaker Level In (RJ 4/4) Outputs: Link Out (RCA Phono)
Low-pass filter	Active 2nd -order, variable cut-off frequency (applies only to speaker level input)
Dimensions	Height: 335.5mm (13.2 in) Width: 289mm (11.4 in) Depth: 347mm (13.7 in)
Net weight	20.5kg (45 lb)
Cabinet finish	Silver with grey trim Black with anthracite trim

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