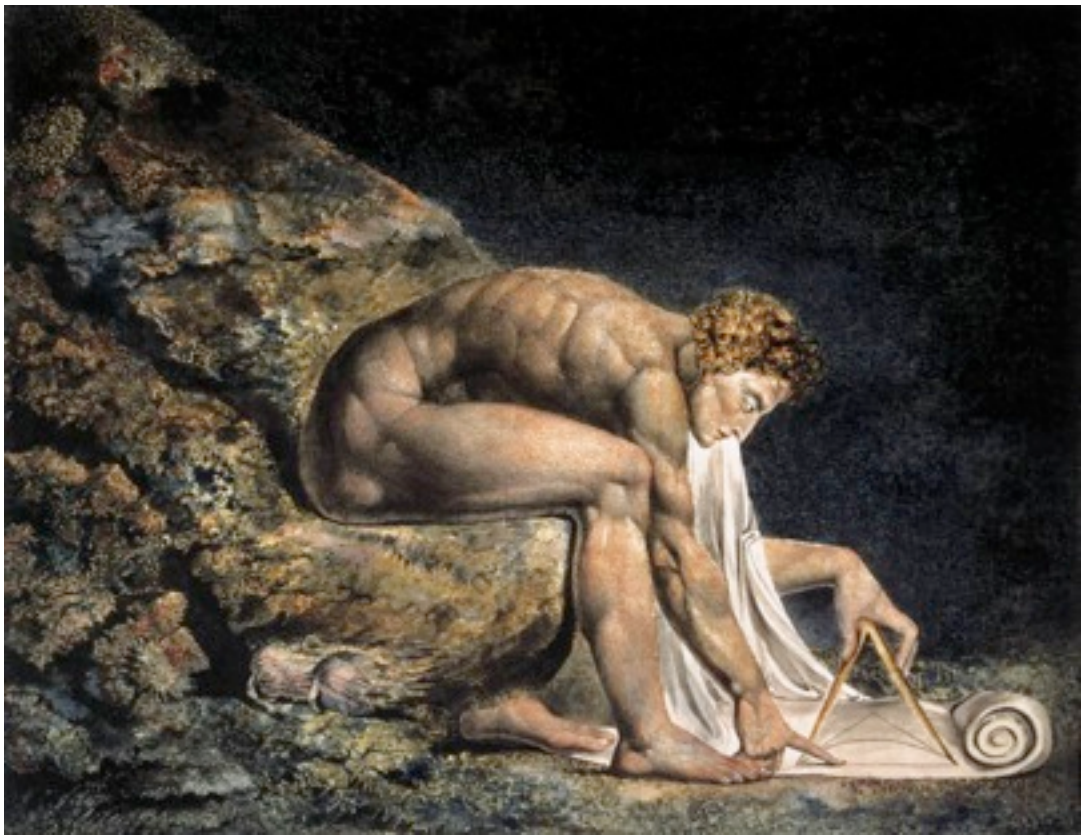
Cardinal



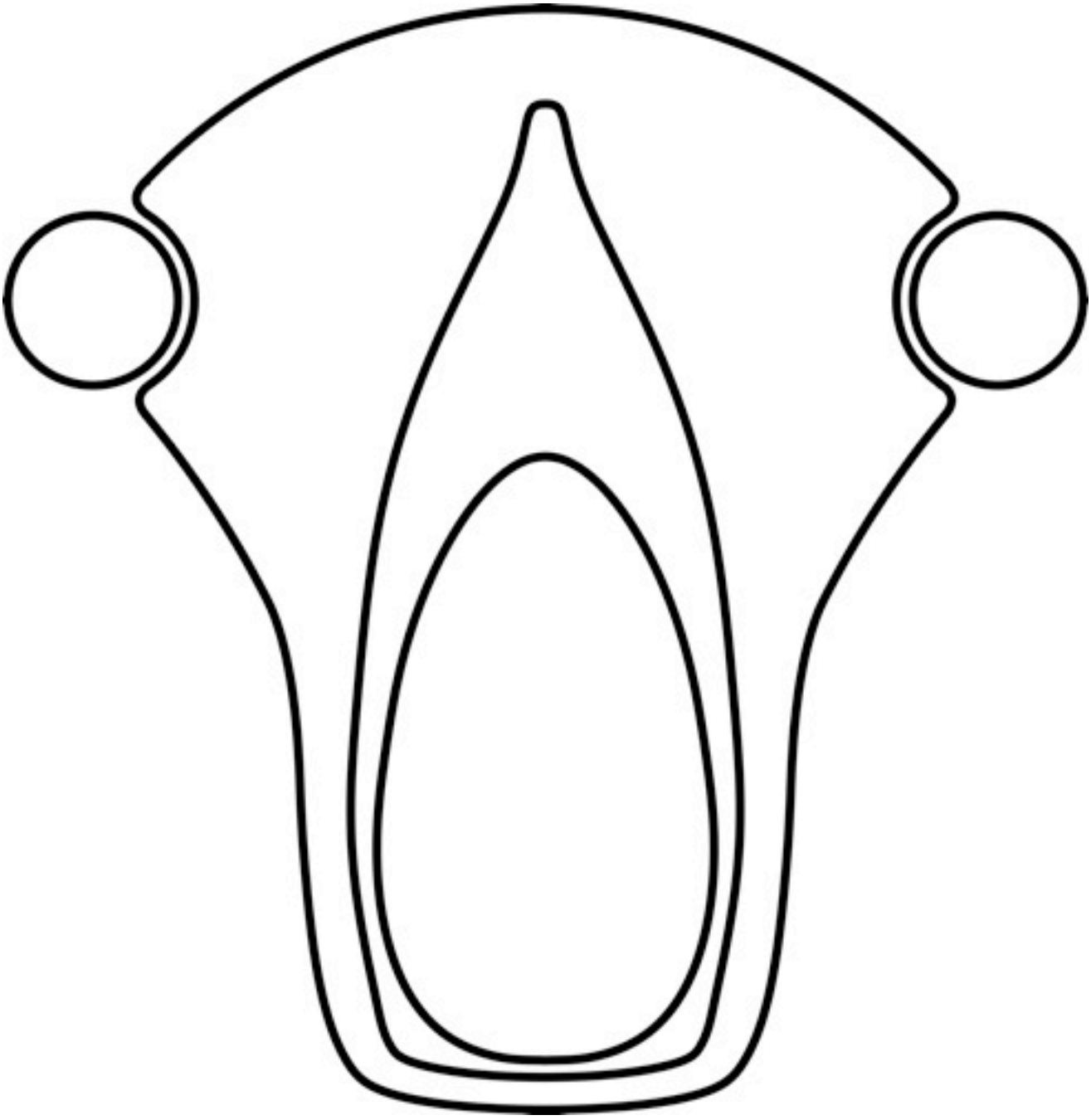
PURE GEOMETRY

The Cardinal White Paper

August 2012

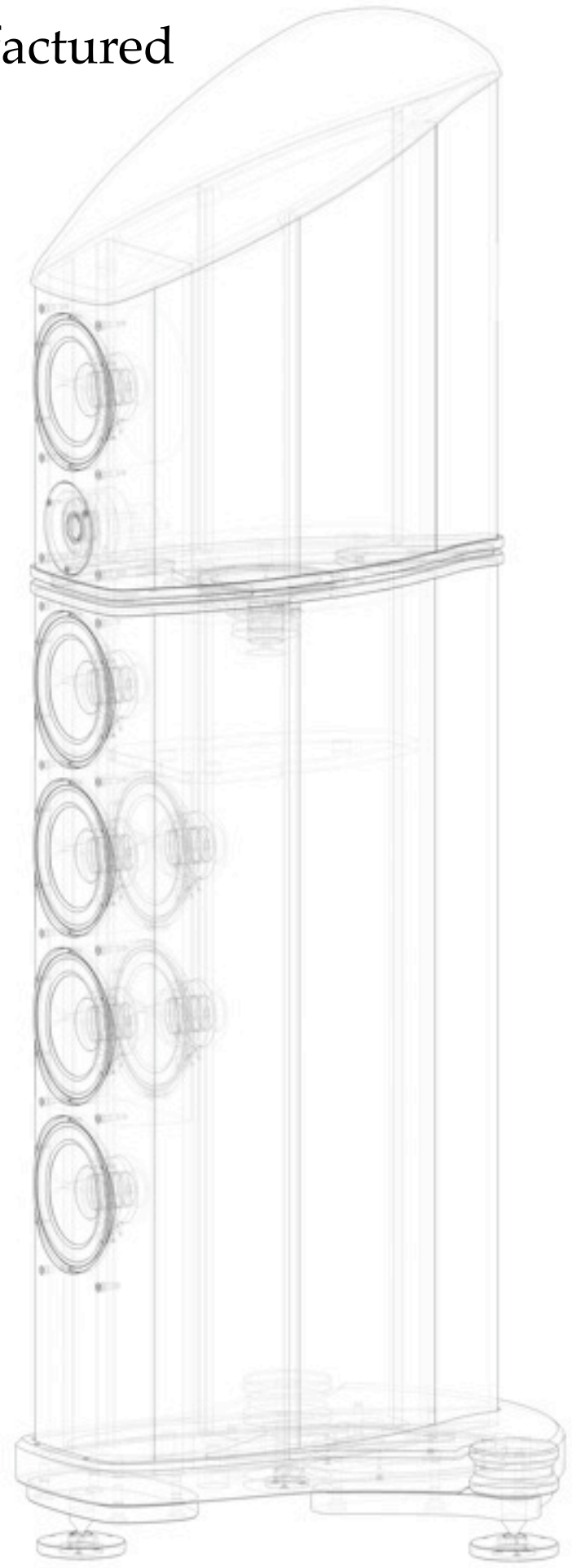
Wilson Benesch Ltd Falcon House Sheffield South Yorkshire S11 7LE
England

Conceived



Developed

Manufactured



&

Assembled

A.C.T. Monocoque

If this sophisticated structure was judged by purely engineering function, it would lay claim to being one of the worlds lightest, stiffest and most highly damped structures ever manufactured. It would exceed with consummate ease the traditional conventional materials typically seen in loudspeaker design to date.

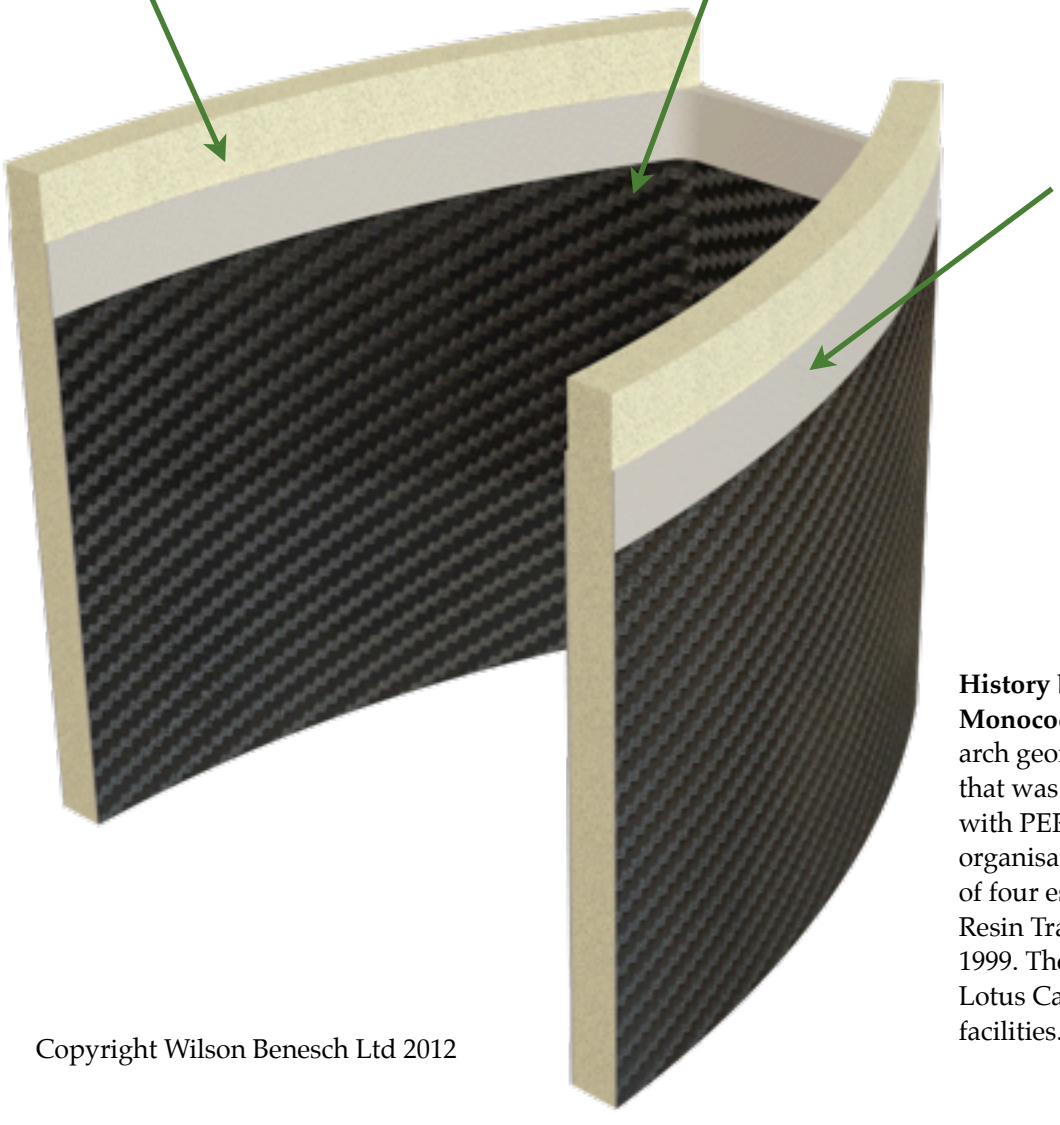
In addition, the A.C.T. Monocoque provides the perfect curvature to propagate sound energy externally, and eradicate any potential standing waves internally.

Aerospace high compression core comprised of billions of gas bubbles. This complex structure can be found deployed in the holds of passenger airliners to mitigate against blast energy. The core creates a super high compression core for the I section.

Similar structures can be found in the McLaren MP4, Formula One racing cars, and many other high performance systems.

Aerospace quality carbon fibre based composites liberate the designer and provide for a completely different approach to loudspeaker design.

In an A.C.T. structure, the carbon fibre is spaced apart by the core, to exploit geometrical benefits of two high tensile skins, spaced apart by a high compression core. The manufacturing systems that have been painstakingly developed to create this structure, are completely unique.

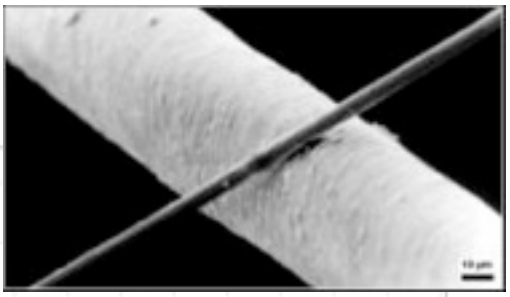


Glass fiber is markedly weaker than carbon fibre, but it does make a small contribution to the strength of the final structure. The principal reason for including this additional layer, is to significantly elevate the damping of the whole system. The combined effect of all three materials is key to attaining the unrivaled properties of the A.C.T. monocoque.

History behind the A.C.T. Monocoque The highly optimised arch geometry is an elegant solution, that was developed in collaboration with PERA, a Government organisation. Wilson Benesch was one of four establishments to introduce Resin Transfer Mould Technology in 1999. The other three companies were Lotus Cars and two M.O.D. research facilities.

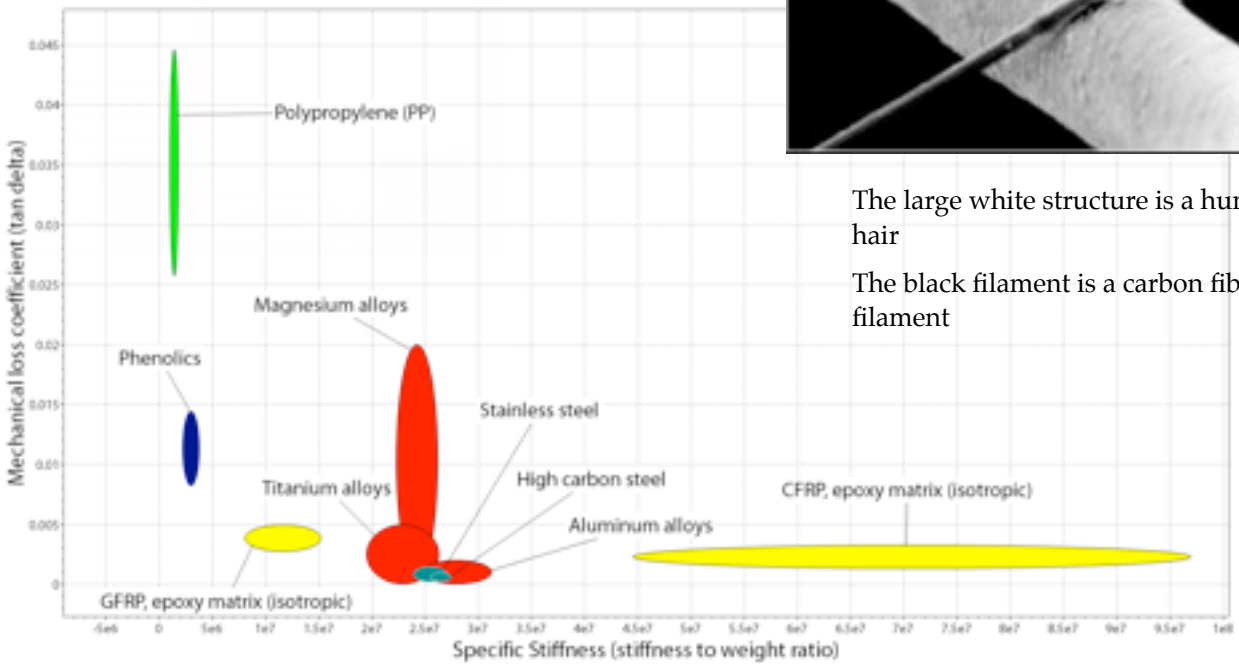
Wilson Benesch is the pioneer of carbon fibre composites in audio design. The company now has more than 20 years experience and intellectual property, relating to the exploitation of this important field of engineering.

Thankfully, it goes without saying, that there are countless Formula One drivers who would probably not be alive today, were it not for the capabilities of these amazing materials. They are the stiffest most highly damped structures known to man. They enable control of both damping, as well as energy flow in one single structure, and can damp energy in ways that are quite impossible with any other material. An additional P.D.F. can be accessed from Wilson Benesch that goes into some detail about the differences between isotropic and anisotropic materials.



The large white structure is a human hair

The black filament is a carbon fibre filament



The graph above, contrasts the damping characteristics of materials against their specific stiffness. As it clearly illustrates, carbon fibre, as and of itself, can span a huge area of performance. It should be noted, that when manifest in an advanced composite, the resulting damping benefits are huge.

Wilson Benesch rejected carbon fibre diaphragms made from carbon fibre / epoxy matrix, after trials undertaken in 1995. The Torus diaphragm is based upon a P.E.T. based matrix, that in sharp contrast, delivers superb self damping properties. It can also be seen that conventional polypropylene, is outstanding in terms of damping. It should be noted, that woven isotactic polypropylene, is five times stiffer, and even better damped than the homogeneous polypropylene represented on this graph.

Cabinet Design in the 21st Century

The image below provides a simple comparison between a carbon composite structure and an MDF structure with the same air volume. As you can see, the size and mass of the two are considerably different. The design limitations of MDF indicate that they are inappropriate for use in loudspeaker cabinets aspiring to be the ultimate solution.

Replacing MDF with aluminium is only a marginal benefit, one that is largely offset by zero self damping and problems of self resonance. Even elaborate and complex bracing will only shift the resonance marginally higher, whilst robbing the internal volume of air.

ALL CABINET STRUCTURES RESONATE & EMIT SOUND.

HIGH MASS = LOW RESONANT FREQUENCY = MORE CABINET NOISE

LOW MASS = HIGH RESONANT FREQUENCY = LESS CABINET NOISE

LOW MASS STRUCTURES ARE EASILY DAMPED

HIGH MASS STRUCTURES ARE DIFFICULT TO DAMP

IF A CABINET HAS 100 TIMES THE SURFACE AREA OF THE DIAPHRAGM, IT ONLY HAS TO MOVE 100TH THAT OF THE DIAPHRAGM TO PRODUCE THE SAME SOUND OUPUT.

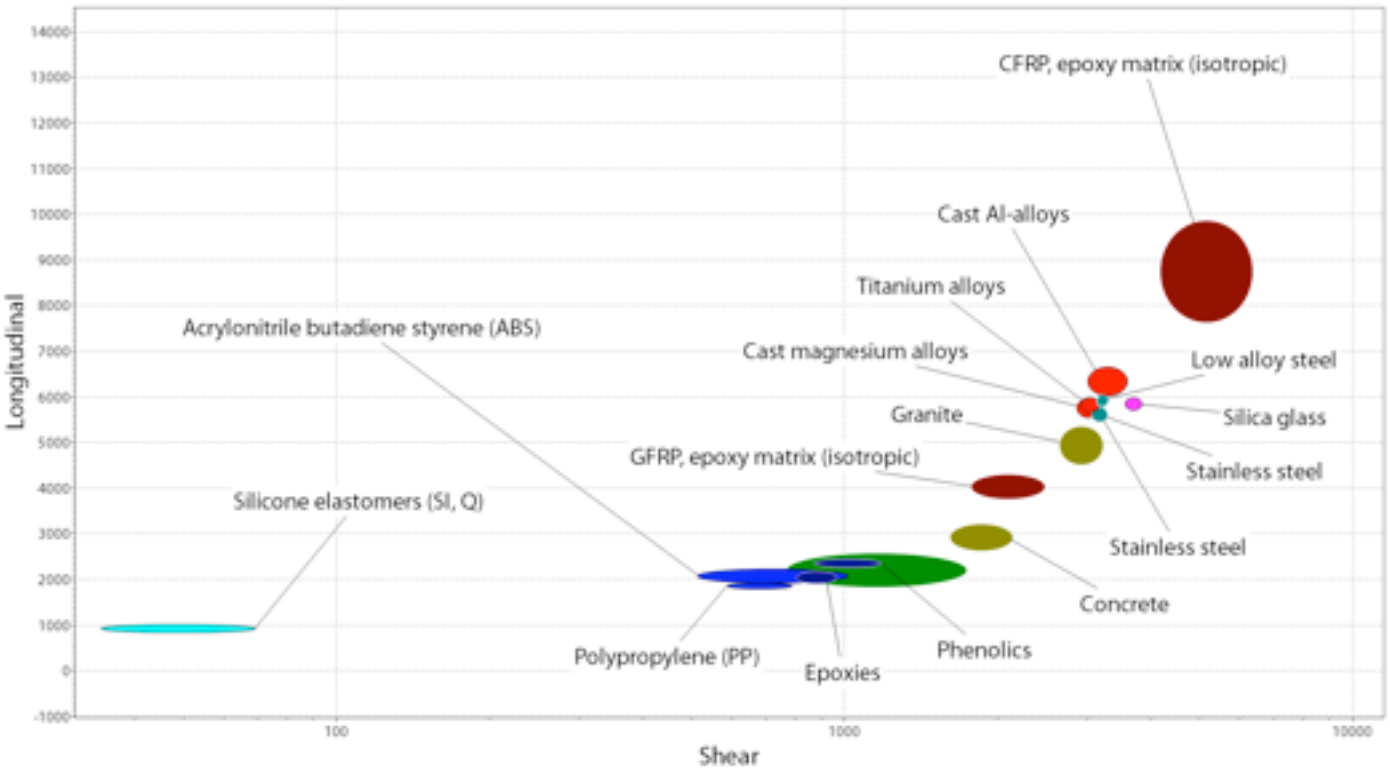
LARGE CABINETS ARE INTRINSICALLY LESS STEALTHY

The graph below, shows comparative data of basic engineering materials. It is important to note that the CFRP Carbon Fibre Reinforced Plastic, is not an advanced composite structure which are multiple orders of magnitude superior.

It is possible to see that the performance of most metals, including titanium and steel, falls between a glass fibre structure and a carbon fibre structure. It should also be noted that the Phenolics that are used by some manufacturers under the guise of exotic names falls considerably below both.

These basic and quite fundamental physical laws, explain why we see carbon fibre structures in F1 racing cars, advanced passenger aircraft, BMW high performance car design, and in fact almost every other application, where performance is a key goal of the design.

In loudspeaker cabinet design A.C.T. structures elevate the performance of the structure. By doing so, they deliver audible improvements in terms of signal to noise ratio and stealth.



Mutual Self Damping

The concept of self damping is well known. It has long been exploited in many other areas of engineering as well as in musical instruments. It is based on the basic energy absorbing potential, of two quite different materials being brought together. The complimentary resonant frequencies of each material act upon each other, and reduce or stop completely, one and the others resonance. The image below shows one such example of a resonating glass, being damped by the finger. This is identical to the percussionist, damping the cymbal by grabbing it, or similarly the felt pads in the piano being used to control the strings.

This phenomenon is exploited throughout the advanced materials in any Wilson Benesch design. Each material acts upon the other and due to their diverse characteristics, they damp each other. However, the complexity is compounded by the addition of several more and quite different advanced material technologies, each of which can be seen to possess, super lossy energy absorbing characteristics. These materials are deployed within the interfaces.

History behind Wilson Benesch Mutual Self Damping Designs.

In 1994, the radical A.C.T. One Loudspeaker signified a departure from conventional loudspeaker designs. Unlike single material loudspeaker designs of that time, it was comprised of no fewer than five different materials, including, solid wood, M.D.F. aluminium alloy baffles, steel foot components and of course A.C.T. carbon fibre curved panels. Many other materials were applied to damp the junctions of these materials as well!.

Why is this so important?

Try to damp a cymbal with another cymbal, the outcome is more noise.

Any single material loudspeaker will always, even if it is damped, possess a resonant frequency that is directly linked to the materials behaviour when subjected to resonant energy. This means that sound energy from the enclosure will increase, when ever this energy is in the music being played.

3D Parametric Design

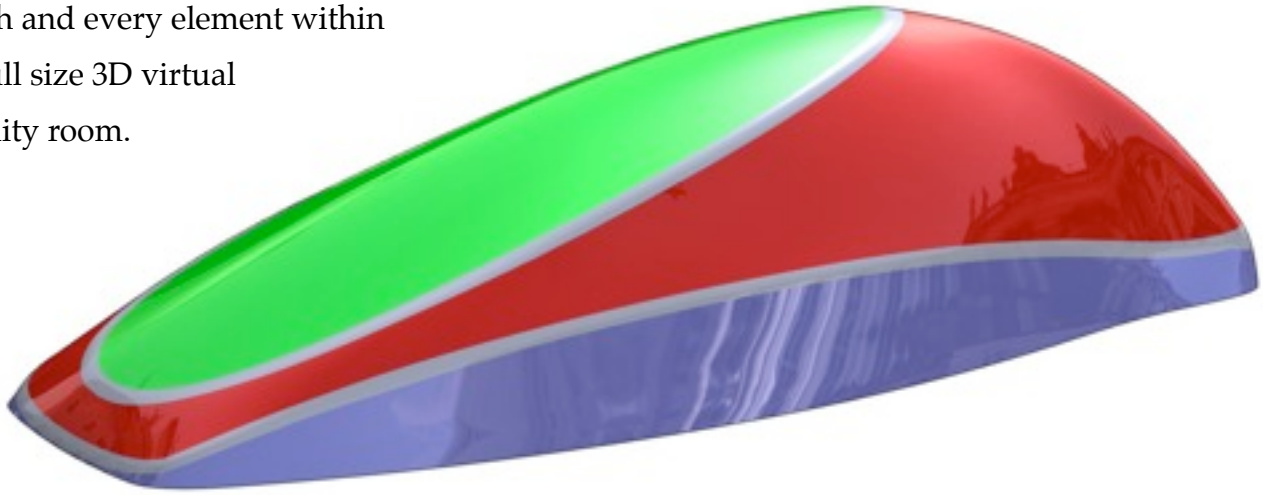
The beautiful architectural designs now being expressed across the world, owe much to the very latest 3D parametric design technologies that Wilson Benesch is using to great advantage in the Cardinal design.

During its lengthy development, the Cardinal top evolved from sketches to full size clay and wax hand sculptured forms. The final sculpture was then transferred for further development into the 3D virtual world, courtesy of high precision metrology and data files ,derived from laser scanning. This methodology is akin to reverse engineering and is another unique approach that Wilson Benesch is developing.

In collaboration with the A.M.R.C. Sheffield, Wilson Benesch are now also able to manipulate each and every element within

a full size 3D virtual

reality room.



History behind the sloping top design.

Seen for the first time in the Wilson Benesch A.C.T. One loudspeaker in 1994, the sloping top has subsequently been adopted by almost every loudspeaker company in the world, in some form or other.

Stereosound Japan first recognised the innovative contribution made by this design. They highlighted its importance in terms of sound wave propagation and stealth capabilities.

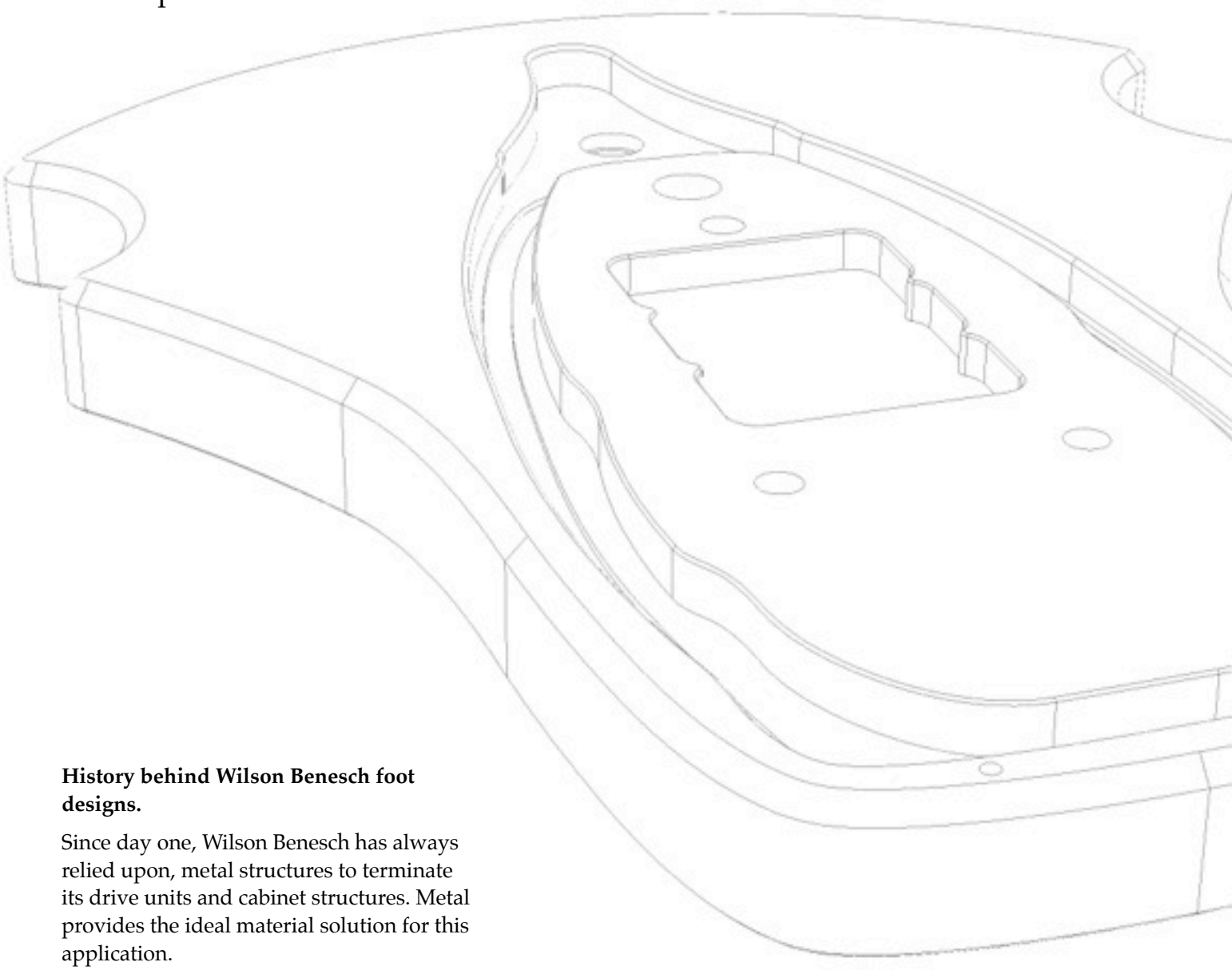
Adjacent image is taken from the Tokyo International Forum and was designed by Rafael Vinoly.

Cardinal Foot Design

The starting point of each foot is an 88 kilogram slab of high grade aluminium alloy. Each side must be machined to exacting tolerances. The foot fulfills a complex range of functions, but the primary goal, is to attain a high degree of strength and stability. No other manufacturing method can deliver this primary goal.

Each of the two sides of the block requires almost six hours of non stop machining time. The complex geometry and subtle curves require hundreds of thousands of lines of G codes.

No compromise.



History behind Wilson Benesch foot designs.

Since day one, Wilson Benesch has always relied upon, metal structures to terminate its drive units and cabinet structures. Metal provides the ideal material solution for this application.

Kinematic Location

The Cardinal is a substantial structure, but it is also a very powerful one. The importance of high integrity stabilisation is crucial, if the micro dynamic detail is to be maintained. The Cardinal's colossal foot extends outwards to increase the base area where upon three, 28 mm, steel threads take up the burden of responsibility. The load and any energy is then reduced into just one 12.5 mm steel ball. This design ensures that locating pressures are measured in hundreds of tons per square inch, as the entire mass of the system is transfered to less than 1 square mm, of surface area!

Huge 120mm turnwheels enable the adjustment of 28mm steel threads, which transfer the load of the system to three 100mm diameter location platforms.

As can be seen in the adjacent image, each platform holds captive three high precision 12.5 mm triangulating balls. These three balls can be likened to a tripod, that kinematically ally with the fourth ball, that is held in the 28mm diameter thread of the Turn wheel.

History behind the Kinematic Location System.
The concept of Kinematic location was first introduced by Wilson Benesch in the development of the groundbreaking A.C.T. One Tonearm in 1991.
Notably, it has been part of every single tonearm produced since that date. Even more important; not one, has ever failed.

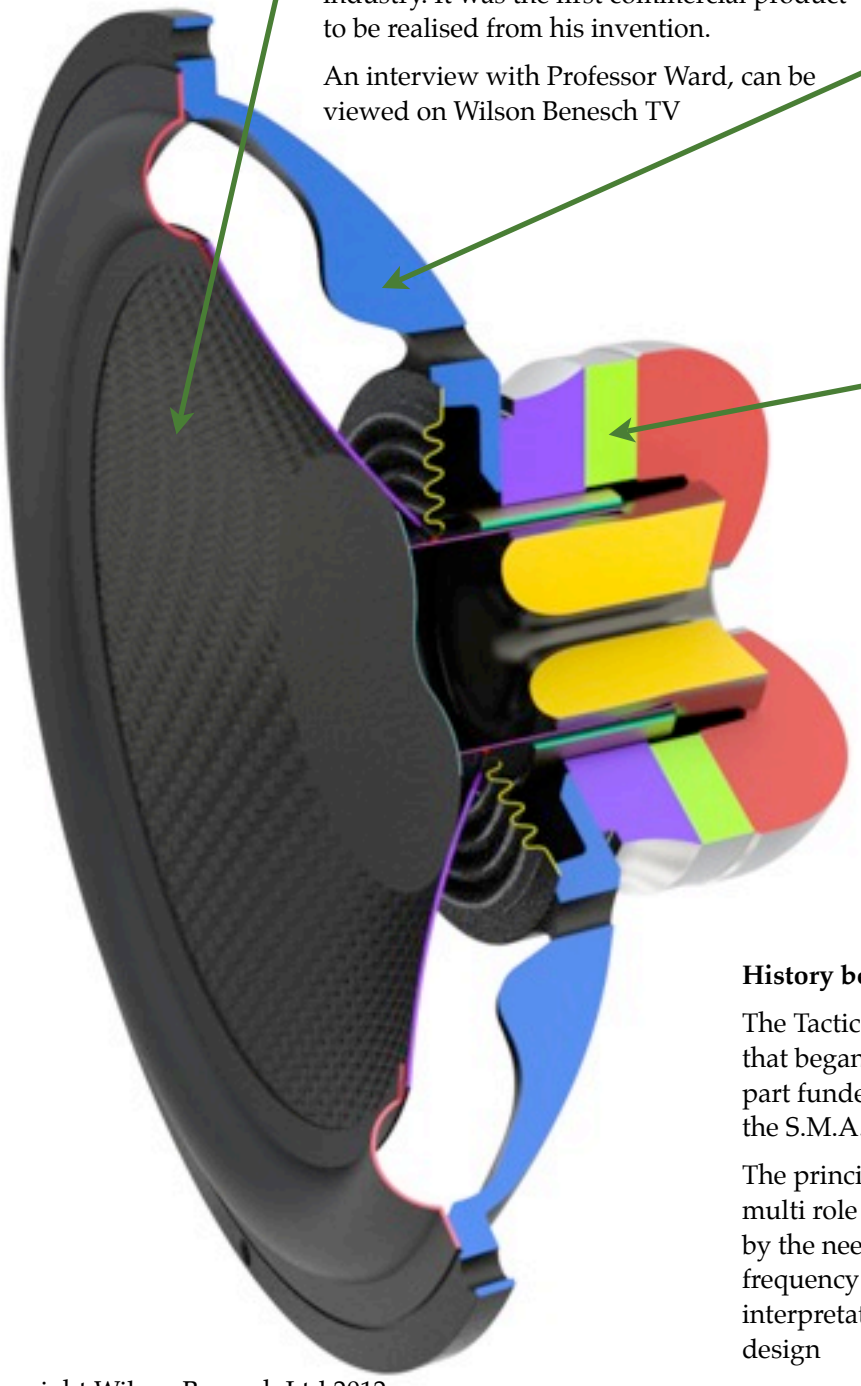
Tactic II Dynamic Drive unit

The Tactic multi role drive unit introduced Nd.Fe.B. or rare earth magnet drive unit technology to the audio industry. The gas profiled motor and basket assembly has often been emulated, but never surpassed.

The Tactic II is more powerful and better controlled. It is subsequently better able to fulfill its function as a bass drive unit in an Isobaric system, or as a superlative mid range unit.

Isotactic Polypropylene was invented by Professor Ward of Leeds University. Wilson Benesch collaborated with the professor to introduce this superb material to the audio industry. It was the first commercial product to be realised from his invention.

An interview with Professor Ward, can be viewed on Wilson Benesch TV



High pressure die cast basket delivers the ultimate window for energy to exit the rear surface of the diaphragm. Its Geometry imparts high levels of stiffness,as can be seen in this detail. The elegant geometry imposes the lowest level of obstruction to the energy from the diaphragm as can be seen on the gas flow analysis on the next page.

The curvaceous motor structure is manufactured in house on high precision CNC machines. Wilson Benesch collaborated with Sheffield Hallam University to accomplish this analysis. In depth gas flow analysis honed this system. The analysis capability is now embedded within the company.

A film has been produced on the manufacture of the motor parts which can be viewed on Wilson Benesch TV

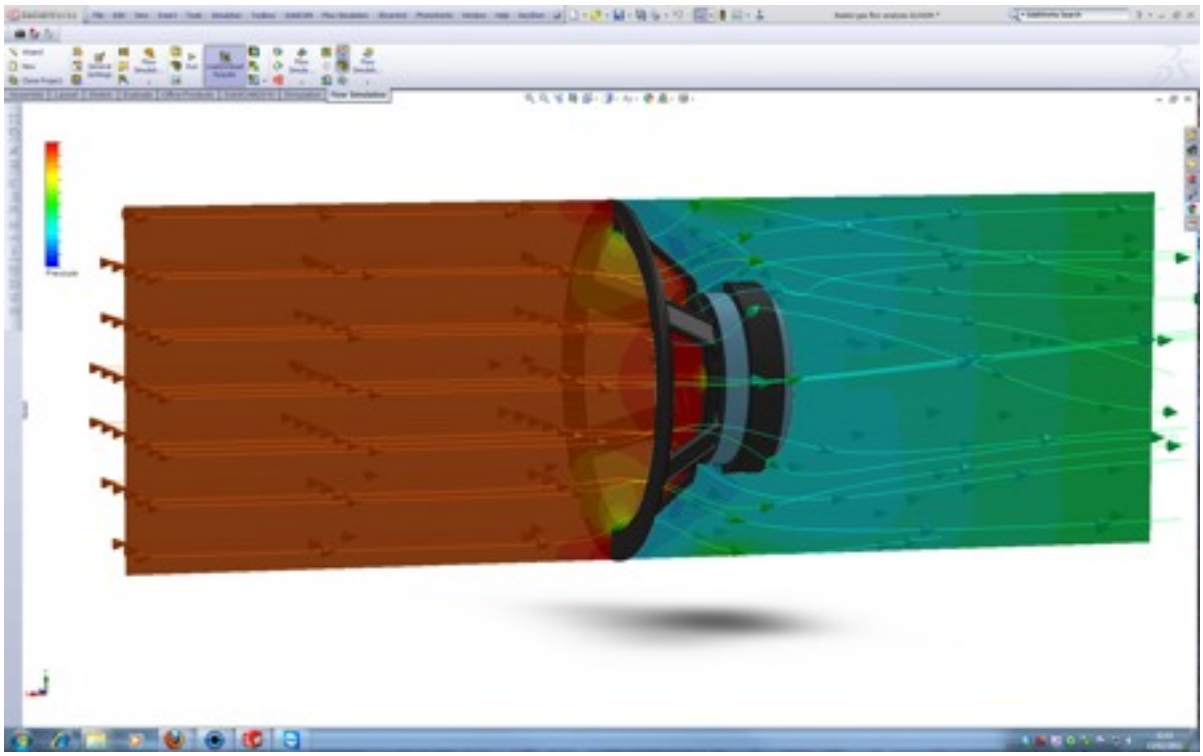
History behind the Tactic II

The Tactic drive unit came out of the Bishop Project that began in 1999. The £130,000 research project was part funded by the D.T.I of the U.K. Government via the S.M.A.R.T. research and development program.

The principle focus of the project, was to develop a multi role drive unit. Another key objective was driven by the need to improve the step response of low frequency drive units through a radical re-interpretation of the French invention, the Isobaric design

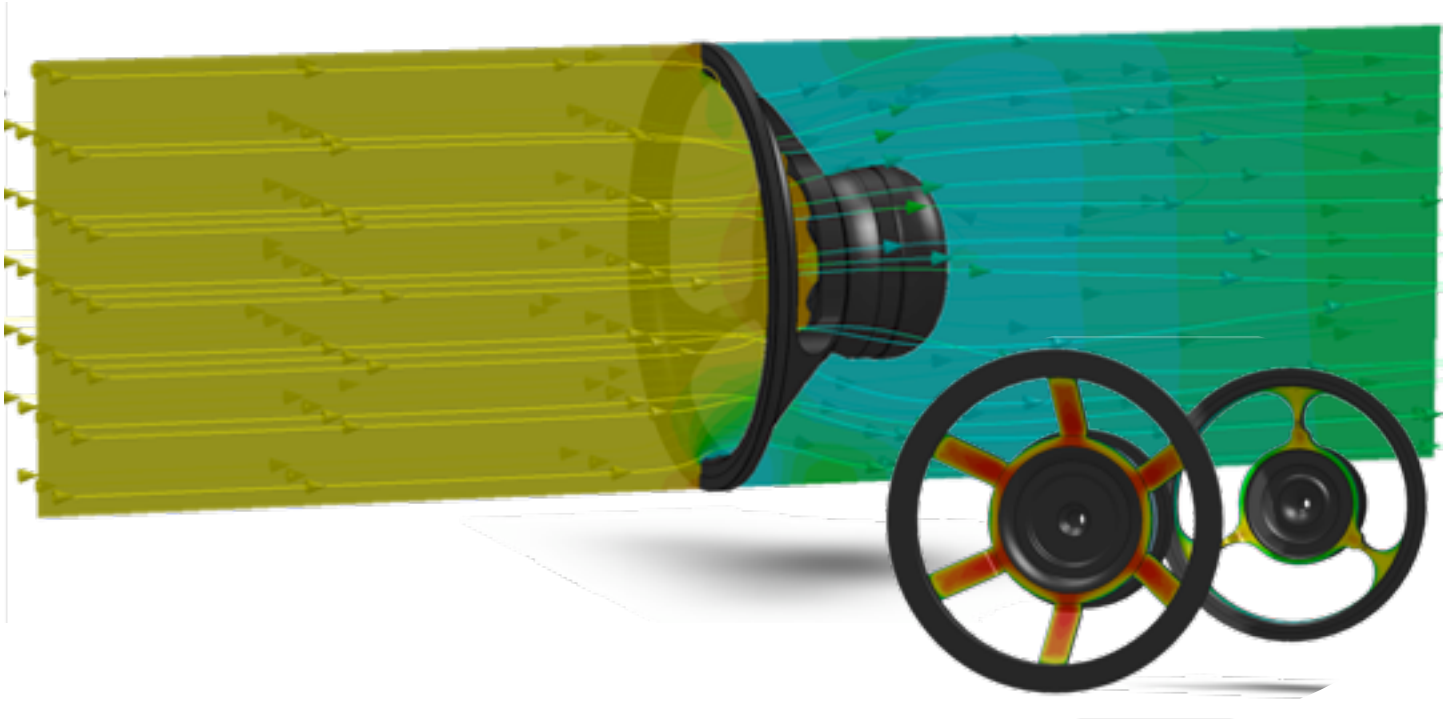
Conventional, off the shelf design

Image below shows gas flow analysis and how it is impeded and reflected back at the diaphragm, causing complex non linear distortions, smearing of the output and noise.



Tactic II

Image below shows gas flow analysis and the negligible impedance to air flow, by comparison to the above. off the shelf design



Tactic II Isobaric Drive

There are no transient delays in nature. So it should come as no surprise, that transducers that exhibit the fastest transient response, come closer to reproducing natural sound more accurately. This has been a guiding principle in all Wilson Benesch drive unit development.

It is the Laws of Physics that dictate that a large woofer will never function like a small drive unit. It is this fact that determined that we would never use a large drive unit. To accept such a compromise would be to accept energy propagation that could never be described as integrated. With large woofers, the foundations of the entire sound scape is compromised by retarded dynamic response both in terms of step response and system recovery.

The key facts about exactly why the isobaric is the ultimate solution for generating bass might be obvious from the adjacent image. However, for your scrutiny, the next page contains a summary.

A brief summary of the principle benefits of the Isobaric system

- Super stiff / super low mass diaphragm. The air link between the two diaphragms can be seen as a composite structure with outstanding stiffness to weight ratios. No other known drive unit diaphragm can aspire to possess such properties.

- The complexity of the isobaric virtually eliminates cabinet noise. First of all imagine a conventional large cone loudspeaker design. Now remove from the design the diaphragm and imagine now what you see. A hole that looks more like a washing machine! So after working so hard to build a massive structure we are asked to ignore this huge hole, this window to noise. Even complex membranes pose little or no barrier to noise that has a direct path to the listener. This simple physical fact is why Wilson Benesch has never used a conventional diaphragm or large drive unit.

- To achieve the same bass extension, a conventional design would require double the air volume. A larger box means more noise. No one can argue with this. The ability of the enclosure to achieve any Stealth qualities is also severely undermined.

- The drive unit that you hear, has no spring effect on it. The drive unit inside the enclosure moves all aspects of the air volume and so the spring effect. The drive unit you hear sees only a single pressure the same as free space. The resonant frequency is as a result, very low. This low resonant frequency could only be achieved in a conventional system by adding mass, at least double. The consequence is a total loss of dynamics and transient performance. Much has been written about the integration of sound between drive units. Conventional design admits defeat at the outset. With the isobaric design, the bass is in fact faster in terms of its step response than the mid range!

- Large drive units are inherently unresponsive. You cannot accelerate and decelerate a large heavy car, like you can a small nimble car. Basic physics tells us this. In large woofers, it is only convenience and cost that are the main benefits. For this you pay the price of poor step response and overhang. You also suffer a character of sound that is completely different to the other dive units that it is expected to integrate with.

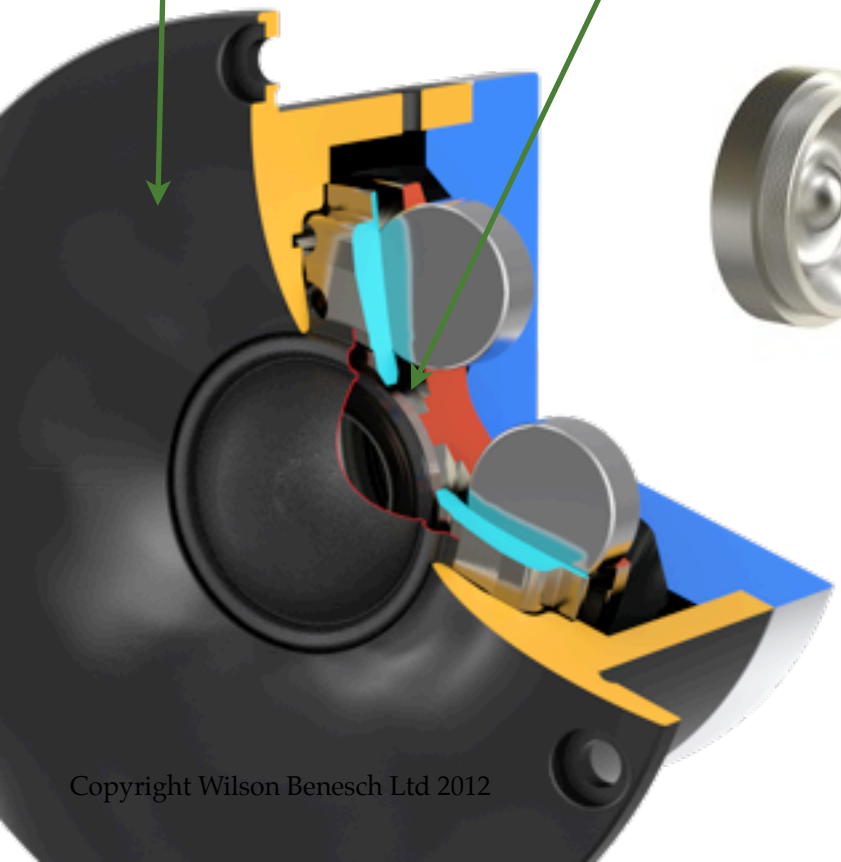
Semisphere Tweeter

The Semisphere was developed to match precisely and without compromise with the Tactic II drive unit. It functions with the simplest of crossover to ensure the lowest possible level of distortion. Like all Wilson Benesch components, every single facet is manufactured in house which is quite unique. It is this level of control that defines the component and ultimately the final product.

The voice coil functions in a high precision gap that has been determined after finite element analysis. Each metal component is machined in house to exacting tolerances that deliver near ideal geometry. The air behind the dome and adjacent to the coil is free to exhaust into the huge rear chamber.

The huge metal face fulfills a variety of key functions. It couples energy from the dome and matches it to the air. It places the voice coil further back, to time align more accurately with the mid range drive units. It provides a huge heatsink, to dissipate heat from the powerful voice coil. It provides the ideal geometry to integrate seamlessly, with adjacent mid range drive units.

Huge metal end cap ensures high integrity structure and adds significant additional mass to cool the system. Heat is one of the biggest concerns in tweeter design especially when the mass of the coil has been reduced, in pursuit of improved dynamics. The Semisphere delivers unprecedented levels of heat conduction.

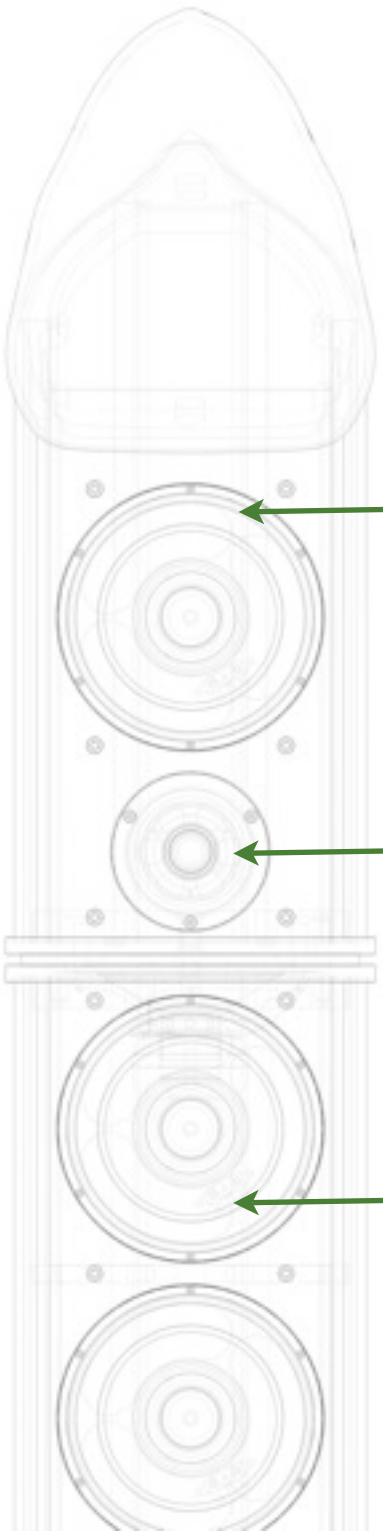


History behind the Semisphere Tweeter

As its name suggests, the Semisphere was heavily influenced by the Sphere ultrasonic tweeter, a design patented by Murata of Japan. The knowledge gained from this technology, influenced and motivated the development of the hybrid dome structure, that is a key part of the Semisphere.

The Troika Concept

The Troika concept, sees two Tactic II drive units with very ordinary demands being placed upon them. Each Tactic has been optimised in every detail to function exactly within prescribed limits. Each Tactic II delivers with consummate ease its own frequency band, without ever being stressed.



Mid / Bass Tactic Two drive unit with high mass cone and a coil specification that delivers the exact sensitivity and response for its prescribed bandwidth. It functions in a sealed enclosure that ensures low noise and ideal roll off.

The drive unit is connected directly to the amplifier with NO crossover. Step response is unmatched.

Semisphere Tweeter disposed between the two adjacent Tactic II drive units. This geometry delivers the perfect acoustic centre.

The resulting sound image is constructed in the most natural way possible.

Mid range Tactic Two drive unit with low mass cone, and a coil specification that delivers the exact sensitivity and response for its prescribed bandwidth. It functions in a sealed enclosure but is tuned by a semi-active A.B.R. This ensures low noise and ideal function no matter how the system is being driven.

The drive unit is connected directly to the amplifier with NO crossover. Step response is unmatched.

Human hearing is extremely sensitive to electrical phase shifts, especially in the mid-band. In an ideal world, electrical current and voltage should contain absolutely no filter related distortions resulting from phase shifts, because it is well known that these distortions lead to a less natural reproduction of sound. It is for this reason, that each range of frequencies in the Cardinal is governed by either the simplest possible filter, or no filter at all.
With no filter one achieves

- Near perfect step response
- The ultimate transient information, which is so critical to the ultimate performance.
- Dynamics that are completely free of any overhang from coil hysteresis and capacitive discharge.
- A complete absence of any overhang that is impossible even with the simplest crossover.

The Cardinal introduces the Troika Concept, a joint agreement between three drive units to work in harmony like never before. This radical design sees no capacitor and no inductor in the signal path. Subsequently, the amplifier has a vice like grip of the voice coils in a way that no conventional design could even aspire to. The results are well known to Wilson Benesch who have worked tirelessly on designs without filters for more than a decade. The Troika Concept, is a key development from this work that began with the Bishop.

The Semisphere tweeter was developed to enable it to be placed precisely between two vertically aligned Tactic II drive units. This geometry produces the ideal acoustic center. The surface geometry of the Semisphere places coil alignment much further back and as a result almost in line to the Tactic II. Significantly it achieves these design objectives without any disruption to the baffle surface geometry. This geometry ensures that the propagation of sound will be seamless and more harmonious.

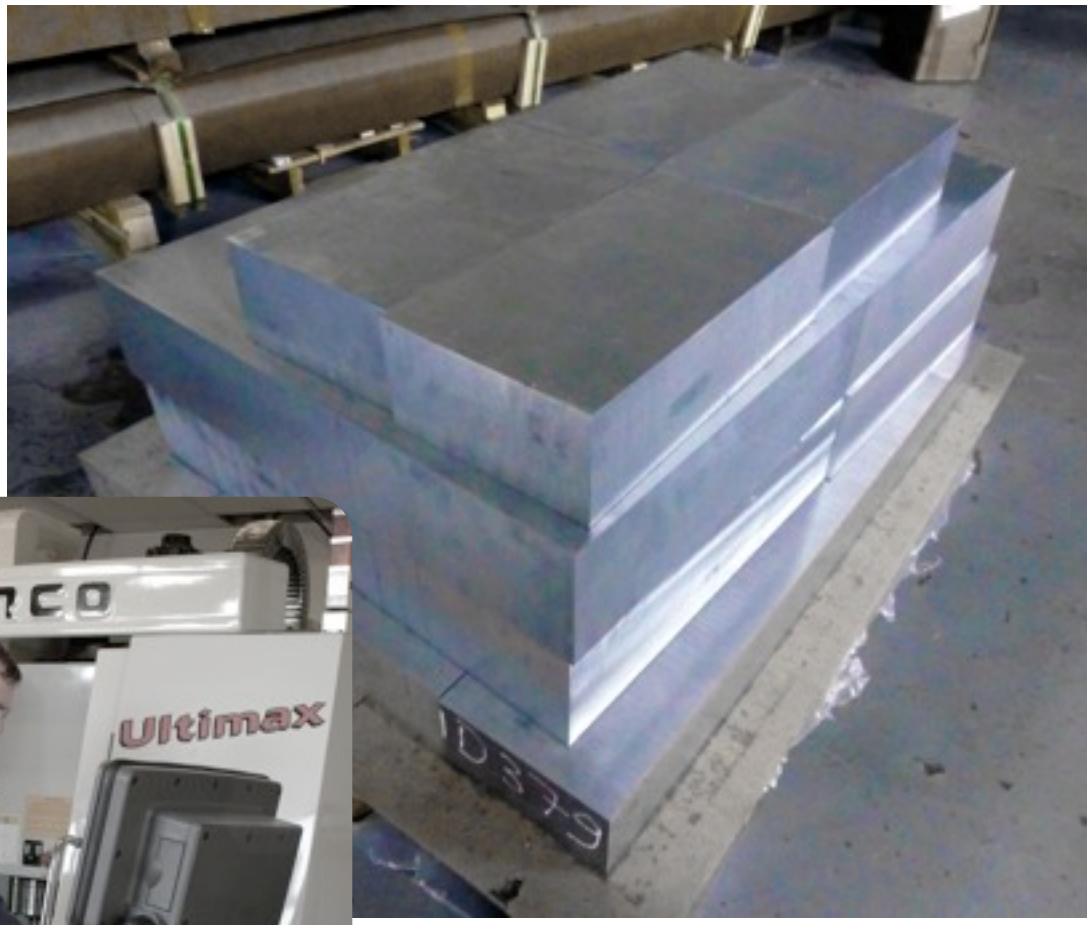
1 divide by 2 = HALF
A problem shared is a problem halved. Troika, sees the responsibility for mid-range sound being shared. By halving expectations real benefits can be secured in performance. Its like going from a four cylinder engine to a V8. Like a V8, each cylinder / drive unit functions at all times well within its performance limits, so over excursion, stress and other distortions are minimised.

To achieve the upper mid and lower mid /bass each unit must have totally different components in its dynamic parts, whilst remaining fundamentally the same. Each unit is exposed to a completely different air volume, that prescribes its first resonant frequency. The upper bass, is optimally tuned by a semi active A.B.R. This innovative mechanical solution was first deployed in the Chimera more than a decade ago. It ensures a precise and linear response, to the function of the drive unit, by exerting more damping when the drive unit is working harder. The A.B.R. has a shorted path on its coil, with this, comes linear electro mechanical damping, that mirrors the function of the drive unit. It is a very elegant solution to achieving that little extra control, whilst affording a little extra bass when the system is driven harder. Essentially, the system functions as a closed box when not being driven hard, then moves gently into a ported design when driven harder.

Manufacturing

State of the Art manufacturing underpins each and every aspect of a Wilson Benesch product.

Every product takes its starting point from raw materials, as in the case of the image below that shows a pallet of aluminium billets, awaiting the C.N.C. machine. The starting point for carbon composites, is resin and dry fabric. The scale and breadth of manufacturing control and expertise is one that is quite unique in the audio industry.



Electrical Connection

The nut and bolt is common place in every field of engineering, simply because it is near perfect in terms of its function and reliability.

Is there any need to make it more complex?

The materials that we make our connectors from are perhaps a little more exotic, (high copper alloys coated in rhodium) They do however, guarantee a trouble free, reliable oxygen free high surface pressure connection.

The filters in a Wilson Benesch loudspeaker are equally simple, and so cause the least amount of damage to the signal, that is transferred by super fine Teflon jacketed military specification conductors. Each hand assembled loom has been optimised according to its current delivery and signal type.

One first order crossover defines the tweeters low frequency roll off point at 5 KHz

One air core inductor is in the signal path of each Isobaric composite drive unit system which rolls off at 500 Hz

No components exist in the signal path of the two mid range drive units.

Aerospace Finishes

Each and every Cardinal is built for you and is quite unique. It is assembled from finished parts, by highly skilled craftsmen, with decades of experience. Each component, has been carefully taken from being a raw material to a finished part, by the same company. Only the parts that have successfully negotiated the multiple stages of rigorous quality checks, actually make it to the final assembly shelf.

British Aerospace quality finishes, come as standard on all, Silk Black, components in the Cardinal. The Silk Black finish is durable, tough, smear free and encapsulates the metal like no other finish.

If you prefer the real wood veneer that has been the hallmark of quality Wilson Benesch design, then as per usual, they come supplied in either satin or high gloss finish. Applied, prepared and finished by Bentley trained craftsmen, they will remain stable, even in the most hostile of humid environments. They are virtually indestructable, due to the metal structure to which they are bonded.

Beautiful architectural grade polymer finishes are also available that can meet your hearts desire. The Pure White finish, is featured in the room placement image, shown on the next page.

Sublimely Beautiful

The Future is Carbon