



Eminence White Paper

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Fig.1 - Wilson Benesch Eminence Loudspeaker. State-of-the-Art Reference Class design 2018

The Wilson Benesch Eminence Loudspeaker

Celebrating 30-Years of Audio Innovation and Excellence

What is a dynamic loudspeaker?

In its purest form, a dynamic loudspeaker is a system comprised of dynamic drive units or woofers that convert electromagnetic energy into acoustic energy. In the process of this energy conversion, some of the acoustic energy that is produced should be heard by the listener, but some of that acoustic energy is unwanted and will diminish the performance of the loudspeaker.

In practice for a loudspeaker designer to aspire to become a master of the art of loudspeaker design in this field, he/she must become an expert in the many difference sciences and also the engineering and manufacturing capabilities that must all work in harmony to create the ultimate reference loudspeaker within the realms of what is currently possible, or what is often referred to as the State-of-the-Art.

When considering the challenge of creating a dynamic loudspeaker such as Eminence, which houses multiple dynamic drive units within a large enclosure, the challenges are many and varied. Through three decades of research and development (R&D), in the fields of science, engineering and manufacturing, Wilson Benesch have arrived at Eminence.

An early review on the first Wilson Benesch loudspeaker attempted to characterise the sound as being “one third dynamic, two thirds electrostatic”. The reviewer had arrived at a summation of a product whole that was in fact a harmony of multiple parts borne of an extensive 5-year R&D project to create a whole system approach to loudspeaker design.

Analogy: The Art of Dance



Fig.2 -Fred Astair and Ginger Rodgers – Dancing Cheek to Cheek

When considering a whole system approach, the art of dance is an interesting visual representation of a common goal. Dancers possess a high power to weight ratio. Dance partners are similar in size and share a passion, drive and determination to create temporal accuracy in movement as an interpretation often of a musical score. In fact “Dancing Cheek to Cheek” says it all. Everything is as one together in harmony with the music.

The typical electrostatic loudspeaker does this with consummate ease, possessing as a result a transparency and coherence that is considered very natural by most who listen. This natural characteristic, honesty and faithful presentation of a music piece has remained a primary concern that has underpinned the evolution of the Wilson Benesch sound since the inception of the company. Like the constituent components from which it is made, the sound of a Wilson Benesch loudspeaker - and in particular the Eminence and its Tactic 3.0 array – is markedly different to almost, if not all its contemporaries.



Fig.3 – Tactic 3.0 Array in the Eminence loudspeaker

Looking at figure 3 above and figure 4 below, the red cross-section slice is used to represent an almost perfectly aligned array of dynamic drive units. The other important observation that should be made is the small radiating surfaces of each drive unit are controlled by very powerful NdFeB motor systems. Taken together, the small diaphragm woofer and high power motor systems deliver a very high power to weight ratio. Subsequently the behavior of the dynamic components is very tightly controlled and precise.

Contrast this with a large woofer design and a number of compromises can be observed, large moving mass, lower power to weight ratio, stiffer surrounds and spiders to control the movement of the large diaphragm and also the inertia of the air acting upon the surface of the dynamic parts. These are the first set of design compromises to consider when adopting a large woofer.

Large diaphragms also require large cabinets which also create another set of compromises namely a significant decrease in the signal to noise ratio of the loudspeaker. This is due in part to the large surface area of the loudspeaker enclosure which resonates as the loudspeaker is in use. But also due to the large holes within the loudspeaker baffle that mount the woofers, which are virtually transparent to the out of phase energy that exists within the chamber directly behind the slender diaphragm membrane affording a relatively easy path for this energy to energy directly into the listening space.

In sharp contrast, the Tactic array affords,

- a much smaller aperture into the loudspeaker enclosure.
- a harmonious fit within a relatively compact front baffle and loudspeaker enclosure.
- the concomitant air load which is inevitably far more significant in large diaphragm designs, is both reduced and distributed across multiple units.

With additional benefits in,

- smaller less stiff rubber surrounds which store less energy.
- smaller less stiff spiders which store less energy.
- together the cumulative effect is a smaller delay signature of the high hysteresis spider and rubber surrounds that are unavoidable in large woofer systems.



Fig.4 – Tactic 3.0 Array in the Eminence loudspeaker in more detail

These differences are not insignificant and naturally provide for superior step response characteristics. But one of the most important key benefits of the Tactic array is the alignment and proximity of each driver. Every drive unit is either within millimeters or exactly the same alignment which legislates for class leading time alignment, whilst at the same time enabling high integrity structures and elegant baffle to be created.

These are some of the more important, but by no means all of the factors that provide a cumulative benefits that translates directly into a more vivid stereo reproduction that is capable of conjuring up in a three dimensional space both the artist and venue ambience in a way that is lifelike and tangible, even at low listening levels.

A.C.T. One: Where the Story Begins

The first Wilson Benesch loudspeaker was launched in 1994. The name A.C.T. is an acronym for 'Advanced Composite Technology' and is a direct reference to the carbon fibre composite materials technology at the heart of the loudspeaker chassis.

History and heritage are important components in the advance of a design. It is only by looking to the past and learning from what has come before that design can evolve and improve. In this respect the A.C.T. heritage serves as an elegant timeline of evolution within loudspeaker design, with no fewer than five designs over 21-years.

The materials science behind the original A.C.T. was borne from 5-years of R&D. The foundation was formed by the development of the turntable sub-chassis materials that formed the Wilson Benesch Turntable. This body of work indicated a clear benefit to using stiffer, lighter materials. The Wilson Benesch Turntable was innovative in a number of ways including several examples of hybrid structures, but this research gave rise to the world's first carbon fibre composite sub chassis. The subsequent work on the tonearms was also critical to the development of our early understanding of just how significant this materials science was.

The original A.C.T. One was a tour de force of design. It was in the words of Wilfried Kress a speaker that "sparked a small revolution" in design. At the point when the A.C.T. One was launched, loudspeaker design had not evolved beyond the square box form. Following Ken Kessler's review of the Wilson Benesch Turntable, Ken asked "so what's going to be your next product?" to which Wilson Benesch Design Director Craig retorted "a loudspeaker". Ken's response? "The last thing the world needs is another loudspeaker!". Ken's statement was a valid one. There was only one designer that was doing anything that wasn't based on a square box and that was the late great Franco Serblin. But the Wilson Benesch design ethos was driven by innovation and materials science, the Wilson Benesch Turntable had been a testament to this and the preliminary design work had already begun on a revolutionary new Wilson Benesch loudspeaker.

Looking back at the pages of Craig Milnes's sketch book from the time, the blueprints of the original A.C.T. One design can be seen. Not only was the new loudspeaker not a square box, but it also introduced the sloping sculptured top. Whilst at the other end of the elegant enclosure was another feature that redefined the concept of the foot. The A.C.T. One featured a complex collection of shapes made from various alloys that stabilised the structure with menacing looking 14mm spikes that are still in use today. The structural importance of this design underlined the attention to detail that could be seen throughout the design. The alloy baffle – itself a another new concept in loudspeaker design - presented a collection of Scan derived drive units that were filtered by a very simple 2.5 way crossover network. Internally, a novel internal wiring loom consisted of solid silver conductors and an over size Teflon jacket that was assembled in house.

As important as each of these innovative elements were to the design, the A.C.T. One's defining innovation was of course the curved carbon fibre Advanced Composite Technology structures from which the loudspeaker took its name.

The A.C.T. One was developed in the prototyping workshop of the now closed Greaves Cabinet Works of Sheffield, which was at that time the centre of UK audio cabinet production. The Director of Greaves had no desire to even try to build a curved speaker but was kind enough to allow the experience and expertise of Greaves best craftsmen to work on the prototypes and subsequent first products to be manufactured.

The A.C.T. structures were made from aerospace pre-preg disposed either side of a Nomex core. Each panel was assembled by hand and the carbon fibre formed a distinctive four by four twill. The engineering expertise required to manufacture such a component was incredibly rare at the time and was confined to aerospace and Formula 1. One of the Engineers behind the development of the A.C.T. panel was the same engineer who had met the challenge of the A.C.T. One Tonearm in 1992. His experience was pivotal to the forward momentum of Wilson Benesch at this time. One of his many notable projects included being part of the Rolls Royce engineering team that had worked on the experimental carbon fibre fan blades of the RB 211 jet engine.

Notable though all these elements were, perhaps more impressive was the fact that they had all been introduced in one product, but most impressive of all was the fact that such technology had all emanated from one small company. The genesis of the A.C.T One can be traced to the turntable, however the ambition that drove the design laid also laid the foundations for a unique development path, a path that was diametrically opposite to the "build em' and spray em'" approach of the traditional square box loudspeaker industry.

The modular design of the A.C.T. One not only legislated for the introduction of mutual self damping within the cabinet through hybrid construction techniques, it also created a framework for a design that could evolve over decades with each new design building upon the strengths and weaknesses of its predecessor. As new technologies enabled better solutions to be realised these could in turn be introduced without sacrificing the achievements seen in the previous designs.

The Advanced Composite Technology 'A.C.T.' 3-Zero Monocoque

The A.C.T. Monocoque has been incrementally developed over 20 years. The original RTM (Resin Transfer Mould) system of manufacture for this key components was radical for its time. Wilson Benesch was one of four organisations that committed to this new manufacturing technology when it was promoted with grant aid by Her Majesty Government through the agency PERA. The others being Lotus cars and two M.O.D. contractors.

By comparison to the manufacturing systems today, the RTM systems developed were crude, with a high scrap rate that was initially more than 60%. Today the VRTM (Vacuum Resin Transfer Mould) is largely automated and controlled to extremely fine tolerances that are monitored by computer controlled manufacturing systems. This entire system has been designed and developed for one purpose. To manufacture a finished part from its highly polished surface thermally controlled metal finish. The resin that is infused under pressure and vacuum with a precise delta pressure emerges from a 5mm hole and is slowly drawn through the fibres in a process that has been honed to perfection. The dry elements that must be expertly dressed into the tool by highly trained technicians will after more than three hours become a unified structural component of uncompromising stiffness and damping.

The actual material content within the structure has evolved over time and is still the subject of on-going research and development. Wilson Benesch is one of four SME's that are part of SSUCHY a €7.5-million, 4-year long research project with a focus of developing next generation of bio based materials to replace the finite oil based materials in common use today. Leading bluechip companies like Akzo Nobel are also involved in this work that includes hundreds of academics from 13 Universities across Europe.

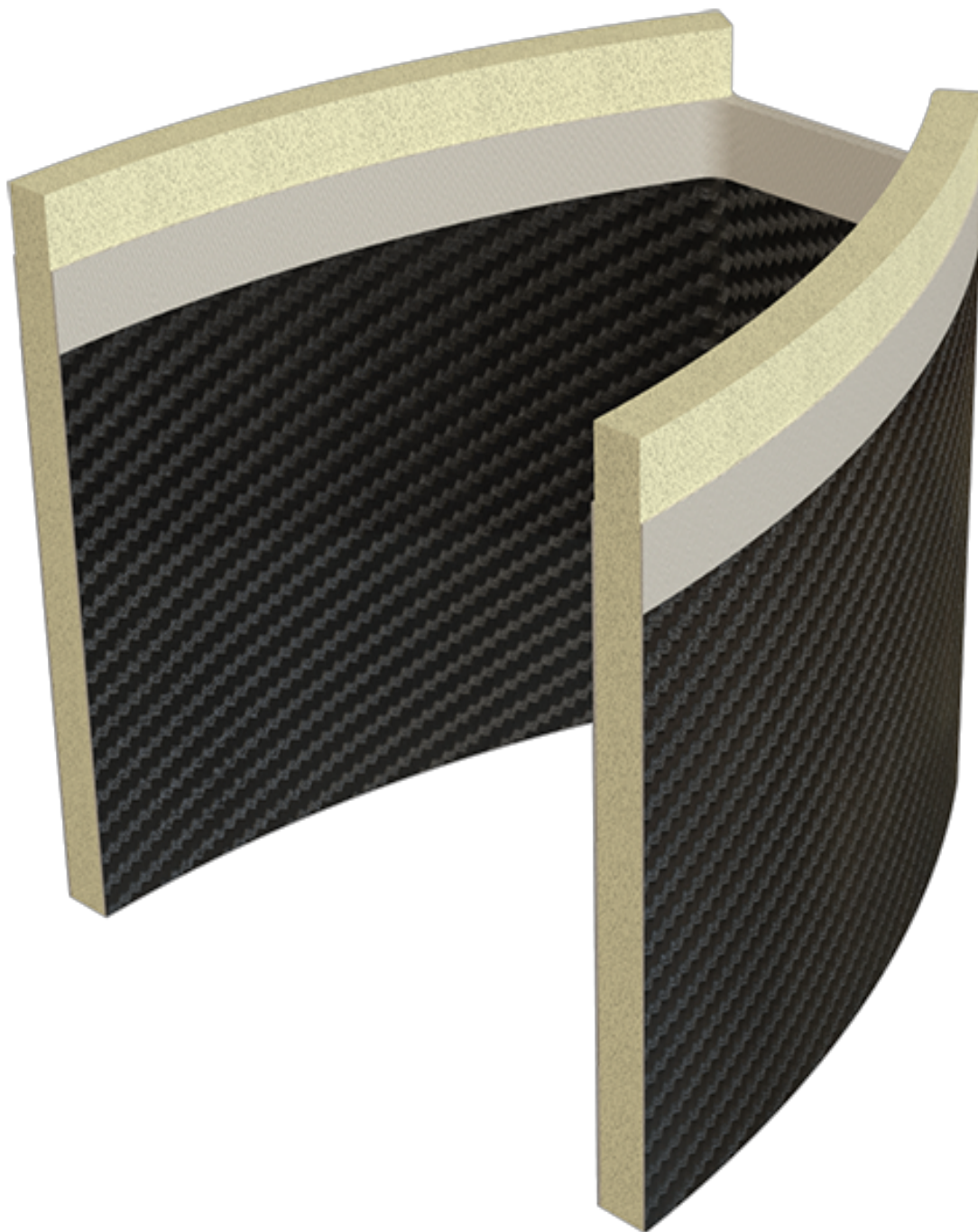


Fig.5 – The A.C.T. Monocoque

If the A.C.T. Monocoque 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.

In terms of energy damping and therefore signal-to-noise ratio, it would exceed with consummate ease the traditional conventional materials typically seen in loudspeaker design to date.

The principle material in the A.C.T. Monocoque is carbon fibre. Perhaps the first characteristics that come to mind when one considers this material, are its inherent lightness and 'strength'. The material has become inextricably linked with F1 racing cars where these properties are readily displayed as incredibly light, high performance race cars elegantly navigate around a race circuit at phenomenal speed, until they [hit a wall at 100+ mph and the driver gets out of the cockpit and walks away](#). However, carbon fibre is a remarkable material with a great many unique characteristics which loan themselves perfectly in the

pursuit of ultimately audio reproduction.

Resonance and Sound

In a loudspeaker cabinet design, the aim of the audio engineer is to produce a cabinet that is silent whilst the loudspeakers drive units reproduce the sound of music. Figure 6 and Figure 7 below show the A.C.T. Monocoque being subjected a wide spectrum of audio frequencies, with a series of sensors across the monocoque to study the resonant frequencies and behaviour of the structure when subject to acoustic energy. This kind of analysis has allowed Wilson Benesch to continually refine the design and improve it. When a loudspeaker cabinet vibrates or resonates it is creating sound waves and therefore additional sound to that which was originally reproduced by the drive unit and thus an unwanted addition to the music. Audio engineers adopt many different traditional methods of reducing resonance within the loudspeaker chassis, a common example is internal bracing, but the most commonly accepted approach to controlling the resonance of the cabinet is to create it from stiff materials that resist resonance. It is in the second respect, that carbon fibre can be seen to push the performance envelope further than any other material currently used in loudspeaker chassis design.



Figure 6 - Image produced courtesy of Femto_ST Research under SSUCHY. Extract from Masters Paper by Aymen Barhoumi.

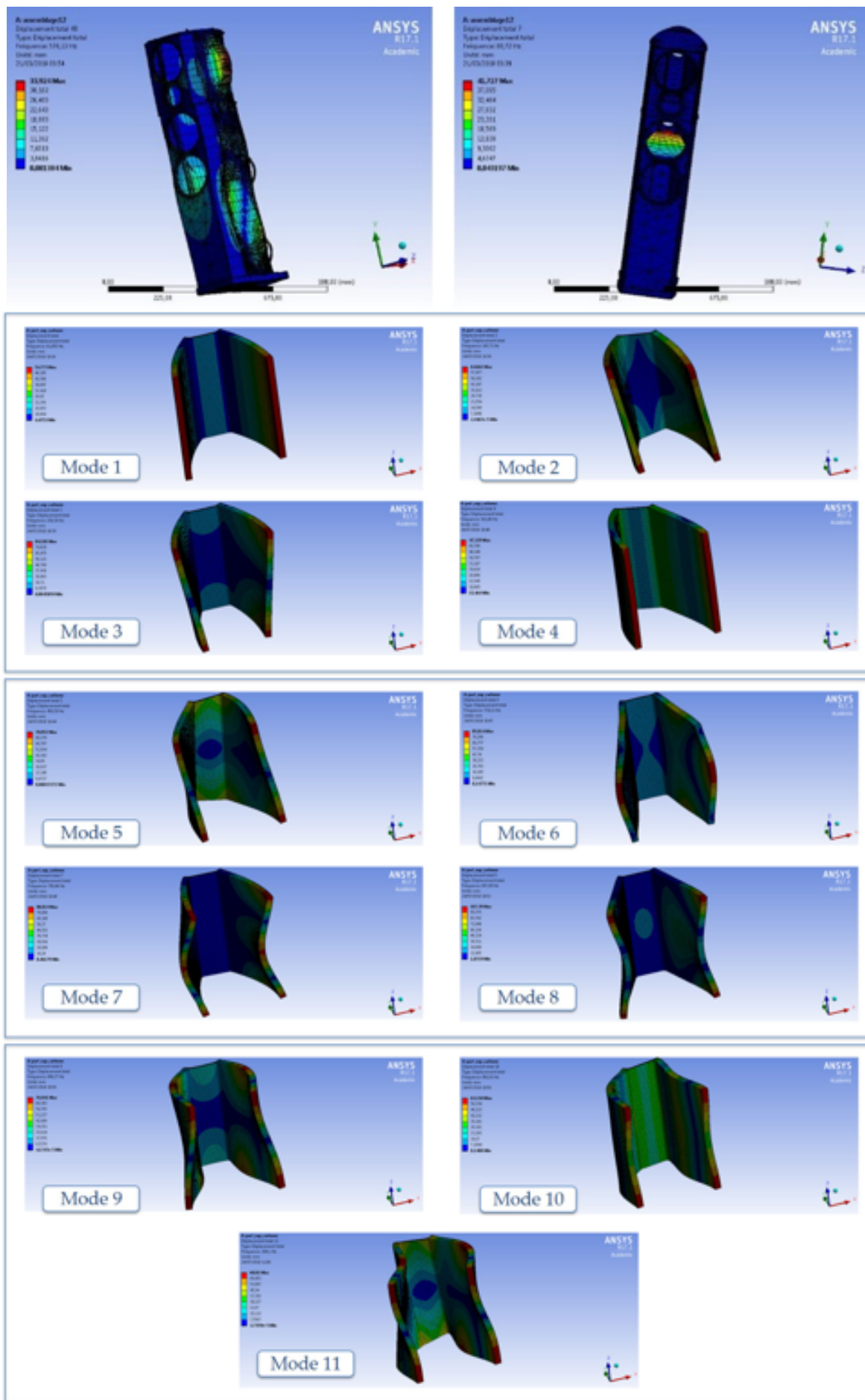


Figure 7 - Image produced courtesy of Femto_ST Research under SSUCHY. Extract from Masters Paper by Aymen Barhouri.

So how does carbon fibre improve performance in a loudspeaker?

Carbon fibre is a fibrous material that is comprised of billions of single fibres which when infused with a epoxy resin and cured, creates a stiff, lightweight material. The orientation of the fibres is key to the stiffness of the material and can be manipulated by the designer to create highly optimised structures and components with stiffness in specified areas where strength is required. Regardless, carbon fibre is known to be 10x stiffer than steel, whilst also having a significantly lower mass than aluminium. Perhaps the numbers are hard to grasp and put into perspective, but watching the video via this link, Top Gear's Richard Hammond demonstrates nicely the remarkable stiffness and strength of a carbon fibre crankshaft compared to a steel crankshaft at Lotus F1 Test facility: https://www.youtube.com/watch?v=hjErH4_1fks

So when you turn up the volume and the amount of energy inside the loudspeaker cabinet increases, at its most basic level carbon fibre as the stiffest known loudspeaker cabinet material resists resonance better than any other solution. However, as can be appreciated by studying the illustrated diagram below, the Wilson Benesch A.C.T. Monocoque is a composite construction which combines the stiffness of carbon fibre with the damping properties of an aerospace high compression core. Now exists a structure that is able to not only resist resonance, but also absorb kinetic energy and dissipate it as a heat exchange with the environment rather than a sound exchange.

Geometry in A.C.T.

It is widely recognised that highly optimised structures exhibit geometrically optimal elements. In pursuit of performance nature has already rejected less than optimal designs and by looking at forms found in nature one can learn many lessons in design. The Wilson Benesch font was designed on pure geometrical forms and it's the ethos that has underpinned every design for three decades.

The shell shown in figure 8 is one of the finest examples of such a structure. The mollusc shell provides protection to the soft flesh of the mollusc residing inside, therefore this structure needs to be strong. The shell has evolved into a curved shape since this geometric form is one of the strongest forms, distributing weight and pressure evenly to the entire structure. The A.C.T. Monocoque uses the same geometric curve to add to the phenomenal stiffness of the carbon composite and optimise its form.

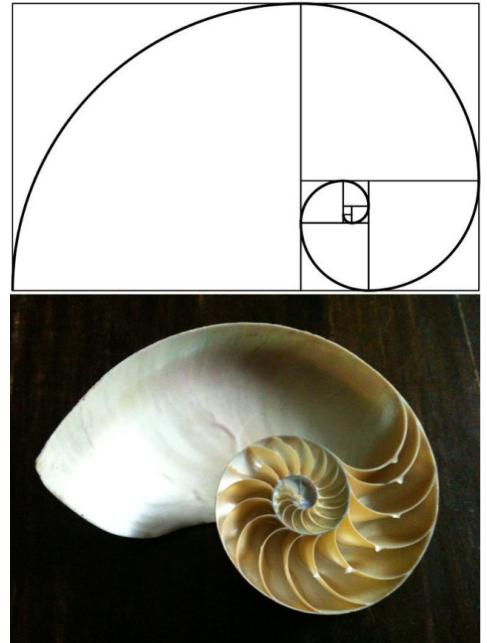


Figure 8 – A mollusc shell

But the curved form also plays a second crucial role in dictating both how the loudspeaker interacts with sound frequencies that are reflecting around the listening room and also how the small acoustic signature of the loudspeaker cabinet is dissipated.

Jodrell Bank telescope uses a curve to focus radio waves onto one point. It can receive signals from deep space millions of miles away from earth. The curved form of the A.C.T. monocoque acts in the opposite, dispersing energy.

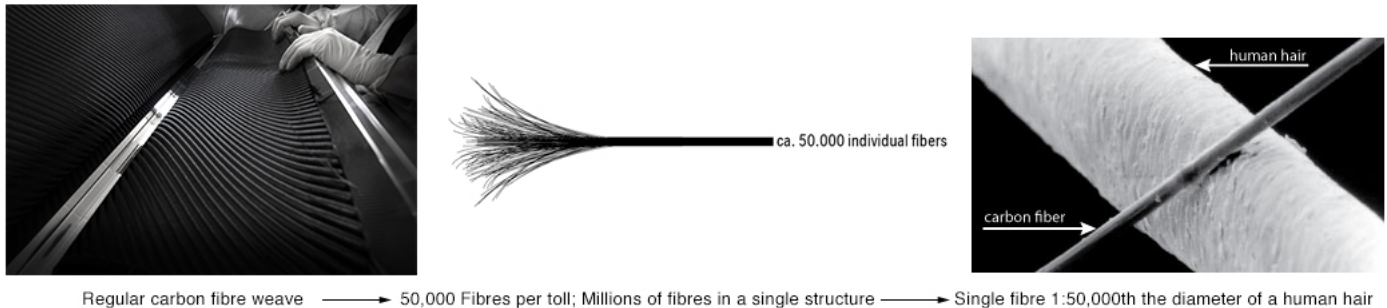


Figure 9 – Jodrell Bank Telescope

If you observe how your voice reflects from a flat wall compared with a curved wall, it is easy to appreciate that the volume of your reflected voice is much lower when reflected from a curved wall compared with a flat wall. This is because the sound energy is dispersed across a wide angle, rather than focused in a direct line back toward you. This is critically important to a loudspeaker, which should disappear within the listening space leaving only the sound of the music.

A.C.T. Monocoque Advanced Composite Technology

If the sophisticated A.C.T. monocoque 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. In terms of energy damping and therefore signal-to-noise ratio, it would exceed with consummate ease the traditional conventional materials typically seen in loudspeaker design to date.



The A.C.T. Monocoque has been engineered and optimised for its critical role in audio reproduction:

1. **Composite Structure;** Its composite three-layer structure vastly improves the damping property of carbon fibre reinforced plastic (CFRP). The combination of the blast core, carbon fibre and glass fibre creates a composite monocoque with the stiffness of CFRP and the damping properties of the blast core.
2. **Fibre orientation;** a single toll of carbon fibre consists of billions of microscopic fibres, 1,50,000th the diameter of a human hair. Each fibre presents a boundary between escaping energy inside the loudspeaker cabinet and the listening environment. Furthermore, these fibres are arranged in a regular fashion. The discernible fibrous weave in the A.C.T. Monocoque allows the energy being absorbed by the structure to flow directionally along the weave into the viscoelastic seals which bond the aluminium structures in the speaker.
3. **Sound transmission;** because of the directional flow of energy down the regular weave and fibres in a carbon composite structure, the velocity of transmission of this energy is greater than any conventional material. This provides the designer with a significant advantage, allowing the small amount of unwanted sound energy escaping from the loudspeaker cabinet to occur as close as possible to the original sound made by the drive units in the loudspeaker. This avoids unpleasant overhang in a musical performance.
4. **Geometrically optimised;** the perfect curvature disperses sound energy both internally and externally evenly across its surface. This is critically important in loudspeaker cabinet design. It eradicates what audio engineers term *standing waves*. This inhibits the ability of the listener to easily locate one point of diffraction, so the loudspeaker cabinet remains silent.
5. **High Resonant Frequency;** every object has a natural resonant frequency. Stiff - light structures naturally have a high resonant frequency, where compliant - heavy structures have a low resonant frequency. High frequencies are easily damped, where low frequencies are very problematic and cannot easily be damped. In the Eminence, structures with a high resonant frequency such as the A.C.T. Monocoque and the aluminium structures are damped using visco-elastic seals, which can easily absorb any high resonant frequencies.

Cabinet Design in the 21st Century

The image below provides a simple comparison between two structures with the same air volume and the same stiffness. The image illustrates the huge difference in the relative size and weight of the two structures in order for each to achieve the same design goal.

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 improves stiffness, however aluminium exhibits very poor self damping, the result would be a highly resonant structure. In order to control resonance in designs based around aluminium, elaborate and complex bracing is deployed, which in turn subtracts from the air volume of the internal cabinet, a major loudspeaker design compromise.



Key Concepts

All cabinet structures resonate and emit sound.

Mass

High Mass = Low Resonant Frequency = High Cabinet Noise

Low Mass = High Resonant Frequency = Low Cabinet Noise

Resonant Frequencies

High Resonant Frequencies are easily damped.

Low Resonant Frequencies are difficult to damp.

Surface Area

If a loudspeaker cabinet has 100 times the surface area of the drive unit diaphragm it only has to move (resonate) 100th the amount of that diaphragm to produce the same output.

So it follows, large cabinets are inherently less stealth like and silent.

The Composites Age

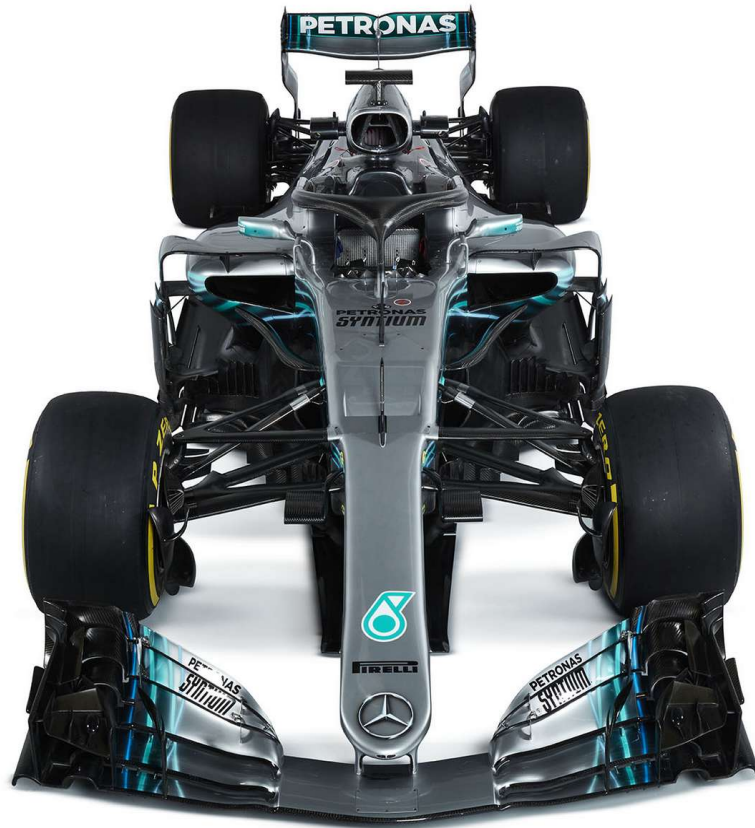
Wilson Benesch pioneered the use of carbon fibre composite structures in audio design. The company now has more than 20-years experience and intellectual property, relating to the exploitation of this important field of engineering.

It goes without saying that this wonder material has revolutionised the automobile industry, aerospace industry and sports equipment industry to name a few. Countless examples can be seen from the McLaren P1, to the Boeing 787 Dreamliner, or to Sir Bradley Wiggins's incredibly stiff, lightweight carbon fibre bicycle used to win the Tour de France.



In each case the unrivalled stiffness, strength and the phenomenal weight advantage that carbon fibre composites have provided has allowed these designs to become a reality. But of course, the inherent property of carbon fibre composites, which is key to Wilson Benesch designs such as the Eminence, is the phenomenal damping properties of these composite structures and the ability to channel and manage energy flow in one single structure.

Perhaps the best 'real world' example of this property is in Formula 1 car design. Here carbon fibre structures have been subjected to the most public demonstrations of the phenomenal capacity of this material to absorb huge amounts of energy, whilst remaining largely intact in order to protect the driver in the car. Today there are countless drivers who owe their life to this material. They are the stiffest most highly damped structures known to man.



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Mercedes F1 W09: the Championship winning F1 car in the 2018 Formula One World Championship

Mutual Self Damping: Aerospace Engineering Materials

damp·ing

noun Physics.

1. a decreasing of the amplitude of an electrical or mechanical wave.
2. an energy-absorbing mechanism or resistance circuit causing this decrease.
3. a reduction in the amplitude of an oscillation or vibration as a result of energy being dissipated as heat.

The concept of mutual self damping is central to any high performance engineering system, especially those where a high degree of control over the structures behavior is concerned. A rudimentary example would be the [use of the fingers in stringed instruments](#) to control the vibration in strings and so changing the sound the instrument makes.

Mutual self damping is based on the energy absorbing potential (damping ratio), of two quite different materials which are brought together. When the materials are disturbed from their static equilibrium, the resonant frequencies of each material act upon each other and reduce or stop completely, one and the others resonance – the mutually self damp one another.

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.



Wilson Benesch exploit mutual self damping through the use of aerospace engineering materials. The carbon composite A.C.T. structure, which is mutually self damped in its own right, is combined with the aluminium baffle, spine and bass board. The carbon composite structure legislates for the use of aluminium, a (relatively) poor damping material, by damping the aluminium before it is excited by the energy born from the loudspeakers drive units.

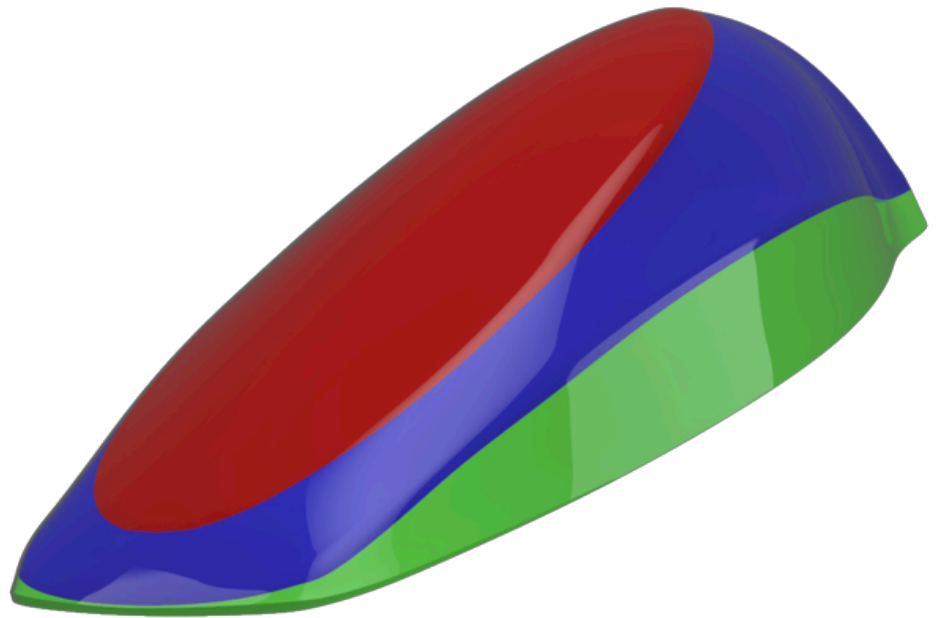
Wilson Benesch: The History of Mutual Self Damping

In 1994 Wilson Benesch announced the A.C.T. One Loudspeaker. At the time the design was radically different from anything that had been seen before in the high end audio market.

Unlike the single material, recti-linear MDF box designs of the day, the A.C.T. One consisted of a curved carbon composite chassis. But the success of the design was based on the use of no fewer than five different materials, including hard wood, MDF, aluminium, steel and of course the A.C.T. composite.

3D Parametric Design

Eminence features a beautifully sculptural carbon composite top. Whilst a very natural, organic form, based on curves and free flowing lines, the shape is an extremely complex 3D structure that has been optimised using powerful 3D Parametric Computer Design software.



Like the Cardinal, the Endeavour top evolved from sketches to full sized clay and wax sculptured forms. The wax model has then been extensively modelled in a digital 3D space using a 3D laser scanner. The data is placed into a 3D design package and the complex forms are then refined further, creating a symmetrical structure down medial plane.

This method is akin to reverse engineering, but the advanced engineering software available to Wilson Benesch provides a unique and highly efficient workflow. Were it not for the 3D laser scanner and the engineering excellence that exists within the Wilson Benesch design team, the Eminence and indeed the Resolution, Cardinal and Endeavour carbon composite tops would not be conceivable.

Such highly engineered, sculptural structures are exclusively the preserve of high performance products or architectural forms. The Eminence top is therefore a testament to the significant design and engineering excellence that pertains at Wilson Benesch, it is the hallmark of a true high end, luxury audio product.

Stealth;

Mastering Reflection, Refraction and Diffraction

Stealth Structure

Stealth

n

1. (Aeronautics) (*modifier*) denoting or referring to technology that aims to reduce the radar, thermal, and acoustic recognisability of aircraft and missiles



The Royal Albert Hall, London: Large fiberglass acoustic diffusing discs in the roof remove the echo from the Albert Hall. Prior to their installation in 1969, it was said that the hall was the only place where a British composer could be sure of hearing his work twice.

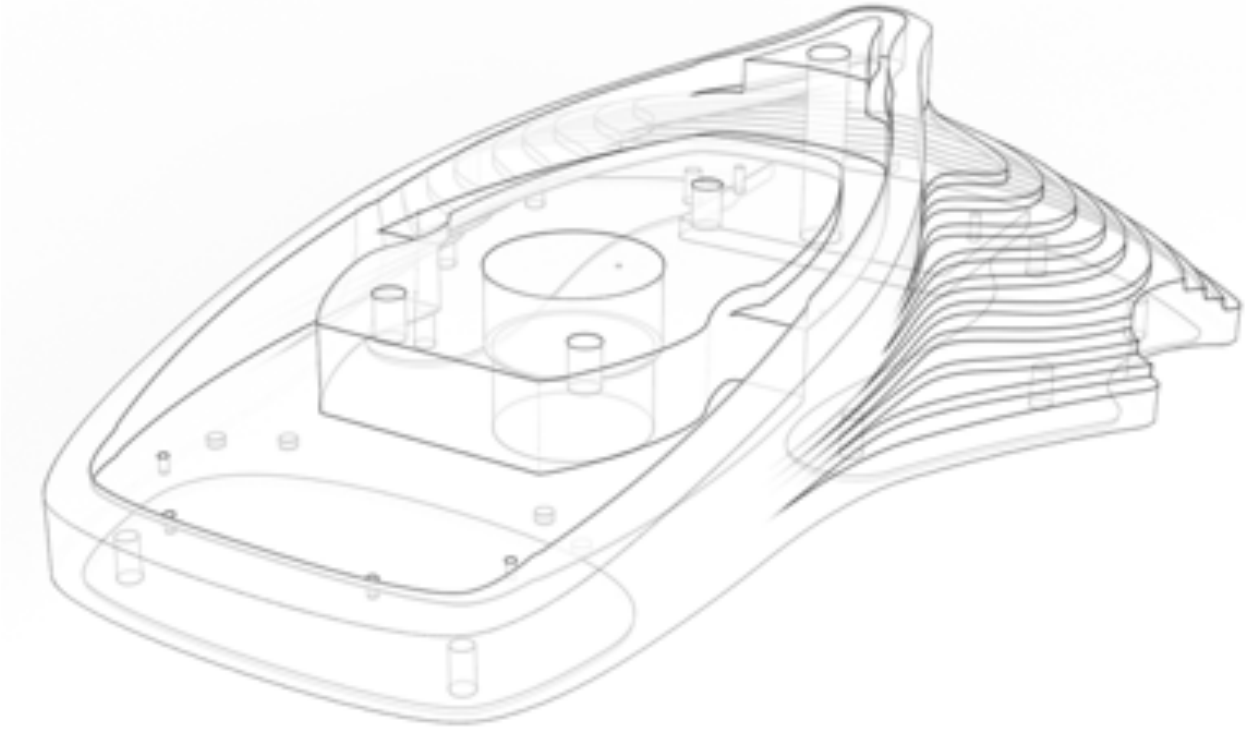
When a longitudinal sound wave strikes a flat surface, sound is reflected in a coherent manner provided that the dimension of the reflective surface is large compared to the wavelength of the sound. However, the reflective nature of a structure varies according to the shape of the surface. Uneven surfaces will tend to scatter energy, rather than reflect it coherently.

In good design, form always follows function. So whilst the Eminence top is a beautiful structure, its complex 'stealth like' form is critical to the performance of the loudspeaker. By removing any flat, reflective surfaces and creating a highly complex structure, any reflective sound energy is scattered. This diminishes its energy and also avoids standing wave patterns within the listening space that are easily detected by the human ear as distortion or colouration.

The Eminence owes much of its phenomenal capacity to present a spatial soundstage and transparent imaging, to the curved carbon composite forms of the top and the A.C.T. monocoque. The loudspeaker stealthily disappears within the listening space, leaving an ethereal soundstage and lifelike presentation.

The Eminence Foot

One of the most important principles in structural engineering is loading. All modern buildings are built upon solid foundations. It is the reference point for everything above it, transferring the load of the structure into the ground and anchoring the structure to the ground, which is crucial in loudspeaker design to create a stable point from which the drive units can propagate complex and accurate waveforms that we appreciate as music.

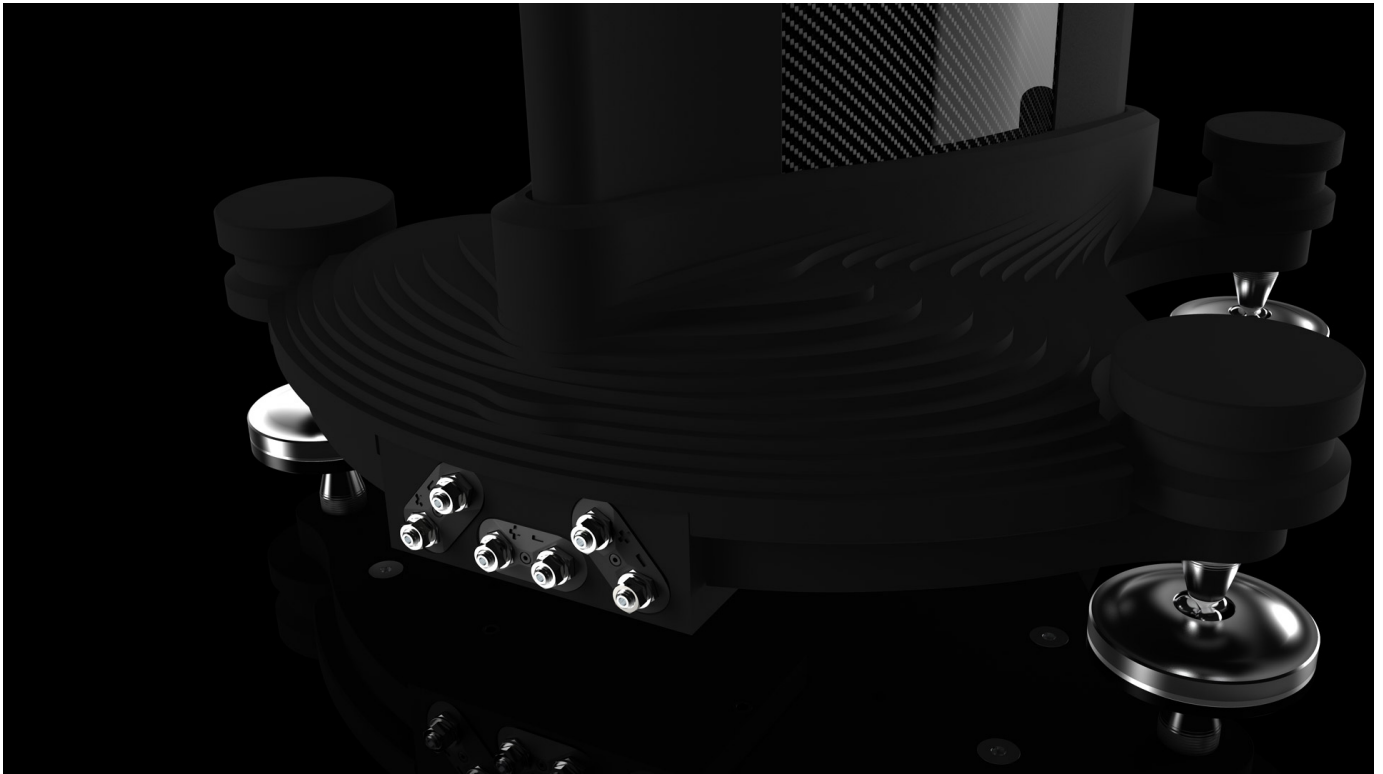


The Eminence foot is comprised of multiple components. The principle component is machined from a 120kg slab of high-grade aluminium alloy, which is then combined with two extension plates that are bolted to the main structure with high tensile bolts. Add hand-wheels and the spikes; all design and manufactured in-house at Wilson Benesch and the whole foot assembly weighs in at well over 30kg.

Looking at the next image it can be seen that tons of compressive force are imposed on all the members in the vertical axis where the first resonant modes will emerge.



Ground up Optimisation: Kinematic Location



At over 140kg per channel, Eminence is a substantial structure. Housing a 10 dynamic drive units in each channel, it is also a phenomenally powerful loudspeaker. The importance of high integrity stabilisation is critical, if the micro-dynamic performance of the loudspeaker is to be maintained.

The Eminence's colossal foot extends outwards to increase the base area where upon four 28mm, steel threads take up the mass of the Eminence. The load and any energy is then reduced into just one 12.5mm steel ball.

Transferring energy via point loads not only ensures maximum pressures at the contact points, but as a result of the spherical structures, the Eminence remains easy to adjust. This design ensures that the point at which the Endeavour's entire mass loads into the floor is measured in hundreds of tons per square inch, as the entire mass of the system is focussed in upon a contact surface area of less than 1 square mm.



Tactic II Drive Unit

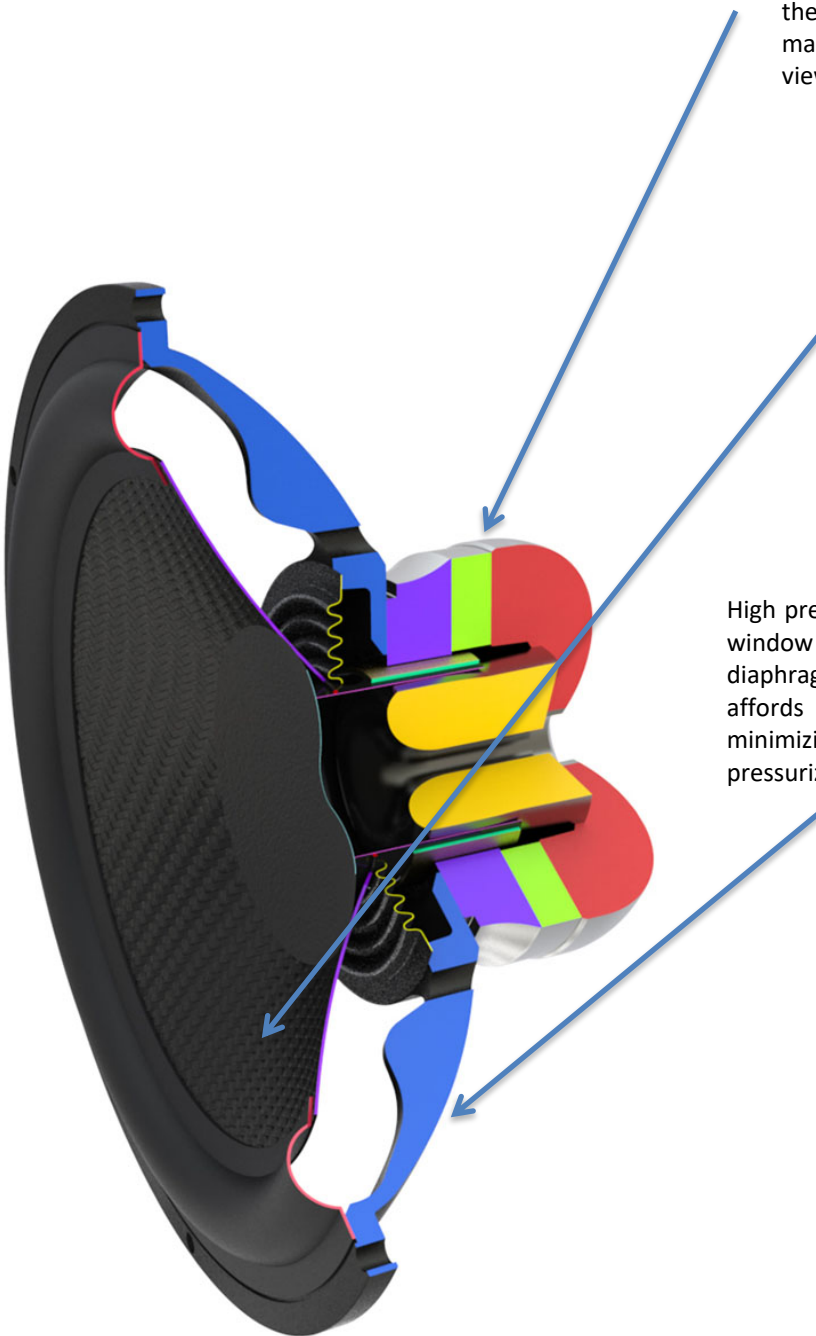
When Wilson Benesch introduced the original multirole *Tactic Drive Unit* in 2001, it was the first drive unit in the market to utilise the incredible magnetic power of NdFeB or rare earth magnet. Now more widely used in high end drive unit designs, but by no means industry standard owing to the very high cost of the material, NdFeB is the most powerful commercially available magnet available.

The curvaceous motor structure is manufactured in house on high precision CNC machines. Through collaboration with the Sheffield Hallam University, Wilson Benesch have been able to perform complex flux analysis across the structure. Every line of flux is fully optimised to extract the maximum power from the magnet. A film has been produced on the manufacture of the motor parts which can be viewed on Wilson Benesch TV

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](#).

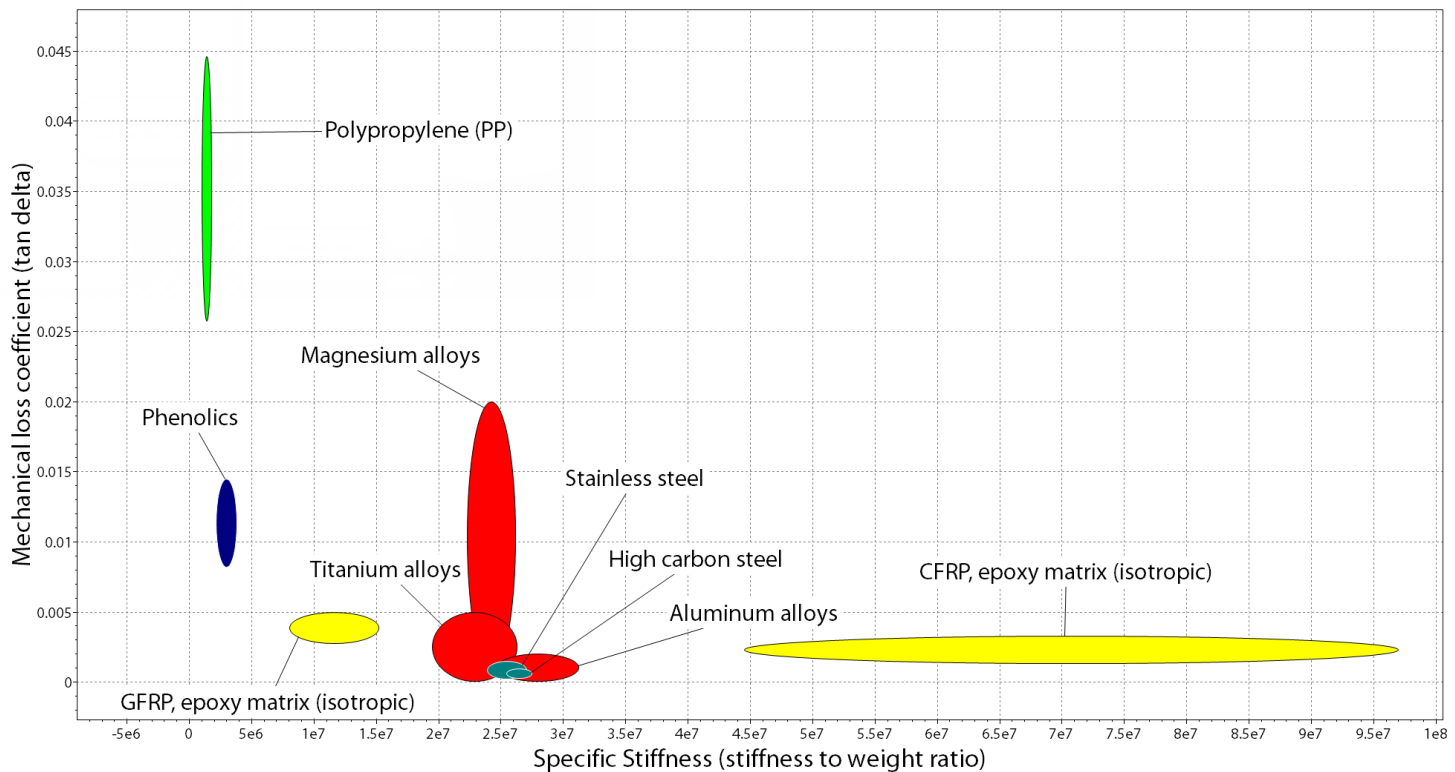
High pressure die cast basket delivers the ultimate window for energy to exit the rear surface of the diaphragm. Its reductive, streamline geometry affords the design a lot of stiffness, whilst minimizing any obstruction to airflow in the highly pressurized zone to the rear of the drive unit.



Isotactic Polypropylene (IPP)

Underpinning the Wilson Benesch design philosophy is science; in engineering and the application of the basic physical laws that govern the universe. Since the foundation of the company in 1989, advanced materials technology has consistently led our extensive R&D programmes and much of our product development has hinged around one wonder material or another.

No where can the concerns for balance in both stiffness and damping be better seen than in the material used in the diaphragm. Wilson Benesch rejected carbon fibre for this application in the early nineties and instead chose a material called Isotactic Polypropylene. IPP was developed by Professor Ian Ward. Isotactic literally means, “of equal inclination” and refers to the repeating, regularly spaced methyl group on the backbone of the chain within IPP chemical structure allowing the macromolecules to coil into a helical shape. It is this chemical property that makes IPP the most suitable choice for a high end drive unit design.

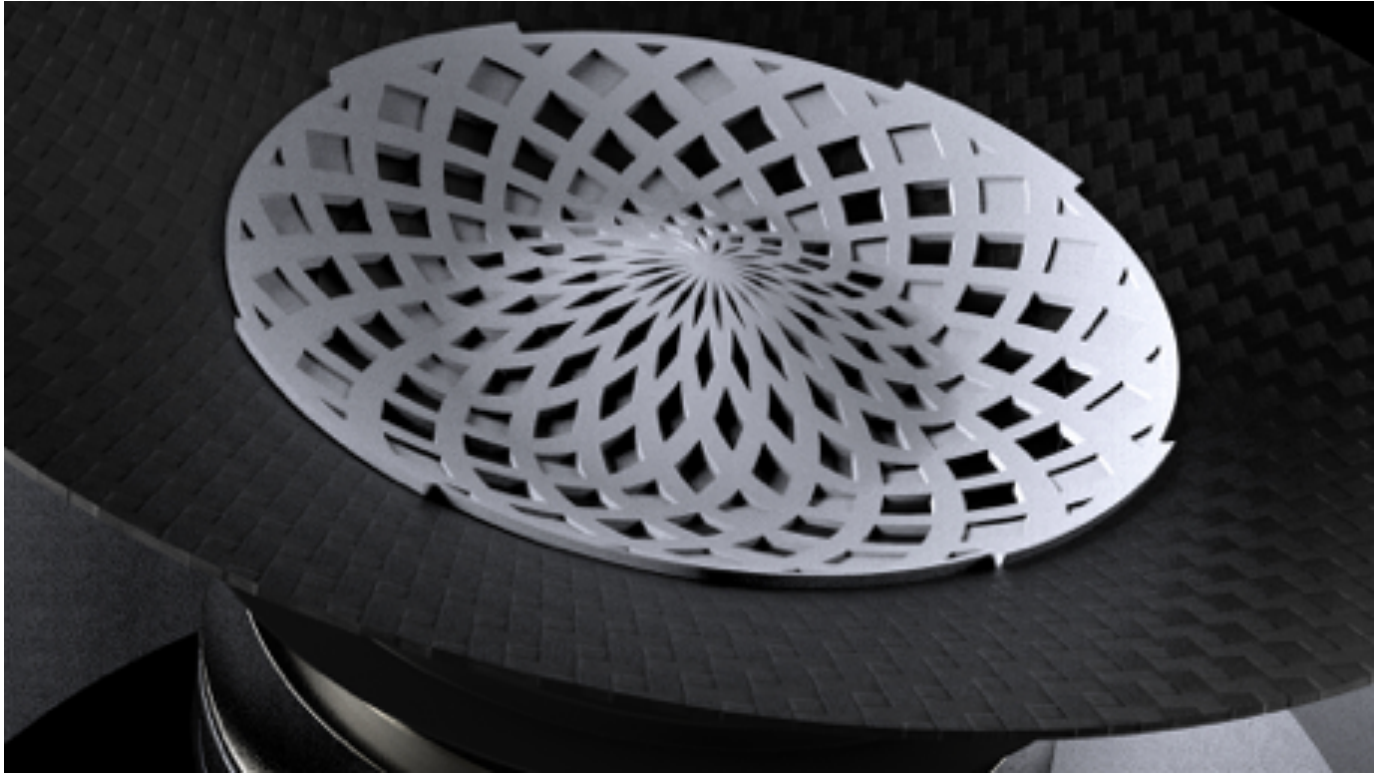


The graph above compares the degree to which a material damps vibrational energy (mechanical loss coefficient) and its stiffness to weight ratio. Whilst polypropylene has a relatively low stiffness to weight ratio, it has excellent ability to damp vibrational energy. Woven Isotactic Polypropylene is in fact five times stiffer and better damped than the homogenous polypropylene shown in the graph above.

When subjected to audio frequencies a drive unit diaphragm moves in and out to create sound waves at different frequencies that produce a musical piece. However the timbre, quality and clarity of the sound produced has a direct relationship to the material used to create the sound.

Wilson Benesch rejected carbon fibre diaphragms made from a carbon fibre / epoxy matrix, after trials undertaken in 1995. Further research has been conducted using alternative hard dome materials. Without exception the highly engineered, highly optimised Tactic Drive Unit accompanied by IPP was chosen for its natural sound and none sibilant sound character.

Tactic 3.0



The image above shows the latest version of the ever evolving Tactic technology represented by Tactic 3.0.

The “dustcap” plays a critical function in the behavior of this system. Different materials are deployed to provide the optimal behavior for the different frequency bands that the driver is required to reproduce. The structure at the centre of the diaphragm plays a critical role in providing damping as well as influencing and to some extent depending on the materials and geometry actually shaping the upper section of frequencies output of the diaphragm. This is a critical aspect of the relationship between the drive unit and its ability to blend and be in harmony with the roll off of the tweeter. In the past, several materials have been drawn upon to enable the fine tuning of this marriage. Additive Manufacturing has opened up a new chapter in the pursuit of this subtle but extremely important aspect of loudspeaker design. For the first time the principle aspects of this structure can all be adjusted in a way that was previously impossible. The result is a new geometrical form that is comprised of a double curvature with both open and closed aspects in the form of a lattice structure again borrowed from natural geometry. 5 different materials and adhesives provide significant improvements in the both the accuracy of the frequency response and the reduction of distortion.

Tactic 3.0 Isobaric Drive



The principle low frequency load of the Eminence is delivered by a series of Tactic 3.0 Isobaric Drive Systems. Here two Tactic 3.0 Drive Units combine to create an Isobaric Drive System.

The Isotactic Drive System is responsible for reproducing incredibly tight and controlled bass response that is perfectly integrated with the midrange Tactic 3.0 drive unit.

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.

The basic Laws of Physics dictate that a large woofer will never function with the speed and dynamics of a small drive unit. It is for this reason that Wilson Benesch ruled out the idea of using large, slow woofers in loudspeaker design.

Such drive units cannot accelerate or decelerate quickly enough to reproduce the sound and energy of a musical performance faithfully. 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 are 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

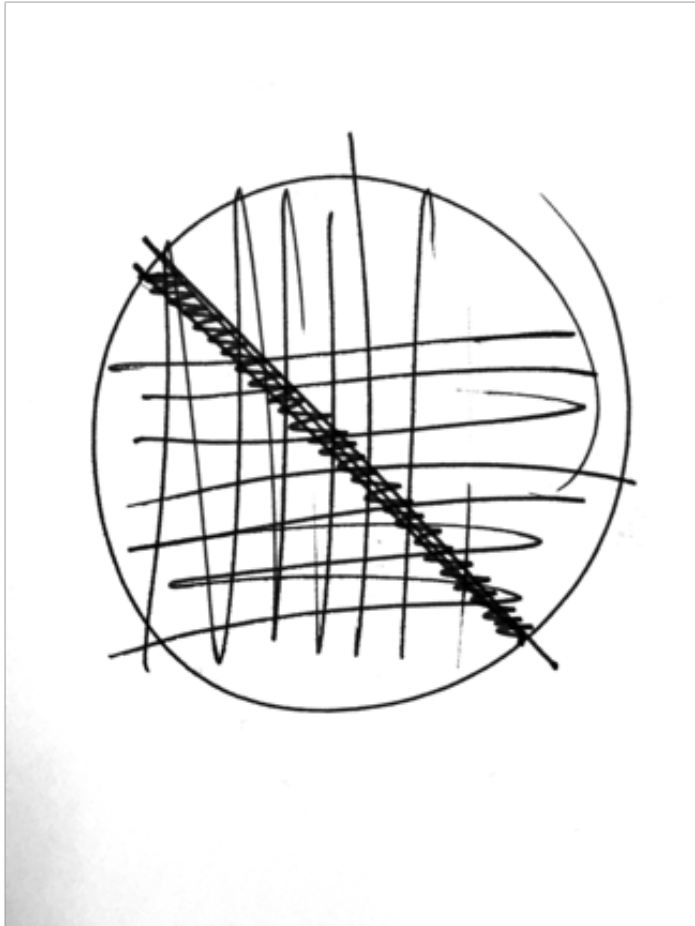
- Super stiff / super low mass diaphragm. The air link between the two diaphragms can be seen as a composite structure with outstanding stiffness to weight ratios. No other known drive unit diaphragm can aspire to possess such properties.



- 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 drive units that it is expected to integrate with.

From Semisphere to Fibonacci

The Semisphere was developed entirely by Wilson Benesch and continues to form one of the most focused areas of research in the company. The Semispehere was borne of two completely different technologies, the soft dome tweeter and the Murata ceramic piezo super tweeter. These two systems gave rise to the need for a third direction. The outcome led to the world's first hybrid dome tweeter structure.



The adjacent image shows one the simple but effective carbon fibre components of the Fibonacci dome.

The sound of the Semisphere and in turn the Fibonacci tweeter was unique and remains distinctively different even today, almost ten years since it was first conceived. Being neither wholly soft nor completely hard the system presents virtues of both these classes of tweeter that are valued in today's high definition systems. Significantly it does not suffer from the principle weaknesses. Fibonacci achieves an extended frequency response that is beyond that of any soft dome achieving an output beyond 30KHz. The absence of any perceptible hard dome characteristics is however the major achievement.

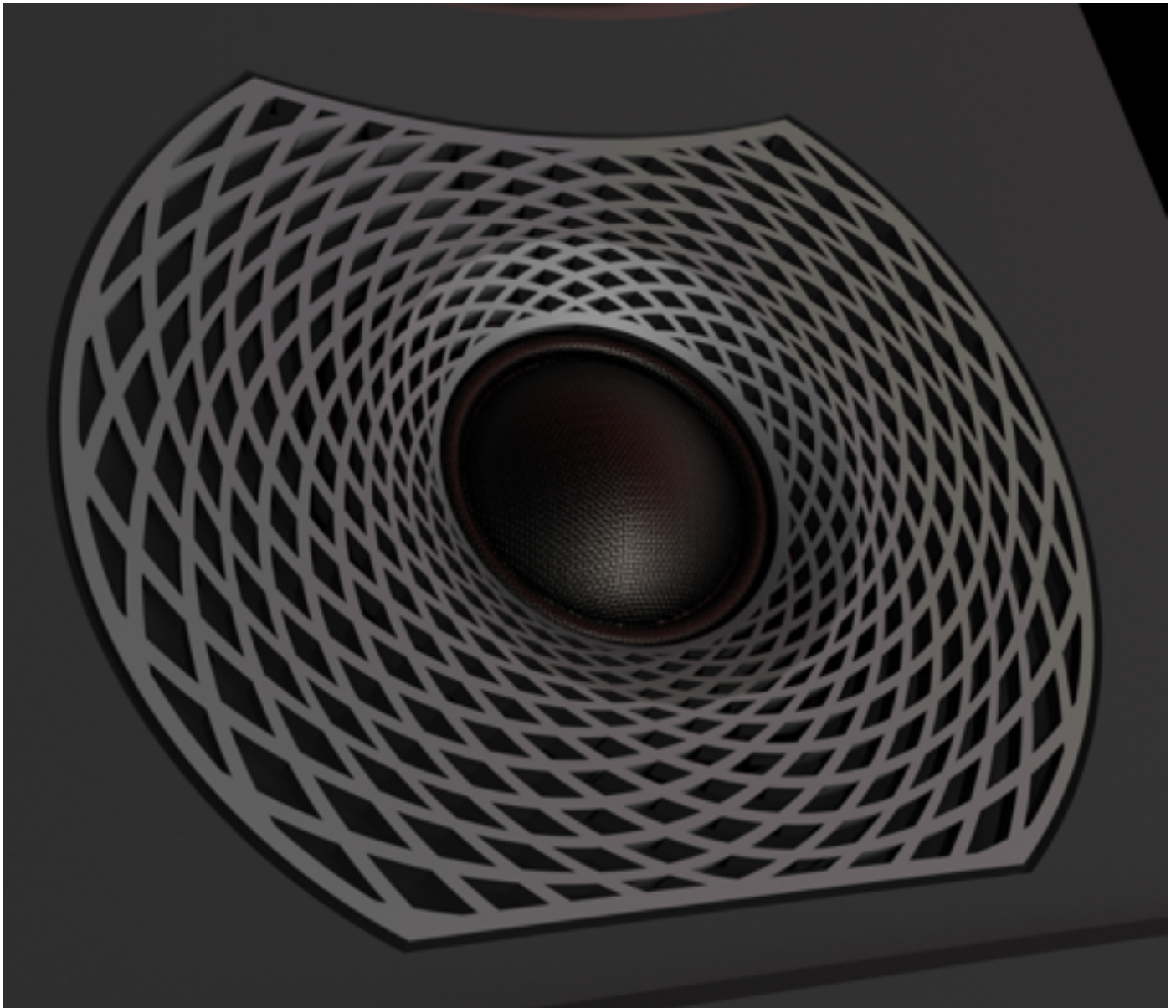
How was this achieved?

A tow of carbon fibre provides for a beam of 3,000 fibres that run across the axis of the dome effectively sub dividing the weakest axis. In addition the voicecoil is elevated in stiffness using the same approach. The added mass is so low that the acceleration and deceleration is only marginally impacted. Another significant advantage provided by the fibrous nature of the structure is the level of damping that exists naturally within the anisotropic nature of carbon fibre which also presents acoustic energy with one of the fastest transfer functions known to man.

Fibonacci Tweeter

Like its predecessor the Fibonacci tweeter was developed in parallel with the principle drive unit being used in the loudspeaker design, in this case the Tactic 3.0 midrange drive unit.

Common to both the Fibonacci tweeter and Tactic 3.0 are the Fibonacci Elements that mimic and exploit the benefits of natural geometry that has evolved over millennia. Additive manufacturing is set to transform the manufacture of all products and Wilson Benesch has been involved in developments in this field at the outset thanks to its collaborations with Sheffield University and the AMRC (Advanced Manufacturing Research Centre) where Craig Milnes was recently invited to make a presentation on the potential of this emerging materials science.



Wilson Benesch added additive manufacturing systems to the company's manufacturing capability in 2017. Since then a broad range of applications have been realised. The Fibonnaci elements pay homage to the Italian 12th-century mathematician.

A 20KHz sound wave is 17mm long. The structures adjacent to the tweeter dome subsequently play a critical function in the constructive and destructive interactions of the sound waves propagated from the dome of the tweeter. One of the major issues of all tweeter faceplates is the output response cancellation effects of uncontrolled energy. Adding to this complexity, each tweeter dome has its own unique signature and therefore requires its own unique faceplate to arrive at the optimal results. Through painstaking iterative design the resulting faceplate known as the Fibonacci Element has been found to deliver the optimal performance exceeding the basic geometry of the original Semisphere by delivering more control and as a result a flatter response.

The result sees a highly optimised structure that has been made possible through very recent advances in manufacturing technology, known as Additive Manufacturing. Wilson Benesch has been working on many structures and numerous materials in this field with both Sheffield University and the AMRC. The company already manufactures many components in both metal and carbon reinforced polymer. However it is the design process behind this work that has been critical to the development of these structures, essentially mimicking nature. The lattice structure is as you would expect a hybrid. The principle "seen component" is built from a carbon reinforced polymer that is extremely low mass and extremely high in damping. Significantly this structure is completely decoupled from the main baffle by the sub structure that is visible through the lattice. The damping properties of felt are well known and have been used in pianos, tweeters and a broad variety of engineering applications. This absorbing substructure adds to the damping ensuring the absorption rather than reflection. The resulting flat response of the Fibonacci tweeter owes much to this perfectly adapted system that represents the State-of-The-Art in tweeter face plate design. This type of development would have been impossible until only very recently. Additive manufacturing has opened up a new arena of design opportunities that Wilson Benesch has been exploring for over seven years and is now exploiting in a broad range of new developments. The unique acoustic signature of the Fibonacci tweeter is clearly quite unique in character. It's success owes much to the innovation of the original Semisphere. It is these small steps that Wilson Benesch will continue to take as an innovator and advanced materials manufacturer that will enable the small but significant accumulative benefits of on-going research and development.

