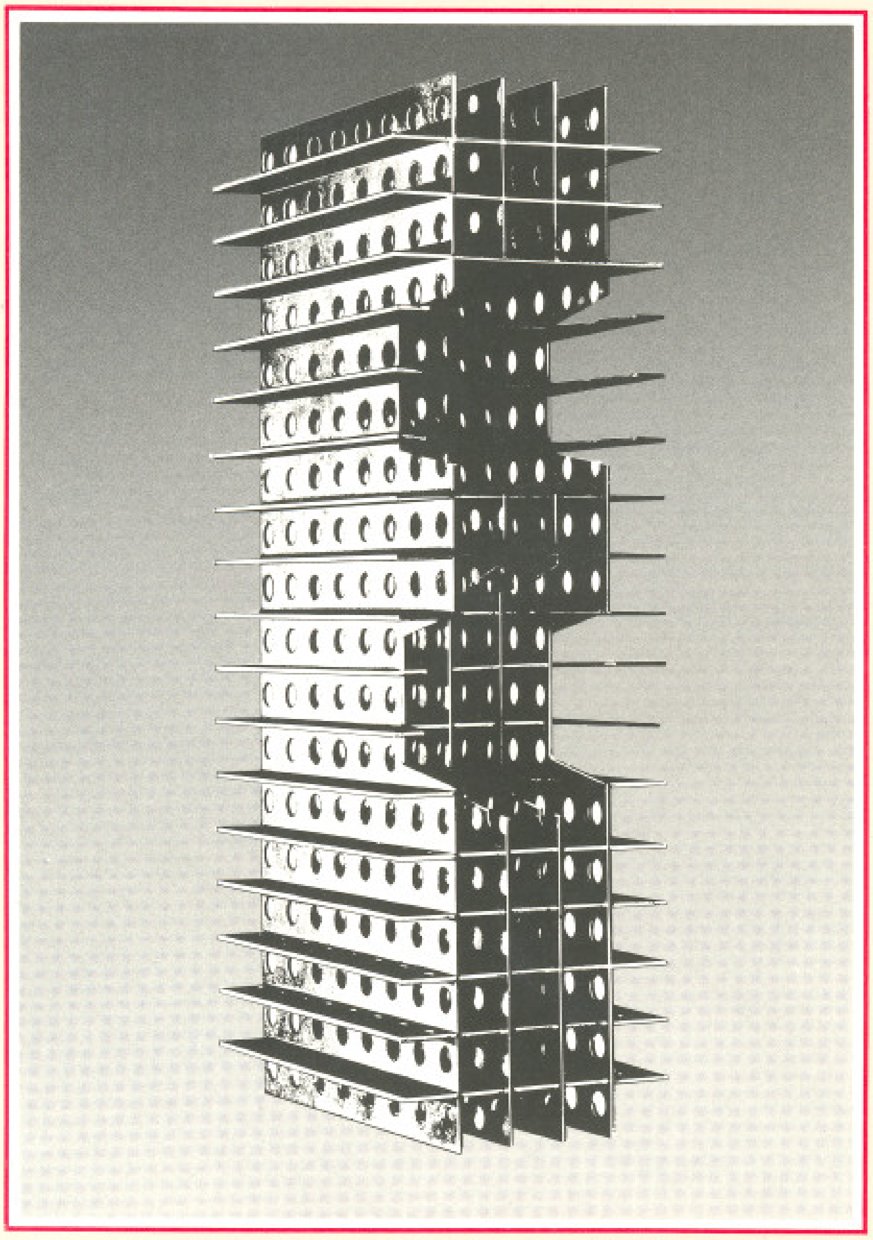
B&W MATRIX
A SIGNIFICANT INVENTION



its testing, proof and incorporation in

THREE NEW DIGITAL MONITOR LOUDSPEAKERS

DESIGN STORY

CONTENTS

The front cover graphics incorporate an illustration of the B&W Matrix inner construction of interlocking, perforated cross members.

1 INTRODUCTION

Over the last decade or two, significant if slow progress has been made in the design of moving coil loudspeaker transducers (the drive units) and of the associated crossover networks that make up a multiway loudspeaker system.

In marked contrast, little work had been done and very little progress made in the basic design of the enclosure that houses these components and which is itself, *ipso facto*, an integral part of the loudspeaker system.

This is the story of a new invention in this field. An invention that has already resulted in the production of a totally new type of enclosure and its incorporation in the design of three digital monitor loudspeakers.

2 PERSPECTIVE ON ENCLOSURE DESIGN

We have called this newly-invented type of enclosure the B&W Matrix. In relating its story, we must first put things in perspective by identifying some of the problems inherent in existing enclosure designs and their influence on the overall performance of sealed box loudspeaker systems.

Nearly all existing loudspeaker enclosures comprise panels of wood (or wood-derived materials), bonded at their junctions to form a structure that is usually rectangular, but sometimes octagonal or trapezoidal. The total surface area of enclosure walls is often some thirty times that of the loudspeaker diaphragm. It follows that although vibration of enclosure panels is small in degree compared with that of the diaphragm, it does make a marked contribution to the sound system as a whole.

Unfortunately, this unwanted contribution by the enclosure is not only highly non-linear in the amplitude/frequency domain, but also slow to decay in the time domain. The factors influencing this contribution are:

Amplitude/frequency domain

Low frequencies:
influenced by panel stiffness.

High frequencies:
influenced by panel mass.

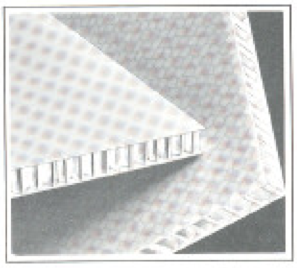
Intermediate frequencies:
(where resonances occur) influenced by panel damping.

Time domain

Rapid decay of resonances demands high damping and/or low mass.

These factors are somewhat inter-linked, in that a larger panel will exhibit lower resonances than a smaller one, because of its higher mass and lower stiffness.

This conflict between the requirement for high mass at the high frequency end of the spectrum and the need for low mass in the time domain has prompted the current use of several different materials for enclosure construction. These include the so-called aerospace materials such as 'Aerolam', the sandwich materials, and concrete. Our studies included detailed measurement and subjective evaluation of all these competing materials, as will be seen later in this narrative.



One of the comparative test studies involved 'Aerolam' – thin skins of aluminium separated by 10mm honeycomb.

3 LISTENING EVALUATION OF ENCLOSURES

It is, of course, widely accepted that the cabinet or enclosure does influence the final sound of the complete loudspeaker. At the outset of our work, we obtained clear confirmation of this by means of simple listening tests involving the transfer of matched components between enclosures of differing construction.

Because of the complex nature of enclosure contribution, it soon became clear that we must devise a method to determine such questions as whether the amplitude contribution or the time delay factor is of greater importance.

Before embarking on listening evaluation and measurement of enclosure contribution, there was a central problem to solve: how to isolate the sound radiated by the loudspeaker drive unit from that of the cabinet, without in any way modifying the structure of the cabinet itself. Because cabinets of various sizes were to be tested, the method had to be flexible in this respect.

3.1 Tools required

A series of jigs as shown in Fig.1 was devised, employing Fibrecrete enclosures and oversize particle board boxes. The inner Fibrecrete shell was contained within the larger box and the airspaces filled with not less than 15cm (6in) of sand. The enclosure under test was mated to the top surface of the jig, where the direct radiation from its driver was almost totally absorbed within the assembly. Thus, only the enclosure radiation was left, available for listening evaluation and measurement.

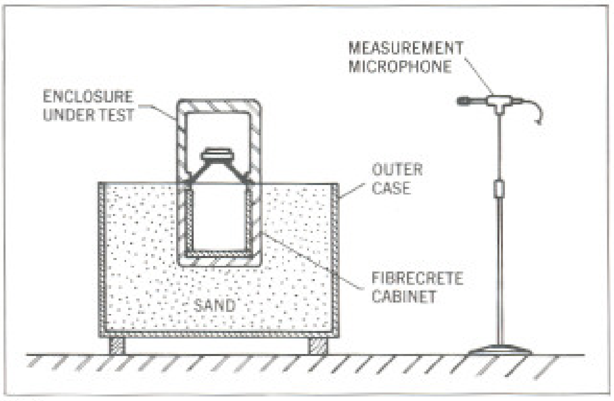


Fig.1

Not without difficulty because of its immense weight, the entire jig structure was transported to the anechoic chamber or to the reverberant environment, according to the test in progress.

In the early stages of research into enclosure colouration, a simpler technique was also used to good effect. A second enclosure was made without drive units, but otherwise identical to the one being studied, as a means of covering the drivers and therefore masking their direct sound output. The result of this 'double-box' arrangement, while not an absolute measure of the enclosure colouration, enabled useful relative comparisons of different constructions to be made.

4 THE B&W MATRIX ENCLOSURE

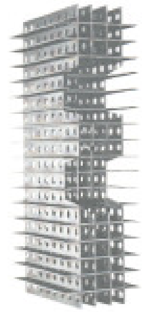
Inventor of the B&W Matrix enclosure is Laurence Dickie, our Chief Electronics Engineer. As with many an audio industry professional, his interests extend well beyond his specialised field and hi-fi is his hobby to boot.

Happy inventor's highest hopes confirmed. Chief Electronics Engineer Laurence Dickie, who invented B&W Matrix construction.

In fact, Laurence built the first enclosure embodying his invention at home in leisure time. On the day he revealed it to the R&D team at Steyning, routine came to a halt and excitement ran high. As with so many significant inventions, this one sprang from original creative thinking and sheer inspiration. Despite all reservations, listening evaluation and measurements were soon to confirm the inventor's highest hopes for this new and unique type of enclosure.

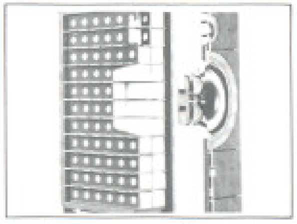
In rural Sussex, England – entrance to the B&W research and design laboratories, Steyning.

Construction of the B&W Matrix enclosure consists of standard high density particle board walls, the inner surfaces of which are grooved to take the matrix inner construction, which takes the form of a cellular honeycomb-like structure, comprising a series of interlocking, perforated cross-members.



When assembled, the honeycomb like B&W Matrix structure has a high degree of stiffness.

The material used for the cellular construction has relatively high damping qualities; when assembled, its end section has a high degree of stiffness.

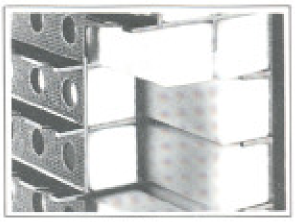


This cut-away shows the B&W Matrix structure integrated within the cabinet assembly.

When this cellular structure is integrated with the particle board assembly, we approach much closer than ever before to the prime requirements for the 'ideal' enclosure.

So far, we have considered only external radiation from enclosures, but it is well known that an enclosure's internal air volume has strong standing waves and resonant modes. Normally, these are dealt with by lining a cabinet's internal surfaces with polyurethane foam of acoustic grade – or by filling the air space with natural or synthetic wool. It must be admitted that in many designs, this proves to be only partially effective.

In the case of the B&W Matrix enclosure, each individual cell of the unique honeycomb structure is filled with acoustic foam. The resulting environment, as seen by the energy radiated by the rear of the loudspeaker drive unit, appears to be completely anechoic, totally absorbing the out-of-phase energy – as in a perfect transmission line, properly terminated.



Every one of the B&W Matrix cells is filled with acoustic foam.

Fig.2 illustrates the free field responses of a standard type of cabinet and a B&W Matrix cabinet, employing identical drivers. It shows the influence of the internal absorption provided in the B&W Matrix enclosure.

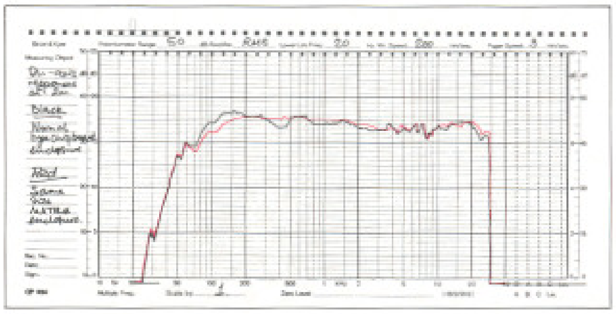


Fig.2 Frequency response measurements of the same drive units and crossover network, etc., mounted in two different types of enclosure of the same dimensions.
Black curve: Normal type chipboard enclosure with bitumen damping pads.
Red curve: B&W Matrix enclosure.

5 TYPES OF ENCLOSURE EVALUATED

The manufacture of loudspeaker enclosures is quite remarkable for the great diversity of materials, sizes and construction methods employed. For our listening evaluation and measurement trials, the list was pruned down to a reasonable number of existing designs, not necessarily of B&W manufacture. The examples selected were divided into two size categories: (1) small enclosures, and (2) larger enclosures. Our B&W Matrix 1 belongs to the former group and B&W Matrix 3 to the latter.

5.1 Small enclosures

(Approximating to 17 litres)

(a) Cabinet with walls of 12mm (½in) particle board and employing 6mm (¼in) 'Croda' pads. Appropriate bracing. Generally representative of good quality production enclosures.

(b) 'Aerolam'. Thin skins of aluminium, separated by 10mm (⅜in) honeycomb.

(c) A British-made enclosure employing sandwich construction (two plastic skins with foam separator).

(d) B&W Matrix 1 enclosure.

5.2 Larger enclosures

(Approximating to 70 litres)

(a) Cabinet with walls of 19mm (¾in) particle board and employing 'Croda' pads. Properly braced. Representative of good quality production standards all round.

(b) Concrete enclosure (Danish).

(c) B&W Matrix 3 enclosure.

6 LISTENING EVALUATION

Dr Glyn Adams devised a simple but very effective test. The jig box already described, with the range of different enclosure types interfaced, was set up in the anechoic chamber. There, the noise floor proved to be sufficiently low to allow a good signal from a suitably-placed microphone.

This was then mixed electronically with the input signal, which could be switched on and off, and varied in level. Top quality headphones were used in the tests, altogether eliminating the loudspeaker, as well as the listening environment. Under these conditions, our listening panel could study the effects of added enclosure colouration on the original signal.

6.1 Results

Our listening tests confirmed the inherently complex nature of the colourations caused by enclosures. For example, comparison between enclosures (a) and (b) in Section 5.1 – when handling a variety of speech and music signals under test conditions – immediately confirmed that the particle board box shows appreciably less output from the middle and upper frequencies. In the lower range, it is the 'Aerolam' construction that shows relatively less output, though it displays high colouration in the middle range.

As the tests continued, it also became clear that the decay time of resonances in enclosure panels is at least as important as amplitude. This was especially apparent among current high quality production cabinets, which showed relatively poor performance in the time domain. Resonances from this class of enclosure were immediately obvious because of the way they tended, on transient sounds, to 'hang on', after the music had stopped.

Under test, the enclosures employing light but stiff material such as 'Aerolam' imparted what our listening panel considered to be an over-bright, unnaturally forward sound. Examination of speakers employing this type of material suggests that to compensate for this undesirable effect, drive unit output has to be reduced in the middle frequencies. In our opinion, such compensating errors, however deliberate, should be avoided in loudspeaker system design wherever possible.

6.2 Conclusions drawn

Two salient conclusions emerged from the programme of listening tests:

(a) That if the influencing factors set out under Section 2 could be taken to the limit, a near-perfect enclosure would be the result.

(b) That in view of (a) there should be good correlation between measurements and listening experience.

7 THE MEASURING TOOLS AND MEASUREMENTS

Each of the several methods of measuring enclosure vibration calls for its own special instrumentation. Fortunately, the B&W research laboratory can claim to be uniquely well equipped in this area, with a veritable armoury of measuring tools for the study of mechanical vibration. At the development stage of the B&W Matrix project, the following measuring techniques and tools were used:

Employing the point accelerometer for measurement of vibration amplitude.

(a) Point accelerometer for measurement of the amplitude of vibration at chosen positions on the enclosure surface, as a function of frequency for sinewave excitation.

(b) Computer processing of these measurements for impulsive excitation of the enclosure, in order to study time effects. This involved the use of our PDP11/35 computer and data acquisition systems.

Heart of the PDP11/35 computer installation at B&W Loudspeakers.

(c) Modal analysis studies, carried out by computer processing of measurements taken from a grid of points laid out over the enclosure surface. These studies facilitated (i) identification of the various modes of vibration, their amplitude and Q-factor and (ii) display and animation of the mode shapes of enclosure vibration.

(d) Processing of modal analysis data for the prediction of the sound radiation from individual cabinet walls.

In general, our subjective testing highlighted the importance of time decay in enclosure vibrations in addition to the more often-studied amplitude/frequency behaviour. This is why our measurements of enclosure vibration are presented under two headings: (i) amplitude or amplitude/frequency responses, and (ii) energy/time curves.

7.1 Amplitude

A simple but very revealing measurement of loudspeaker enclosure performance is a reading of the broadband vibration level on the enclosure wall for pink noise excitation of the bass/midrange drive unit. Fig.3 shows this level as measured (under the same conditions of excitation) for three of the small enclosures tested. This reveals that on the basis of simple amplitude vibration, the B&W Matrix enclosure is greatly superior to both the classical particle board/bitumen and the 'Aerolam' types of construction.

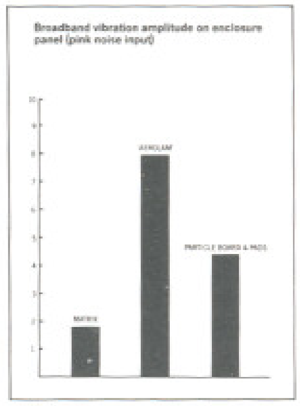


Fig.3 Graph showing relative broadband levels of vibration (on the centre of the enclosure side panel) for various construction types. Same drive unit used in each case; fed with pink noise signal via usual low-pass crossover filter.

It is also relevant to determine the frequencies at which enclosure vibrations occur. Figs.4-7 show the amplitude of vibration measured at the centre of the side panels of the four types of small enclosure studied. Each response is shown relative to the vibration level measured on the diaphragm of the bass/midrange driver. These figures speak for themselves and it is interesting to note that the B&W Matrix enclosure shows lower vibration (over the whole operating band) than any of the other types put to the test.

Similar measurements were carried out on the larger enclosures and are presented in Figs.8 & 9. Fig.8 shows the quite dramatic reduction in panel bending at low frequencies achieved by B&W Matrix compared with ordinary construction. Fig.9 shows that B&W Matrix is even better than concrete. The large peak in vibration of the concrete enclosure at 350Hz is largely due to the lack of damping in the concrete.

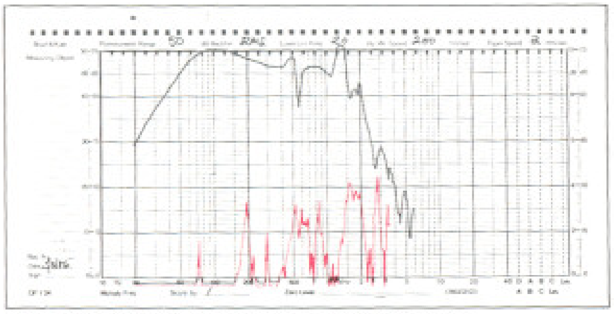


Fig.4 Vibration amplitude/frequency on small-size B&W Matrix enclosure.
Top curve: Acceleration level on bass/midrange driver diaphragm.
Lower curve: Acceleration level on centre of side panel, *raised by 20dB.*

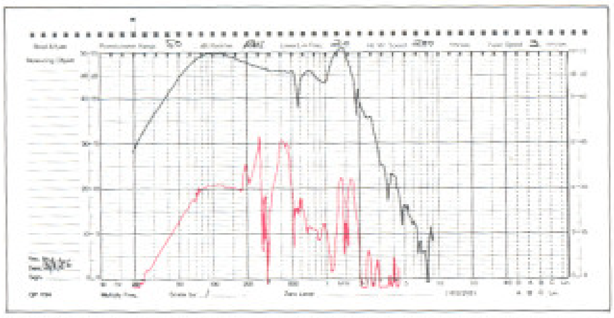


Fig.5 Vibration amplitude/frequency on small-size particle board enclosure (12mm (½in) board with 6mm (¼in) pads).
Top curve: Acceleration level on bass/midrange driver diaphragm.
Lower curve: Acceleration level on centre of side panel, *raised by 20dB.*

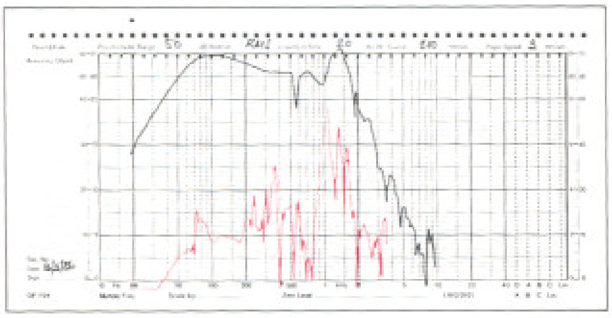


Fig.6 Vibration amplitude/frequency on small-size 'Aerolam' enclosure (10mm (⅜in) walls).
Top curve: Acceleration level on bass/midrange driver diaphragm.
Lower curve: Acceleration level on centre of side panel, *raised by 20dB.*

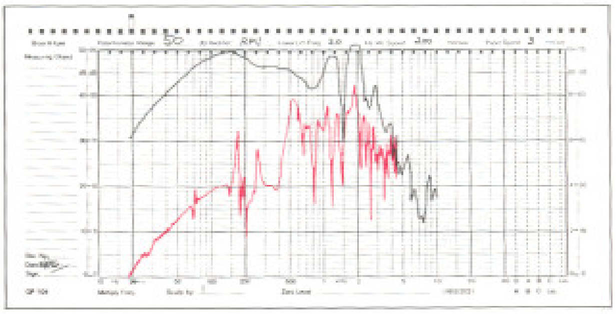


Fig.7 Vibration amplitude/frequency on small-size sandwich-type enclosure (plastic skins with foam core).
Top curve: Acceleration level on bass/midrange driver diaphragm.
Lower curve: Acceleration level on centre of side panel, *raised by 20dB.*

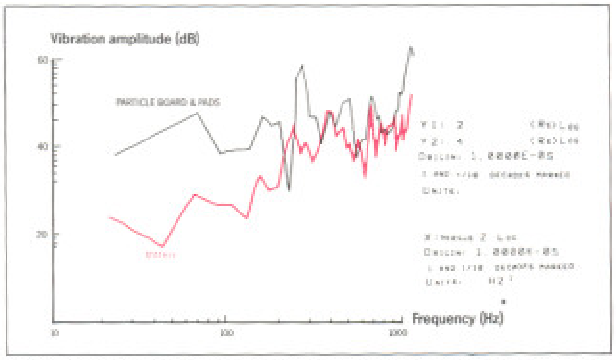


Fig.8 Comparison of vibration levels on large-size enclosures. Black curve is acceleration level, measured on centre of side panel of normal type particle board (19mm (¾in)) with 6mm (¼in) pads. Red curve is for same size enclosure constructed using the B&W Matrix technique.

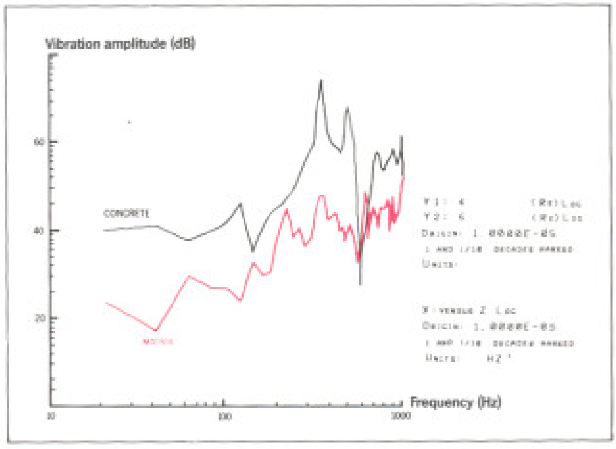


Fig.9 Comparison of vibration levels on large-size enclosures. Red curve is acceleration level measured on centre of side panel of B&W Matrix type enclosure. Black curve is for same conditions on similar size of concrete-type enclosure made by Danish manufacturer.

7.2 Time

The energy/time measurement technique developed by Richard Heyser is now widely recognised as a most useful means of studying time domain responses of loudspeakers and listening rooms. We applied this measurement to the study of enclosure vibration, with useful effect.

The measurement is obtained by computer processing of the impulse response of enclosure vibration; the processing enabling the decay of vibration level to be displayed on a logarithmic scale, which relates more closely to our natural hearing mechanism that does the linear amplitude scale of simple impulse response.

The ideal is a rapid decay of energy in the enclosure after the excitation is switched off – rapid enough to avoid audible hangover effects. Fig.10 illustrates the energy/time plots for the B&W Matrix and for normal particle board constructions; the more rapid decay demonstrated by the former shows that it is possible simultaneously to improve both time and amplitude performance. In the case of 'Aerolam', because it is a low mass construction, decay time is short – but as Fig.11 demonstrates, the B&W Matrix construction exhibits even shorter decay time, despite its much higher mass. This results from the additional damping achieved by the B&W Matrix stiffening panels. Thus we established that our new enclosure design delivers both *low level* and *rapid decay* of vibration.

Fig.12 shows the energy/time plots for two of the larger enclosures and allows detailed comparison of the B&W Matrix with a concrete enclosure. The poorly-damped concrete exhibits a serious hangover problem, with the energy hanging on for a tangible period after excitation is removed.

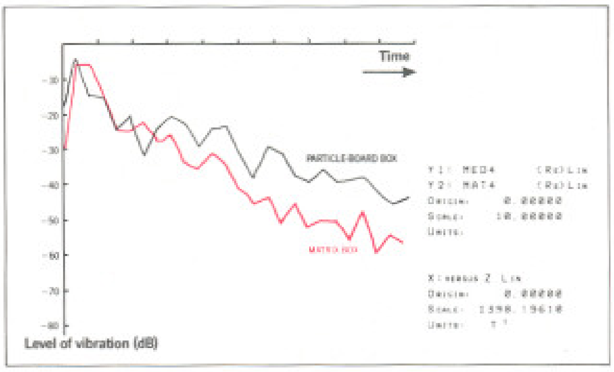


Fig.10 The time decay of enclosure vibration following an impulsive sound signal fed to the bass drive unit. Small-size particle board enclosure compared to B&W Matrix.

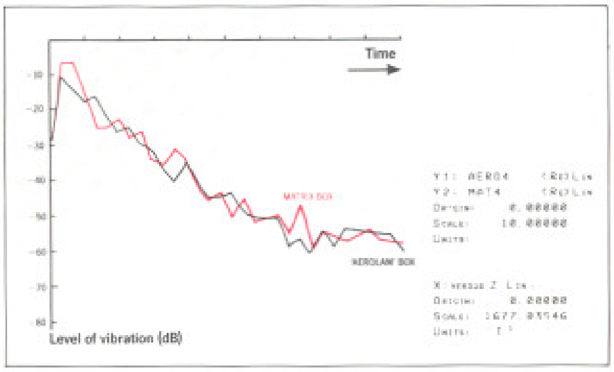


Fig.11 The time decay of enclosure vibration following an impulsive sound signal fed to the bass drive unit. Small-size 'Aerolam' enclosure compared to B&W Matrix.

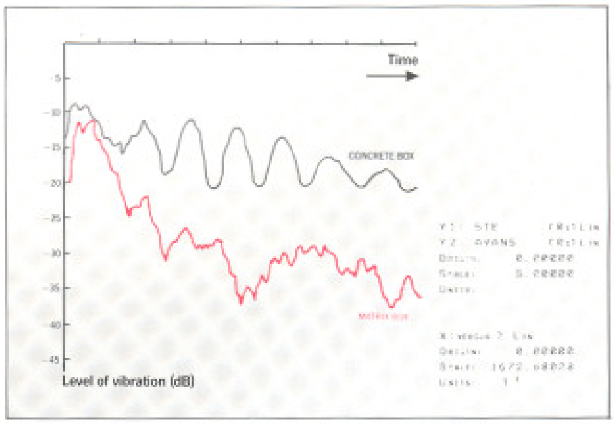


Fig.12 The time decay of enclosure vibration following an impulsive sound signal fed to the bass/midrange drivers. Large-size B&W Matrix enclosure compared to similar sized concrete enclosure of Danish manufacture.

8 ENVIRONMENTAL, VISUAL & COST FACTORS

Rightly, the greater part of this B&W Matrix design story has been taken up with listening evaluation and measurements. But by definition, the domestic loudspeaker is destined to become a feature of the home – a piece of furniture – so let us consider that aspect.

To begin with, B&W Matrix shows considerable advantages in both cost and cabinet design over 'Aerolam' and concrete, two of the alternative enclosure constructions. In the larger size category, concrete (even if it were as good as B&W Matrix) would be quite unacceptably heavy. Moreover concrete shares with 'Aerolam' the frustrating limitation that painted finish is the only option.

Looking now at cost, we find that an 'Aerolam' enclosure is something like three times more expensive than the comparable B&W Matrix.

We present B&W Matrix, confident that it is the best enclosure design to date. Not only does it embody the best listening and measuring solutions; it permits us to offer a range of cabinet finishes including conventional wood veneer and a lacquered version.

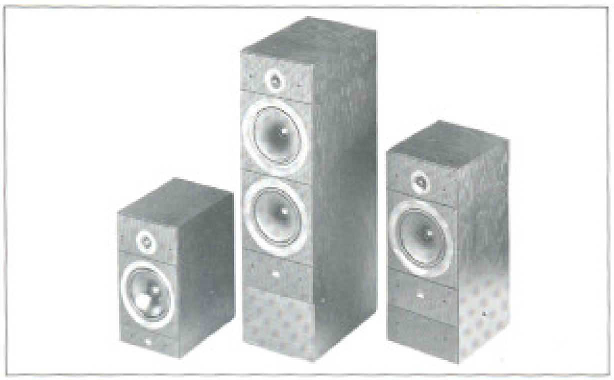
In addition, Dr Kenneth Grange has already perfected 'limited' designs incorporating the B&W Matrix concept, and there is no doubt that these handsomely complement and supplement the standard veneered versions now available for general release.

Dr Kenneth Grange of Pentagram, responsible for visual design of the B&W Matrix series.

9 THREE LOUDSPEAKERS OF DIGITAL MONITOR QUALITY HOUSED IN B&W MATRIX ENCLOSURES

The design brief called for three loudspeaker systems – varying in size, sensitivity and peak acoustical output – to replace four existing models (DM1200, DM1400, DM2000, DM3000). Broad target specifications for the three were set as follows:

	Drivers	Sensitivity	Enclosure Volume
B&W Matrix 1	2	85dB	17 litres
B&W Matrix 2	2	87dB	30 litres
B&W Matrix 3	3	90dB	70 litres


The three digital monitor loudspeakers in the B&W Matrix series.

Each new model was to out-perform its predecessor in all respects and to equal or better any competitive model in its own price category.

A further challenge was thrown down: even higher quality production standards were to apply to the B&W Matrix series as compared with its distinguished predecessors, with repeatability of components, especially drivers, to the very closest tolerances.

Not surprisingly, such demanding target specifications and production requirements created the necessity to generate completely new drivers, crossover networks and components. From the visual design aspect, Kenneth Grange of Pentagram required all models to mirror the new technology they embrace.

Having related the B&W Matrix enclosure design story in some detail, we now deal with the component parts which together form the final loudspeaker systems.

9.1 Drive units – choice of cone material

We have found that our aim to achieve consistently high performance in quantity production of cones has led inexorably towards the use of man-made materials. We successfully used plastic cones made from styrene, then went on to develop the B&W patented process for forming woven fibre cones of Kevlar.

The Kevlar cone is superior to styrene in terms of material damping; it therefore contributes smoother amplitude/frequency characteristics. However, the production of Kevlar cones is a rather labour-intensive process and one with a fairly high wastage factor, given the tight tolerances we lay down. For this reason we have for some years been actively seeking a plastic cone material to rival the performance of Kevlar.

Of all the materials tested, only polypropylene in various forms was found to have damping qualities comparable with those of Kevlar. Unfortunately, the form of polypropylene most commonly used, and consequently available off the shelf, is a copolymer (incorporating polyethylene) which is rather soft and falls well short of the stiffness of processed Kevlar. Despite this lack of stiffness, copolymer polypropylene has been widely used by several loudspeaker manufacturers in recent years. But the low stiffness results in cone break-up occurring at too low a frequency – that is, before the roll-off due to cone depth has started – with a consequent undesirable step in output in

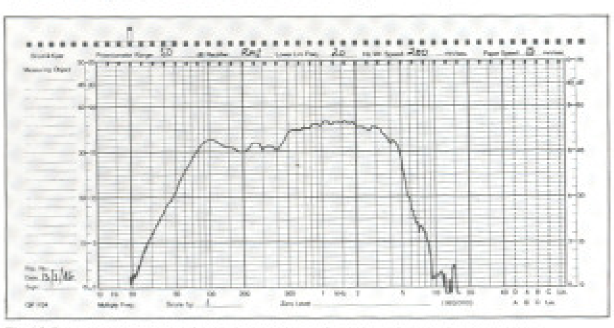


Fig.13 Frequency response of well-designed bass/midrange driver using copolymer polypropylene cone. Illustrates break-up region starting at too low a frequency; hence step-up in response.

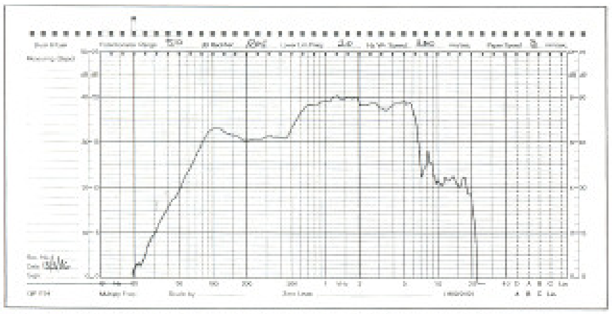
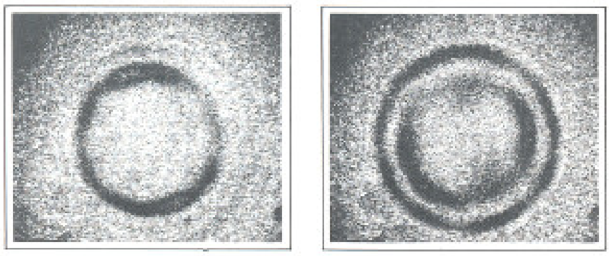


Fig.14 Frequency response obtained from a typical bass/midrange driver that employs a copolymer polypropylene cone. Showing the typical undesirable step in the response characteristic.

the middle frequencies. Some examples of this behaviour are shown in Figs.13 & 14.

The homopolymer form of polypropylene has the very desirable property of being about 1.6 times stiffer than a typical copolymer form. While unsuitable for the packaging industry, and hence not generally manufactured, homopolymer polypropylene has ideal characteristics for loudspeaker cones. In fact, it approaches the performance of processed Kevlar more nearly than any other plastic material we know of. An additional advantage of this material is that it has these ideal properties as manufactured – without the need for additional coats of damping material. B&W now have homopolymer polypropylene manufactured especially for this application by one of Britain's most experienced plastics manufacturers.

The greater stiffness of homopolymer causes the cone break-up region to start higher up in the frequency range compared with copolymer, so that the roll-off due to cone depth is correctly compensated for. The result (an example of which is shown in Fig.15) is a smooth response without the step-up characteristic.



Electronic speckle patterns produced by ESPI. These two frames show the well controlled, symmetrical break-up behaviour of the 200mm homopolymer diaphragm.

Having become used to the good performance of Kevlar cones, B&W found it difficult to accept the rather poor stepped characteristic of copolymer polypropylene cones, and this explains why we have not up to now made use of polypropylene. However, with the timely discovery of the ideal properties of the homopolymer form, B&W are now pleased to enter the market with a much superior design of polypropylene loudspeaker drive unit.

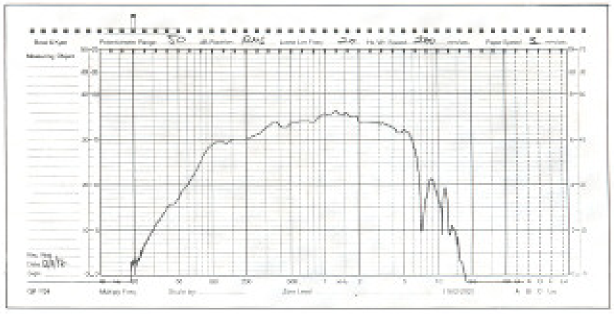


Fig.15 Frequency response of B&W-designed *homopolymer* polypropylene type bass/midrange driver for the B&W Matrix series. The smooth, well-damped response of copolymer polypropylene cones at high frequencies is retained; but the typical step in the response characteristic is completely absent, by virtue of using the stiffer homopolymer form of polypropylene.

To conclude this section, we present a table of mechanical parameters of the various materials discussed, indicating the combination of the desirable qualities of maximum stiffness and damping with minimum mass provided by the homopolymer polypropylene.

	Young's Modulus (GN/m^2)	Loss Factor	Density (kg/m^3)
Kevlar (treated)	3.20	0.09	1040
Styrene (doped)	2.10	0.06	1020
Copolymer PP	1.40	0.10	910
Homopolymer PP	2.20	0.10	918

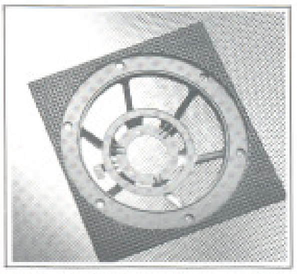
9.2 Bass and midrange drive units

B&W Matrix 1 employs a 150mm (5⅞in) piston diameter driver, B&W Matrix 2 a 200mm (7⅞in) driver and B&W Matrix 3 a similar 200mm (7⅞in) bass/midrange driver plus a

200mm (7⅞in) bass driver. All cones are of homopolymer polypropylene construction, with high temperature 31mm (1¼in) voice coils, on a ventilated Kapton former, resin-bonded and heat-cured.

On all models, the motor systems of the drive units have been optimised for high power handling and high acoustical output. Extended pole pieces and dished backplates ensure large cone movement without damage. Extremely generous magnet assemblies have been used throughout to give high system sensitivity coupled with low system 'Q'. Some indication of the massive magnets employed can be judged from their weight:

B&W Matrix 1	B&W Matrix 2	B&W Matrix 3
1.1kg (2.4lb)	1.7kg (3.8lb)	Two drivers, each of 2.3kg (5.2lb)

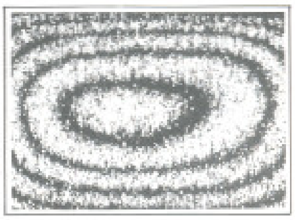

Drive unit chassis and front plate, cast in one piece.

Both the drive unit chassis and front plate are cast in one piece from magnesium alloy in order to ensure utmost rigidity.

B&W have always re-invested in new research tools in order to push forward with development and in 1985 we installed electronic speckle pattern interferometry.

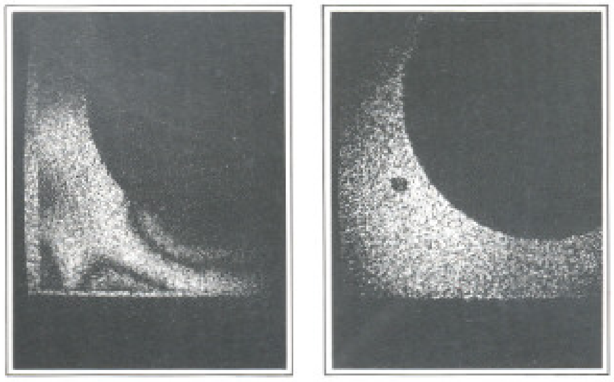

At work with a new research tool: electronic speckle pattern interferometry.

One of Britain's oldest optical equipment companies, Ealing Beck of Watford, have developed a laser-based system which allows tiny movements caused by stress in engineering components to be seen on a television screen as they happen. Movements as low as half the wavelength of light can be displayed. This installation, costing some £30,000 ($45,000) is based on the results of a £1.5m research programme at Loughborough University in England, which is being funded over about ten years by the Science & Engineering Research Council.


Typical fringe pattern obtained in real time from the ESPI equipment. Unlike the normal holographic technique, ESPI requires no photographic developing process.

The ESPI was used to design the bass/midrange castings, among other aspects of the B&W Matrix series. We mentioned previously that these magnesium castings are of one piece to strengthen the chassis/baffle interface. These castings have a complex structure of annular channels and cross members which are filled on their rear surface with high density polyurethane elastomer. When bolted to the enclosure, the final assembly results in an almost totally rigid structure with high acoustical damping, which complements the high performance of the enclosure with which it interfaces.


Bass/midrange, one-piece assembly with cross members and cavities filled with high density polyurethane elastomer, making it rigid and virtually resonant-free.


ESPI patterns showing two stages in the improvement of vibration behaviour of the 200mm driver chassis. They were taken before and after the addition of stengthening ribs and vibration-deadening material.

9.3 New high frequency transducer, FFT2

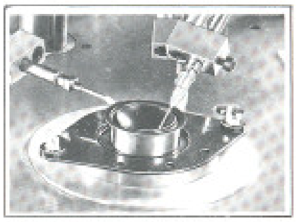
The new FFT2 high frequency transducer mounting plate cavities are filled with high density polyurethane elastomer.

Digital source material (the compact disc) differs from analogue material in a number of respects, including greatly reduced noise floor and greatly increased transient peaks. The latter demands vastly improved performance of the loudspeaker system's high frequency transducer if these transient signals are to be faithfully reproduced.

B&W currently produce some 250,000 tweeters a year, entirely in-house and from our own designs. This has given us a wealth of experience in design, production and quality control. The many favourable press reviews we have regularly received are testimony to the success of these designs – which for the last three years have largely been used on digital material.

For the B&W Matrix series, it was decided to take the tweeter design a stage further – introducing, among other improvements, Ferrofluid into the magnetic gap. Fig.16a shows the output voltage read from a calibrated microphone against input voltage, for both Ferrofluid and non-Ferrofluid tweeters of similar design and construction. It can easily be seen that with the non-Ferrofluid design there is some limiting in output after the input voltage exceeds 6V, due to the voice coil of the tweeter becoming hot, and the consequent rise in its resistance. In contrast, with the Ferrofluid design the temperature of the voice-coil remains at a lower level due to the thermal conduction of the fluid, and output continues linearly to 14V. The non-linearity of the output/input characteristic of the design without Ferrofluid causes compression and limiting for high signal inputs. In practical terms, the Ferrofluid design has more than an additional 6dB of 'headroom' for transient information (see Figs.16b & 16c).

From production experience over an enormous number of tweeters, much has been learned, making it possible to incorporate improvements which affect not only performance, but consistency in production. A new automatic assembly machine will produce the new FFT2 tweeter by the proven current production method, in which all critical glue joints and assembly operations are entirely automatic.



FFT2 tweeter construction employs automated assembly operations.

The final specification of FFT2 shows, depending on environment, an almost totally linear frequency response with −6dB points being approximately 2kHz and 35kHz. The FFT2's transient power handling is excellent and due to its relatively small diameter, dispersion is wide and even.

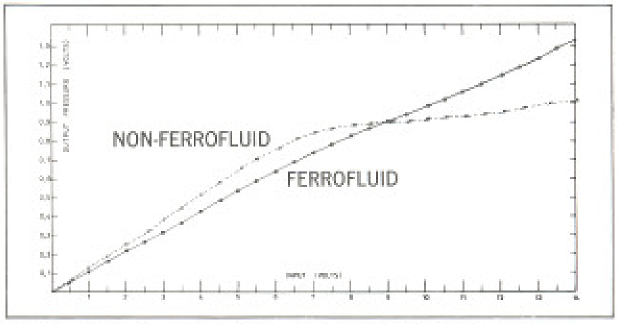


Fig.16a Comparison between Ferrofluid and non-Ferrofluid tweeter, with all other elements identical.

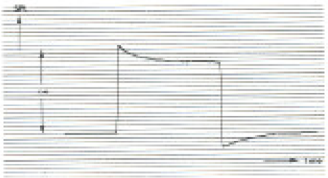
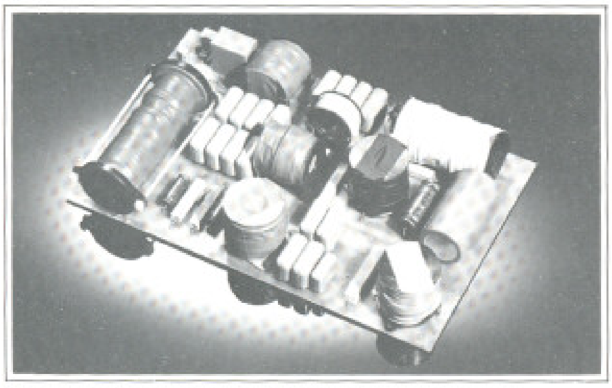


Fig.16b Showing compression or 'squashing' of dynamic range of normal type tweeter, due to heating effects. Input voltage step was 10dB. (Compression = 2dB approx.)

Fig.16c Showing improved performance obtained from new Ferrofluid-cooled tweeter FFT2. For same initial pressure level, and +10dB input voltage step as normal type. (Compression = 0.2dB)

10 CROSSOVER, TIME DELAY & PROTECTION SYSTEM

Recent thinking suggests that the best crossover is no crossover at all, and we subscribe to that aim. However, until we are able to design tweeters and bass/midrange drivers which have totally linear response throughout their pass band and ideal roll-off characteristics in their stop band the 'crossoverless' loudspeaker is not feasible.



B&W Matrix 3 crossover assembly with laboratory quality components throughout

However, in the case of the three B&W Matrix models we have designed the bass/midrange drivers so that they have a 2nd-order roll-off characteristic, and for the low pass filter only two components are necessary to satisfy the design requirement of 4th-order Butterworth squared characteristic overall.

The crossover system for the B&W Matrix 3 will be used as the example to

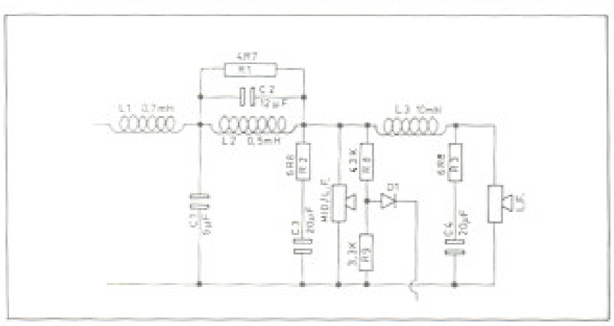


Fig.17a Part of the crossover network for the B&W Matrix 3 system, showing the components associated with the bass and bass-midrange drivers.

illustrate the designs. The circuit for the bass and bass/midrange drivers is shown in Fig.17a. R2 and C3 perform the function of linearising the electrical impedance of the bass/midrange unit. The inductor L1 and capacitor C1 form, along with the inherent 2nd-order low-pass characteristic of the drive unit, a 4th-order filter. The bass driver, also with impedance equalising components, has additional low frequency roll-over provided by L3, so that this unit contributes to system output at frequencies below 150Hz. The damped resonant circuit of R1, C2 and L2 effect a linearising of the amplitude-frequency characteristic in the middle frequency region.

The high frequency unit, with equivalent impedance linearising, is fed via the all-pass network for time delay compensation. This approach is an electrical alternative to the physically stepped configuration employed in such B&W designs as DM6, DM7, DM17, 801 and 802. The performance of these famous designs received wide acclaim, but while Kenneth Grange wished externally to mirror the high technology of the B&W Matrix series, the design concept was for a slim, conventional, and elegant enclosure.
The high-pass function of the crossover is provided by the inherent 2nd-order characteristic of the drive unit, along with the damped T-section filter circuit formed by C5, C6 and L4, together resulting in the preferred 4th-order characteristic (see Fig.17b).

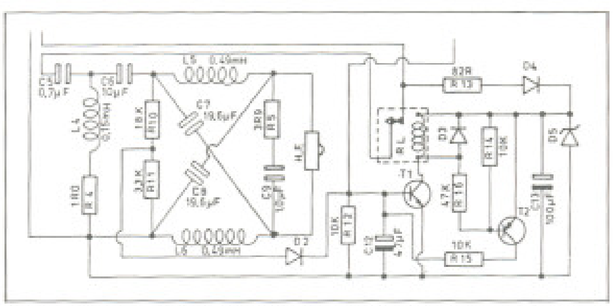


Fig.17b Part of the crossover network for the B&W Matrix 3 system, showing the components associated with the high frequency driver and its APOC overload protection circuitry.

The use of Ferrofluid in the high frequency unit has additional advantages beyond the thermal improvements mentioned above. The high damping provided by the fluid reduces the output at the fundamental resonance of the unit, smoothing the characteristic and enabling the high-pass filter design to be considerably simplified. This takes us one step, at least, towards the theoretical ideal of the 'crossoverless' system.

In view of the current-drive characteristic of transistor power amplifiers, the preferred load is one of relatively low impedance. Accordingly, a 4Ω impedance was adopted for the B&W Matrix series. The part of the equalising circuit shown in Fig.17c serves the function of flattening the impedance of the load presented to the amplifier by effectively providing a reciprocal network to the relatively complex crossover circuit. In this way, the amplifier is provided with a totally safe resistive load of 4Ω impedance. This is especially valuable when driving loudspeakers at high sound levels from a relatively small amplifier.

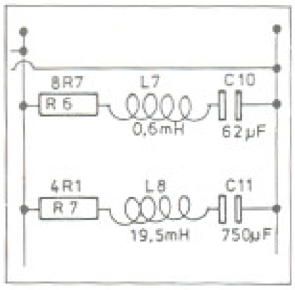


Fig.17c A part of the B&W Matrix 3 crossover network which serves to flatten-out the magnitude of the input terminal impedance which is presented to the amplifier.

10.1 Crossover components and internal connecting leads

The introduction of compact discs with their dramatically increased dynamic range has necessitated new approaches to the transient power-handling capacity of loudspeaker systems and their associated amplifiers. B&W have responded by examining those aspects of the loudspeaker which can affect the transient power capability of loudspeakers. Higher temperature voice coils and Ferrofluid cooling for the high frequency transducer are but two factors which assist this aspect of driver design. Higher input powers, lower impedance and bigger transient peaks also place an additional burden on crossover components, expecially series inductors and interconnecting leads. In this area, two particular aspects have been found to yield improvement.

Hitherto, crossover inductors having values greater than about 1mH (where air cores would involve the need for too many turns and result in too high a resistance) have generally been of ferrite material. Investigation of the performance of these materials when programme material with increased high power transient content is used, has indicated that partial saturation of the ferrite is possible, causing transient distortion. This saturation of the inductor cores can be avoided by the use of high purity iron dust cores in place of the ferrite. Higher power levels may therefore be accommodated before the onset of any distortion due to the saturation effect (see Fig.18).

The insertion loss attributable to the series reistance of the inductors in the bass driver signal path has the effect of slightly reducing the overall efficiency of the system and of reducing the beneficial amplifier damping. In the B&W Matrix 3 design the inductor L3 is wound with 1.6mm copper wire over an iron dust core to minimise these effects.

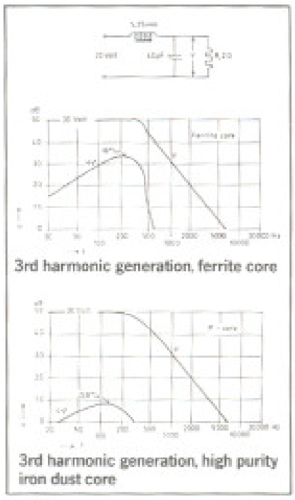


Fig.18

A number of workers in the audio field, notably Martin Colloms, have proved beyond reasonable doubt that the insertion of different cables between amplifier and loudspeaker affects sonic performance. Whilst these effects become more pronounced the longer the interconnecting lead, it was considered to be good engineering practice to make the relatively short internal leads in B&W Matrix series loudspeakers with a heavy duty mono-crystal copper cable.

10.2 Overload protection

B&W pioneered the protection of loudspeakers from potentially damaging high input powers. The patented APOC (audio-powered overload circuit) system of the 800 series employed current-sensing circuits which disconnected drivers from input when the thermal limit of the voice coils was approached. The B&W Matrix series uses an even more advanced system, in which the user is effectively warned of the onset of damagingly high power levels by the automatic disconnection of the high frequency driver. Loss of high frequency output alerts the user that input power should be reduced; the circuit will then automatically restore full connection. This method avoids the use of circuit-breaking relays, connected in series with the bass and midrange drive units. This results in potentially trouble-free operation of the circuit, and avoids the introduction of any resistance or non-linearity associated with degradation of mechanical contacts in the relay. Because of the small size and low thermal inertia of high frequency units, an automatic protection circuit in all B&W Matrix models disconnects the high frequency unit at the onset of dangerously high input levels.

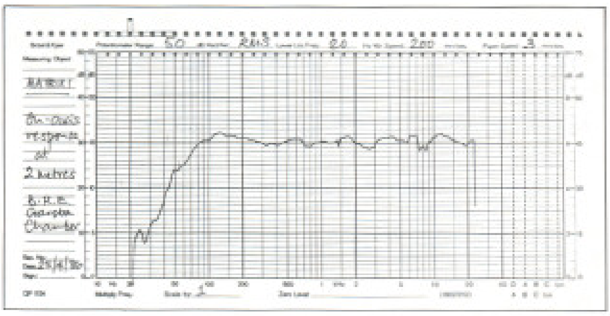
11 SPECIFICATIONS

For the reader who has little experience in the finer points of loudspeaker design, measurements may have little meaning. However, to the more experienced reader – whether it be interested home user, journalist or professional engineer – we trust the following measurements will provide useful information and give a measure of the performance of this series of loudspeakers.

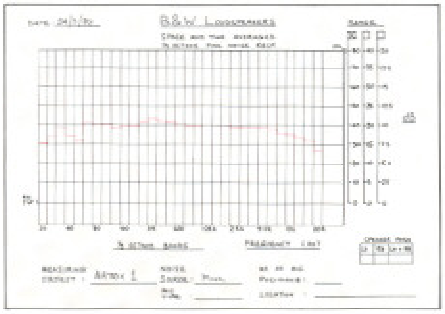
	B&W Matrix 1	B&W Matrix 2	B&W Matrix 3
Frequency range	(−6dB points) 55Hz to 35kHz	(−6dB points) 51Hz to 35kHz	(−6dB points) 43Hz to 35kHz
System resonance	60Hz. System 'Q' 0.7	51Hz. System 'Q' 0.6	43Hz. System 'Q' 0.5
Free field response	listening axis ± 2dB, 80Hz to 25kHz ± 30° horizontal ± 2dB to 10kHz ± 5° vertical ± 2dB to 20kHz	listening axis ± 2dB, 80Hz to 25kHz ± 30° horizontal ± 2dB to 10kHz ± 5° vertical ± 2dB to 20kHz	listening axis ± 2dB, 70Hz to 25kHz ± 30° horizontal ± 2dB to 10kHz ± 5° vertical ± 2dB to 20kHz
Averaged room response	See plot and caption	See plot and caption	See plot and caption
Sensitivity	85dB (1W 8Ω)	87dB (1W 8Ω)	90dB (1W 8Ω)
Drive unit complement	Two: one 150mm (5⅞in) bass/midrange driver with homopolymer polypropylene cone, 31mm (1¼in) voice coil on Kapton former, phenolic bonded and heat cured; one 25mm (1in) Ferrofluid-cooled tweeter with laser-optimised polyamide dome	Two: one 200mm (7⅞in) bass/midrange driver with homopolymer polypropylene cone, 31mm (1¼in) voice coil on Kapton former, phenolic bonded and heat cured; one 25mm (1in) Ferrofluid-cooled tweeter with laser-optimised polyamide dome	Three: one 200mm (7⅞in) bass, one 200mm (7⅞in) bass/midrange with homopolymer polypropylene cones, 31mm (1¼in) voice coils on Kapton formers, phenolic bonded and heat cured; one 25mm (1in) Ferrofluid-cooled tweeter with laser-optimised polyamide dome
Distortion	for 90dB SPL at 1m 2nd harmonic: <3.0% (20Hz to 500Hz) <1.0% (500Hz to 20kHz) 3rd harmonic: <3.0% (20Hz to 500Hz) <1.0% (500Hz to 20kHz)	for 95dB SPL at 1m 2nd harmonic: <2.0% (20Hz to 500Hz) <0.5% (500Hz to 20kHz) 3rd harmonic: <1.5% (20Hz to 500Hz) <0.5% (500Hz to 20kHz)	for 95dB SPL at 1m 2nd harmonic: <2.0% (20Hz to 500Hz), <0.5% (500Hz to 20kHz) 3rd harmonic: <1.5% (20Hz to 500Hz), <0.5% (500Hz to 20kHz)
Impedance	Modulus 4.5Ω ± 0.5Ω Phase ± 5° (essentially resistive)	Modulus 4.5Ω ± 0.5Ω Phase ± 5° (essentially resistive)	Modulus 4.5Ω ± 0.5Ω Phase ± 5° (essentially resistive)
Amplifier limits	50W-120W (recommended)	50W-150W (recommended)	50W-200W (recommended)
Dimensions	Height 41cm (16in) Width 23cm (9in) Depth 32.2cm (12⅝in)	Height 60cm (23½in) Width 26cm (10¼in) Depth 32cm (12½in)	Height 91cm (35¾in) Width 26cm (10¼in) Depth 41cm (16in)
Weight	10kg (22lb)	16kg (35.2lb)	29kg (64lb)
Cabinet finishes	Real wood veneers of walnut, black ash, natural oak, rosewood. To special order: high gloss lacquered finish within a choice of colours	Real wood veneers of walnut, black ash, natural oak, rosewood. To special order: high gloss lacquered finish within a choice of colours	Real wood veneers of walnut, black ash, natural oak, rosewood. To special order: high gloss lacquered finish within a choice of colours

B&W Loudspeakers Ltd reserve the right to amend details of their specifications in line with technical developments.
B&W Matrix series bass/midrange drivers are manufactured under licence from CBS Inc.

Matrix 1



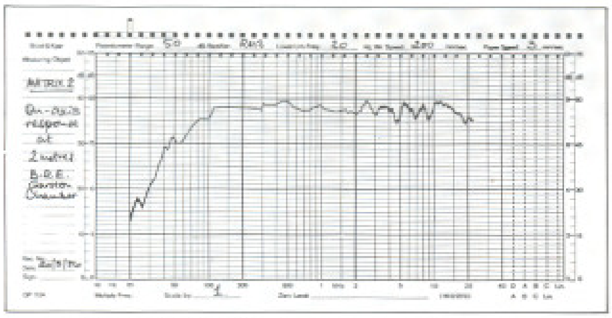
On-axis free-field frequency response at 2m.



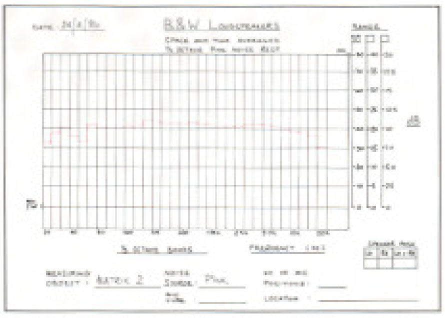
Third octave pink noise. Space and time averaged room response in typical domestic environment.

Optional stand available as illustrated

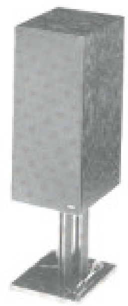
Matrix 2



On-axis free-field frequency response at 2m.

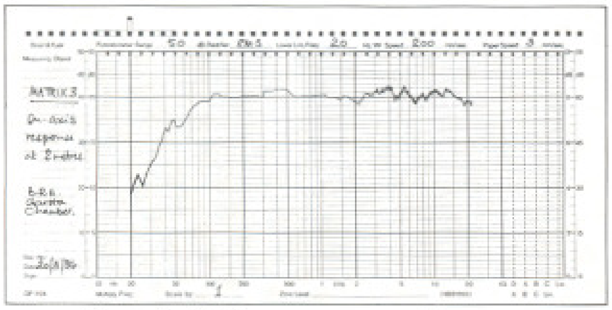


Third octave pink noise. Space and time averaged room response in typical domestic environment.

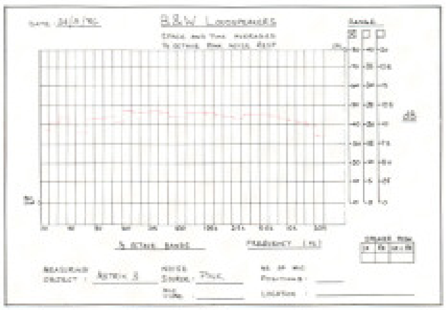


Optional stand available as illustrated

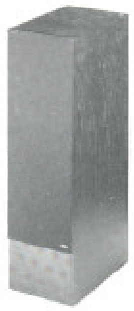
Matrix 3



On-axis free-field frequency response at 2m.



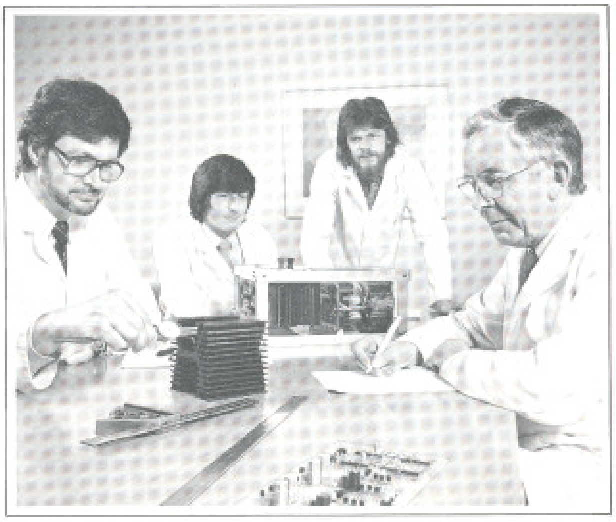
Third octave pink noise. Space and time averaged room response in typical domestic environment.



12 CONCLUSION

In a detailed account like this, amounting almost to a technical paper, it is usual to see an author's credit. This would, however, be quite inappropriate in the case of the B&W Matrix story, since the entire project has been a team effort by the B&W Research Establishment at Steyning. So it is the team members who are the joint authors and it is due entirely to their dedication, hard work and extra effort that this paper, not to mention the B&W Matrix series itself, is presented for your interest.

Stephen Roe BSc (Electronics)
Glyn Adams BSc PhD
Laurence Dickie BSc (Electronics)
Douglas Standen FTC
Malcolm King BSc(Eng) MSc BA
Kenneth Grange CBE RDI FSIAD
Pentagram Design Ltd
John Bowers



John Bowers (right) with members of the design team (from left) Dr Glyn Adams, Stephen Roe, Laurence Dickie