Like so many of the specialist British pro audio companies, the loudspeaker manufacturer Harbeth is a deceptively small-scale operation, based in an industrial unit in Haywards Heath, Sussex. The dedicated and enthusiastic work force of nine currently produce nine different loudspeaker models, with something like 400 pairs leaving the factory each month — most of them destined for the Far East.

Alan Shaw, the Managing Director, bought the company from its founder, ex-BBC loudspeaker R&D guru Dudley Harwood, 11 years ago. Since then, he has built upon Harbeth's reputation for producing very high quality loudspeakers, designed in the traditional BBC fashion with accurate presentation of speech uppermost in the design brief.


Alan Shaw at work with his computer aided design tools.

The Making of a Monitor Loudspeaker

HARBETH ACOUSTICS

Harbeth's approach to designing a replacement for the venerable BBC monitor loudspeaker, the LS5/8, has involved ground breaking research and painstaking attention to detail. **Hugh Robjohns** talks to Alan Shaw about his passion for loudspeakers, which became his business.

Bringing his former career experience in quality control to bear on the production process, Shaw has ensured extremely consistent manufacturing standards. His long held determination to improve on the sound quality of commercial drive units has led to ground breaking research and development of a pioneering new cone material with phenomenal levels of transparency.

The latest Harbeth creation is the Monitor 40 — a three-way professional monitor designed to replace the BBC's ageing house-standard speaker, the LS5/8, and incorporating all of Alan's ideas of how a true monitor speaker should sound. The prototypes certainly sound extremely promising, and we will include a detailed review of the Monitor 40 in a subsequent issue of *Sound Pro*. Meanwhile, Alan explained his approach to loudspeaker design and how that has lead to his new creation.

"The BBC tradition in loudspeaker design is all about high fidelity in the truest sense — highly accurate sound. That is the definition of a monitor speaker and I'm not interested in making anything which does not have that credibility about it. The BBC loudspeaker designers were in the unique position of being able to walk between the studio and control room and hear for themselves the comparison between the live and reproduced sound, which is why their designs are so accurate.

"I'm really only interested in that 'BBC way' of doing things, and to my mind there is a very clear objective. When I play a speech test tape and put the real voice next to the loudspeaker, I am listening for characteristics in the reproduced sound — in terms of chestiness, nasality, and so on — that are there in the real voice, and the closer I can get the two, the better a job I'm doing. It's never going to be quite the same because the way a human voice projects into a room is a little different from a loudspeaker, but it is possible to get extremely close to that goal.

"I certainly don't see this as an extension of an 'art form' — I'm not trying to enhance reality. Some loudspeaker designers, quite legitimately, say that they are trying to express a certain kind of sound, in the same way that an instrument maker would want a certain sound. But that is not what I'm about — the ultimate aim for me is not to be able to tell the voice and loudspeaker apart.

"When I'm developing a new loudspeaker, I base a lot of my listening around speech because if you can get speech right, the rest falls into place. We all know how speech sounds — you can take people off the street with no training and put them in front of 10 loudspeakers and they would be able to spot their deficiencies on voice very easily. We were interpreting speech thousands or millions of years before musical instruments came along, so there is an innate understanding about when it sounds right. There are artifacts of speaker characteristics that the human voice box is just not capable of — like treble brittleness — because it is a soft structure and those kinds of mechanical problems in a loudspeaker stand out as being unnatural.

"I passionately believe if you get speech right the rest pretty much falls into place. However, I would admit from the word go, that if you want a punchy, earthshaking kind of bass — a real slam and crack — I can't give you that. Achieving that always has a trade-off in the mid-band and I can't find a way of combining those two things without compromising the quality too much. If you want that kind of sound, don't waste your time coming to Harbeth. What I can give you is a very clean mid-band."

The Harbeth Monitor 40 (right) alongside the BBC's LS5/8.

DESIGN APPROACH

How do you approach designing a new loudspeaker?

"I like to have my test equipment right next door to my listening room, because I'm always shuffling backwards and forwards between them. I have two primary measurement systems which I use: a B&K 2012 analyser, which is a £25,000 sine-wave system; and the industry standard FFT system, MLSSA (in fact we have four of those).

"Most of the industry has gone over to FFT systems now, but we bought the 2012 about five years ago and I think we were the first people in the country to have it. It is quite slow, but as it is sine wave-based you can *hear* things during testing. For example, if you sweep a damaged tweeter, you can actually hear it is damaged without having to look at the plots. If you were to do that with an FFT system (which uses a noise-like signal), it would measure the same as the sine stimulus, but you wouldn't be able to hear the problem for yourself because the white noise FFT 'chirp' is of too short a duration for the ear to interpret as a frequency response. You cannot design a loudspeaker with test equipment alone, that would be absolute madness, and being able to audition the testing is an important aspect of the way I work.

"MLSSA does some things extremely well of course and it is an important tool, but I am very comfortable listening as the test is in progress. That way, I can spot when I've done something wrong — damaged a driver or whatever — and so I use the 2012 as my primary measurement system. Another strength of the sine testing is in measuring harmonic distortion, because it is very difficult to tease that kind of thing from an FFT unless the harmonic distortion causes aberrations in the frequency response — and it might well not. With the 2012 I can measure up to the 20th harmonic above a fundamental, look at any combinations of harmonics for intermodulation effects, and all sorts of things that just are not possible with FFT systems.

"Another example of the limitations of the FFT approach is that I discovered many years ago that when calculating the Thiele-Small parameters of drive units, FFT systems don't put enough energy into the drive unit so you get wildly inaccurate results. You have to measure the steady state response with sine waves, because drive units have inertia and the rubber surround has a heating effect — you have to put in enough energy to overcome its elasticity. If you go back to the original papers from Thiele and Small, their original (pre-FFT days) method was to use the steady state approach, not to

THE HARBETH LS3/5

"We were one of the few companies who were licensed to make the LS3/5A, which really came about from my interest in that loudspeaker from its very earliest days. In fact in 1976 there was a home-build kit version called the Symphony — which I couldn't quite afford — and I built my own version from scratch with hand-wound coils in the crossover.

"In 1988 I heard there was a complete redesign of the 3/5, because the pre-1988 LS3/5s had a very pronounced peak in the 1.2kHz region (of anything up to 11dB!) and a dramatic tip-up at the extreme HF (which was deliberately engineered to reveal tape hiss). The loudspeaker used a bextrene cone with lots of dope and a very soft surround and at the time, the primary use for bextrene was in fuse box covers for automotive applications, mainly in America.

"Over the years, the bextrene specifications gradually changed as fire-retardant material was being added in ever increasing quantities, but no one had thought what effect that would have on its acoustical properties. It was only when a late model was compared with an early reference that the huge mid-range peak was discovered! KEF were asked to redesign the crossover in 1988 to take out the mid-range peak and smooth out the top end response.

"Although it appears from the outside to be the same, that Mark II model is a very different animal indeed and at that point Harbeth applied for a licence to make them. We had the advantage that as we were starting from a completely clean slate, anyone buying a Harbeth LS3/5 knew it had to be a Mark II model, and our production tolerances were second to none.

"KEF's decision to stop making the drivers used in the LS3/5A have finally caused its demise and our very last batch of LS3/5s has just left the factory."

hit the drive unit with an impulse.

"When I am designing a new loudspeaker, I will put the prototype on a lift and crank it up high into the air in the middle of the factory until the reference axis is in line with a B&K 4133 measurement microphone. Then I take the frequency responses of the raw drive units in the cabinet (*sans* crossover) above and below the axis, and after rotating the speaker in 15 degree increments to build up its polar characteristics.

"The end result of our three years of research is a patent and about 10 years supply of ready made mid-range cones."

"I use the 2012 for that process because I have so much confidence in it, but since this is a reverberant space rather than an anechoic chamber, I have to 'window out' the reflections within the room from the measurements. A side effect of the windowing is that below 100Hz the frequency plots are an understatement of reality (the window time is too short to allow accurate capture of low frequencies). However, I've been working in this way long enough to know that I can rely absolutely on the response to 100Hz, and I make a mental adjustment for frequencies below that. If I really want to know what the LF response is, I can always bring the microphone in closer of course.

Ten years supply of Harbeth cones stored in a humidity controlled tent.

"So I capture the frequency response of the raw drivers with no crossover but in the real cabinet and across a hemispherical arc, and I do that because one of the things that really bugs me about loudspeakers is that as you sit down in front of many typical loudspeakers, the quality changes dramatically. It is all to do with the laws of physics when there are multiple drivers in a cabinet, but I am very troubled by that and find it quite disturbing. So I try to get the biggest and smoothest 'balloon' of energy that I can, with as few (and as shallow) dips in it. That way, you can bob up and down in front of the speaker and the quality doesn't change at all.

"The problem is that you can only optimise the design for two axes out of three — that is on-axis and in the vertical plane, and you have to allow a notch of some sort below the listening axis. To get the best results, you need to know where the listener is going to be sitting in relation to the loudspeaker.

"For example, the new Monitor 40 speaker will be used in broadcast situations where the mixing engineer will be on-axis to it, but there might be a producer or the tapes and grams operator standing behind and above the main axis. So with that in mind, I am confident that the correct polar pattern for this speaker should be flat on the axis and for 10 degrees above it. In optimising that, there will inevitably be a notch of some sort below the axis, but that is actually an advantage because it cuts down on some of the energy reflected off the mixing console.

"As far as the lateral dispersion is concerned, I find that largely takes care of itself. On the Monitor 40 for example, if you compare the on-axis frequency response with that at 30 degrees, they are exactly the same — the two traces lie exactly on top of each other."

Do you use computer aided design tools to help with the development?

"Yes. One of the programs I use is called LEAP, which is a well known American program used

THE BBC HERITAGE OF LOUDSPEAKER DESIGN

"The history of the BBC's development of loudspeakers has always fascinated me and revolves entirely around Dudley Harwood and Spencer Hughes (late of Spendor). In the late '60s these two men were responsible for the discovery of bextrene as a cone material after testing hundreds of different materials in the BBC's R&D department. The loudspeaker this research produced was revolutionary for its day and the BBC realised that the internal demand was going to be far greater than they could possibly meet from in-house manufacturing. At that point, Spencer decided to leave the BBC and set up a company to build this new loudspeaker, which became the Spendor BC1 — Spendor being a contraction of Spencer and Doris.

"However, Dudley was troubled by the amount of dope that had to be used on this new bextrene cone, because what that suggested was that there was a fundamental mechanical problem in the cone itself. So he carried on the research and eventually came up with polypropylene. He left the BBC about seven or eight years after Hughes to set up Harbeth (from Harwood and Elizabeth), with a patent on the polypropylene cone, but Spendor and Harbeth were very different companies. Harbeth was, at best, a two-man company, whereas Spendor was a real commercial concern.

"My lucky break was in 1988 when I looked at the then current Harbeth speaker and decided to make something which was more domestically acceptable and about 20% smaller. That became the Compact 1, which was an enormous success, particularly in Japan. The unusual thing about that speaker was that it had a TPX cone and an aluminium tweeter, neither of which Harwood had used before. Just before Harwood sold the company, he had been introduced to this new TPX cone material from Audax and was so convinced this was a major breakthrough that he sold his patent on polypropylene cones, believing they were obsolete.

"That was what really started my interest in cone materials, and in 1991, I decided to try to come up with my own 'brew' to overcome the deficiencies of existing materials. I went to the Science and Engineering Research Council and said we were a small company with no engineering resources, but we wanted to find a replacement for polypropylene cones. To me, polypropylene sounded dull and lacklustre, and bextrene was rather nasal and 'quacky', so there had to be something better in between. As it happened, the DTI were running a 'Teaching Company' scheme to soften the entry of graduates into industry. The deal involved us being bonded with a university for three years (Brighton in our case), paying half the graduate's salaries, and a contribution to the equipment costs. At the end of the term, the equipment went to the university and the graduates would either be working with us, or be able to write a jolly good CV!

"We started the project with three postgraduates in mechanical and chemical engineering, and I described the unwanted characteristic sounds of the existing cone materials. Obviously they needed hard data to confirm my descriptions, but after a month of trying every kind of testing on a huge variety of commercial drive units — waterfall plots, wavelets, frequency responses, impulse responses — they could not establish any kind of correlation with what I had told them. I think their confidence in me at this point was pretty low, but we decided the only way forward was to rationalise the process and that meant we couldn't test commercial drivers because the effect of different cone shapes was swamping the subtle material differences we were looking for.

"We thought the problems with the existing cone materials were to do with their stiffness — the stress-to-strain ratio or Young's Modulus — so we obtained the manufacturers' figures. These were effectively DC measurements — a strip of the material is clamped in a jig and its Young's Modulus determined statically — which is clearly not representative of what happens when the material is being excited in a loudspeaker cone. The only solution was to spend two years developing and building a unique machine which allowed us make Young's Modulus measurements across a wide frequency range. We made identical strips of hundreds of different materials and found that their damping characteristics were highly frequency dependent — and in a way which correlated with what we could hear.

"For example, we found that on a plot of the Young's Modulus against frequency, aluminium was very stiff at LF, but had virtually no damping at high frequencies, and consequently was very 'ringy'.

extensively in loudspeaker design. Basically, you give it your proposed crossover circuit and which components it can change in order to match your target frequency response curve. Unfortunately it can only calculate the result for one listening axis at a time and is virtually useless at giving any impression of how a speaker performs over the wide physical arc of real interest. We need to know how changes in the crossover will affect the response above and below the listening axis, as well as the lateral response, and so I had a program specially written a few years ago which is called HALNET — Harbeth Acoustics Limited Network Analyser. This is a modeller capable of displaying and calculating five different axes simultaneously, for a system of up to five drivers.

"As you play around with the design of the crossover network, it calculates the new frequency response (taking into account the measured responses of the drivers in the cabinet) and you can see the projected acoustic results on each of the various listening axes. By very careful tuning of the network, you can optimise the system for the smoothly integrated 'balloon' of sound, which will be a perfect model of the real crossover and measured complete system.

"One of the more alarming things that HALNET can reveal is what happens when you perform a 'Monte Carlo' analysis to calculate the frequency response extremes with crossover components at the limits of their tolerances. For example, we used it to run through the DPM-1 active crossover design and found that unless we used 2.5% (or better) capacitors and 1% resistors, we would get

Alan's secret granules — the raw product for Harbeth's new cone material.

errors of the order of a dB or so in the transfer functions, and in passive networks, unless you use the *exact* values you won't get two speakers off the production line to measure remotely the same. So we always start with individually measured components and build the crossovers up to the exact value — that way all our speakers leave here measuring exactly the same.

"We also have another program, which analyses data from the 2012 and produces 'wavelet transforms' from impulse response measurements. Wavelet transforms are shown as a 3D plot with level as coloured vertical contours against frequency and time on the other two axes. It is a tool I use to look for delayed releases of energy — resonances — in the loudspeaker system."

THE MONITOR 40

"The Monitor 40 is the largest loudspeaker we have made and really derives from my experience of listening to the BBC's grade one monitor — the LS5/8. I was shocked by the 5/8's sound, because it was so out of date! Having said that it does have two virtues: every loudspeaker sounds the same; and there is a lot of low frequency energy so that rumbles are very obvious.

"We make sub-woofer units for the LS3/5 and the DPM-1 — both band-pass units — but neither are capable of the same kind of performance you can achieve with a good 12-inch speaker, so I knew that if I was to build a replacement for the 5/8, it would have to be in a big box with a big bass driver.

"When I acquired a pair of LS5/8s and started measuring them, I discovered that there is a pronounced suck-out in the mid-range — something the original design report alludes to. It seems there was some recognition of problems with colouration and the frequency response of the 5/8 was adjusted to try to mask them — hence the depressed middle. My other discovery was that the 5/8's cabinet back produces a sound output only 10dB lower than the direct output from the drive units!

"The Monitor 40 is very slightly shorter, narrower, and deeper than the 5/8 so it is a 'drop-in replacement'. It was originally going to be exactly the same size, but the cabinet-maker said that by knocking off an inch from the height we could make better use of the 8 by 4 panels the cabinet is constructed from.

"The 5/8 is a two-way unit whereas the Monitor 40 is a three-way design using our own driver for the all-important mid-range [one story suggests that there was determination to make the LS5/8 active, but for reasons of cost, a commercially available amplifier had to be used, thereby restricting it to a two-way design — Ed]. I have used a Vifa 12-inch paper cone bass driver with a very large voice coil in the Monitor 40, but it took me quite a while to recognise that there was an alternative approach to the kind of polyprolene cone used in the 5/8.

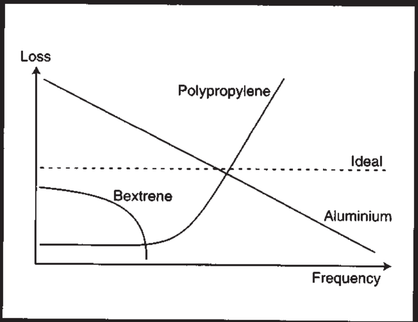
"When I took one of those original bass units apart and weighed the cone I found it to be extremely heavy — 107 grams or something like that — so the inertia is enormous. In fact it will ring on for about half a second after an impulse, and that ringing is easily sustained by the energy in speech, which is a big contributor to the coloured sound quality.

"I have been experimenting with tweeters, and have settled on the top of the range Seas soft dome unit, which is a fabulous device and probably the best in the world. However, I had also been using an aluminium dome tweeter with great success."

Bextrene was much less stiff than aluminium at low frequencies, but was more or less uniform up to about 500Hz, when it would just keel over with no damping at all — hence the dope needed to give it some damping at HF. Polypropylene ran along to about 1kHz and then became extremely lossy or soft, which is why it tends to sound dull.

"No one had ever done this kind of research before — even the guardian of standards, the National Physical Laboratory, said it would be impossible to gather wide frequency Young's Modulus data. Well, we proved them wrong, but the exact details of how we achieved it, and the data we collected will remain a closely guarded secret!

"Having gathered the data, we were able to deduce what we thought would be the ideal



characteristics for a loudspeaker cone material, and then scoured the world trying to find something that matched our profile — but to no avail. To cut a long story short, we ended up hiring a compounder for a week (a machine which makes plastic granules from a number of raw products) and made hundreds of different blends in an attempt to produce our 'ideal' material. Once we thought we were close, we used an injection moulded process to make prototype cones and then listened to them to see if our theories were right.

"A side issue from the blending stage was that we discovered we could easily introduce tiny amounts of dye into the mix. The dye didn't affect the damping qualities but produced very attractive and distinctive coloured cones — hence the purple cones in the DPM-1.

"The end result of our three years of research is a patent and about 10 years supply of ready-made mid-range cones. We also have enough of the raw products to make a lot more, which is just as well because as it turns out, two of the ingredients are no longer commercially available!

"All of the Harbeth range of loudspeakers (except the P3 which is intended as an LS3/5 replacement) use our in-house designed drive unit, and the majority of speakers employ it to handle frequencies up to around 4kHz before crossing over to the tweeter — unusually high perhaps, but our driver is easily capable of it."

The prototypes have been passive, but will there be an active version?

"We have recently started making active speakers because there is increasing interest in some markets — particularly for home studio applications — so we have an active version of the DPM-1 for example. The amplifiers are out-sourced, but we worked with the designer in its development so that a 'personality module' can be incorporated. This is the active crossover, which defines the integration of the drive units, and we are now working on a three-way version of the amplifier design for an active version of the Monitor 40 which will cost between £3000 and £3500. That is a very competitive price, which is critical, because budgets in the marketplace this speaker is targeted at are always tight.

"Although you have a much greater degree of flexibility with active crossover designs, the whole of the development of the Monitor 40 has been with a passive crossover for good reason. That may seem a little odd for what is ostensibly a professional loudspeaker system, but we know the Monitor 40 has a hi-fi existence. In that market they are not too keen on active speakers because the dealer loses the sale on an amplifier! If you develop a loudspeaker with an active crossover it can be extremely difficult, if not impossible, to back-engineer a passive design from it, so you have to get it right with a passive crossover first — even though the crossover can become a horrendous thing to design!"

THE PRODUCTION LINE

Would you describe the production process please?

"The first job is that as the raw crossover components come in the door, we measure and mark every one. It doesn't matter what the manufacturer says they are, we need to know precisely! The crossover boards are then made up 'to order' so that we can compensate for tweeters which might be a bit low or high on sensitivity.

"When the various drive units come in from the suppliers, there is no way of knowing from just looking at them, what their sensitivity or frequency response is, so we use a MLSSA test set and a special jig to measure and log every drive unit. We also test the drive units we make ourselves of course, but we have found they have far tighter tolerances than anything we have ever bought in. For example, the sensitivity of this particular batch of our mid-range drivers is from -0.2dB to -0.8dB (relative to our master reference unit), in other words a spread of 0.6dB over the whole working range, and the shape of the frequency response is perfect. The variation in sensitivity is primarily due to the fractional changes in the strength of the magnets. However, the real problems come when you test the tweeters where, in the same batch, we typically find a variation from +0.8dB to -0.2dB — almost twice that of our own drivers. Having measured everything, they are individually matched to the crossover boards, which have been built with the exact compensation required.

"When I design the crossover circuits, I build in

Mark Williams uses a MLSSA system to measure and calibrate crossovers.

Drive units sorted according to their sensitivity await installation in Harbeth's nine different loudspeaker models.

BUYING HARBETH

"I was very lucky in being one of the first employees of NEC (UK) Semiconductors in 1981 when there were just five of us and no office. Eight years later there were 110 of us and a turnover of £150 million a year! In those early days, Sinclair was one of my accounts with the Spectrum and ZX81, which were really the first home computers. Then IBM started to build the first generation of PCs on the old Thorn TV automated production line in Enfield, and that fell into my remit too.

"That was where I learned about quality control (QC). At that time the Americans used to have something like 60% waste in their semiconductor fabrication plants whereas the Japanese had about 1% waste — a saving which translates into pure profit. The difference was that the Japanese would test the basic silicon wafer, weed out the rejects, then add a little bit of value to it through the next stage of production and test again, add more value, test again and so on. That way they added as little value as possible at each stage before test failures meant throwing that value away.

"I would still be at NEC now I guess were it not for one day when I happened to be in South London. I had always been a loudspeaker buff and I knew Harbeth were in the area. I was very familiar with Dudley Harwood's writings about loudspeaker design, so I thought I'd go and meet him. I tracked down this lock-up garage at the end of a little lane but couldn't believe this was the right place — in my mind Dudley Harwood, Harbeth, ex-BBC... it was mega-corporation stuff! Anyway I went in to find, sleeping in a Victorian clerk's chair, this old man who was Dudley.

"After spending some time there I came away thinking I couldn't let this company decline the way it appeared to be and I thought about offering to go into partnership with Harwood. The nature of the man was such that this was a very unlikely proposition, but we formed a relationship and six months later Dudley told me the business was up for sale. The company had been losing money for years, but at least it had a solid distribution network and the product was very well known in the Far East. I knew that if you could sell a product in Japan, you must have quite some image, and I was sure I could build on that, so we agreed terms and I moved the business down to Haywards Heath. That was 11 years and three factories ago now. Speaker manufacture is certainly not the road to riches, but the scale of the operation has changed rather dramatically from when I bought the company. In the year before I took over sales were about £50,000, and now they are around £800,000!"

the provision for matching components because it is the only way we can get every loudspeaker to conform to our master reference. I believe our quality control and component matching is probably the best in the industry, and by setting a high standard at each stage of the production process, it means that when we test the final speakers they always sail straight through.

"Most of the tweeters we use are Seas units, but the DPM-1 uses Morel soft dome units which have a much wider variation in sensitivity. It is extremely difficult to make two soft dome tweeters the same, and so there is inherently a very wide variation. Aluminium tweeters can be matched very accurately across a batch, and I prefer to use them where I can, but soft dome tweeters have been in vogue for a while and that is the real reason we use them in the DPM-1. I think metal dome tweeters had a bad press, because they were often used from too low a frequency which gave them a

"... highly accurate sound... That is the definition of a monitor speaker and I'm not interested in making anything which does not have that credibility about it."

'barking' quality, whereas the suspensions in soft domes have a bit more 'give' and that allows them to take more abuse.

"We keep log books for each model of loudspeaker (going right back to when I took over) where we record the serial numbers, the customer, the sensitivity of the drive units (relative to the master reference), and the crossover version used to compensate for driver mismatch. That means that we can replace a damaged driver with one of exactly the same sensitivity (although driver sensitivity tends to vary slowly across batches and we might have to wait a while before we find a perfect match).

"The last stage of testing is in a small anechoic chamber where we measure the loudspeaker against data from the reference model, firstly using an automatic MLSSA sequence, and secondly with a manual sine-wave sweep (because the MLSSA is not able to spot buzzes and rattles like a human ear can). The whole of the final test sequence is recorded on video for two reasons. The first is so that we have a record of the cabinet veneer in case a cabinet is damaged and we need to issue a replacement — some veneers are very strongly grained, and at least with the video record, we can

The production version of Harbeth's new Monitor 40 loudspeaker.

Alan Shaw fine tuning the Monitor 40's passive crossover.

make a good stab at matching the veneer. The second reason is so that we can prove each loudspeaker has passed its final test (the serial number of each speaker is spoken at the start of the test and is captured on the video tape).

"The difference in frequency responses between each loudspeaker and its master reference are stored on the computer's hard disk, which is then archived to a tape streamer so we have the frequency response of the final speaker, the video tape recording of the final test, and the log books of what was installed in each speaker.

"It's all about quality control at every stage. We test the crossover components when they come in, we test the individual drive units, the completed crossovers, and then the final loudspeaker — and because of that we have absolutely no failures in final testing all. The purpose of multi-stage QC is to catch the very occasional silly, like a tweeter that's reversed (yet will, of course, still measure the same until part of a completed loudspeaker system!), but in terms of significant QC problems, there aren't any. At the end of the year, if we have issued more than 20 replacement drive units I'd be surprised. There just isn't an after-care problem.

"The cabinets are out-sourced from a firm in East London which we have been using for many years now, and the veneers are very carefully matched in speaker pairs. The design of the cabinet, including the bracing and damping, is done in house though."

How do you build you own drive units?

"An out-worker assembles the roll surrounds to the injection moulded cone, but its design and construction is absolutely crucial. The secret is what is called a 'flapping edge' which is the way in which the surround and cone are joined. It has to be a 'lossy joint' so that energy from the cone is not reflected, and the type of glue used is very important in making it work properly.

"The spiders are built up using voice coils, which are made by another out-worker, and the alignment between the voice coil/spider and cone assembly is also critical. The whole lot is then installed in our own-designed plastic chassis and a dust cover is fitted over the voice coil. We also make the magnet assemblies ourselves from a kit of [Taiwanese] parts before magnetising them. The magnetiser we use actually came from the BBC's R&D department in Kingswood Warren and it is probably 50 years old now, but still works perfectly."

Can you sum up what it is about Harbeth designs that makes them stand out from the rest?

"There are some very fine 'monitor' loudspeakers available, and many of them are capable of far higher power handling than Harbeth designs. But are they really able to reproduce voice the way we can? We are specialists in the voice area and that is where most of the energy is and the most important frequencies. For such a small company, we have invested a great deal of time and trouble in developing our own cone materials, purely because we were dissatisfied in the quality we were achieving with existing materials in that specific frequency band — and I believe we have made a significant improvement on what was previously available. So I would say it is that which sets us apart from our competitors." SP

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