A SUBJECTIVE ASSESSMENT OF THE ACOUSTICAL PROPERTIES OF CONCERT HALLS, BASED ON PERSONAL EXPERIENCE OF CONCERT HALLS AROUND THE WORLD

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INTRODUCTION

Unlike many of those participating in this conference, I cannot be counted among technically-qualified acoustics engineers, but should be considered rather as a consumer of their products. In twenty-five years at the B.B.C. as a Music Studio Manager I have had responsibility for the sound balance of music broadcasts ranging from recordings from the B.B.C.'s Maida Vale Studios to opera relays from Covent Garden, and from the Proms at the Royal Albert Hall to live transmissions and recordings during numerous foreign tours with the B.B.C. Symphony Orchestra.

In 1986 I proposed to the B.B.C that I should use a three-month period of "grace leave" to visit concert halls in far-flung corners of the world in order to assess how well they meet the acoustical criteria deemed desirable for music, particularly orchestral music. My travels took me to parts of Australia, the United States and Japan, and my internal report stimulated so much interest that I was invited to extend the research to cover halls nearer home as well. It was felt that the direct experiences of an informed pair of ears such as mine could help to nail down what has eluded so many acousticians for so long.

The number of concert halls which have failed to meet desirable standards is legion. The reasons for such failures are many: among them are the lack of concerted opinion as to what these desirable standards are, the technical problems of predicting the acoustical outcome of particular designs, and the external strictures imposed upon acoustical designers by economic factors or by the ambitions of visually-orientated architects unable to resist the thought of large numbers of captive admirers for their work. The failures ultimately represent an enormous waste of resources, often necessitating costly remedial measures of limited effectiveness. Poor acoustics can do damage to musical and architectural reputations, and the professional competence of acoustics experts can be brought into question, often through no fault of their own.

Acoustically successful halls, on the other hand, enhance musical performances and are popular with artists, audiences, broadcasting organisations, recording companies and administrators. They usually justify their costs, play a major part in stimulating musical culture, and bolster national prestige in this most international of arts.

MUSIC AND ACOUSTICS

Before assessing halls it is necessary to identify the acoustical criteria which need to be met. Like music itself, the art of acoustics has no absolutes, though both arts adapt physical laws in the pursuit of aesthetic goals. Good musical acoustics complement the Art of Sound which they serve by helping performers and composers realise their objectives, and by enhancing the subjective perception of listeners.

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Given the inevitable diversity of taste to be found in any artistic field, the task for the acoustician is no mean one. Furthermore, if the net of an acoustician's brief is cast too wide in order to entrap not only every kind of music - from chamber to symphonic to rock-and-roll - but also speech events, then satisfactory acoustical compromise becomes impossible; the needs are simply too different and impose unacceptable constraints one upon another.

When designing a new auditorium it is therefore essential to define the prime purpose for which it will be used, and then to strive to fulfil the acoustical demands of that purpose. In the case of music it must be appreciated that this is a constantly evolving art, and that the musical tastes of the twenty-first century are bound to extend beyond the conventional symphony orchestra, whose roots are firmly in the nineteenth. The electronic projection of "surround-sound" is already playing an increasingly important rôle and it cannot be assumed that future sounds will only emanate from the conventional platform. Electronics apart, the complex harmonic structure of modern music means that hitherto fashionable long reverberation-times can produce undesirable acoustical blurring.

As long ago as the sixteenth century composers took care to write music suitable for the acoustics of the buildings in which it would be performed. A typical example is the simple homophony of Gabrieli's brass music, composed for the vast echoey spaces of St Mark's in Venice, while the strict rules of counterpoint in Italian church music of the period actually laid down a minimum rate at which harmonic changes could take place, largely, I'm sure, in order to accommodate unwieldy acoustics. That intoning came to play such an important part in church liturgy is arguably attributable, at least in part, to acoustical needs, since it slowed down the speed of delivery and overcame the pitch fluctuations of normal speech inflection.

On the other hand, complex chromatic polyphony developed primarily in the secular music of Northern Europe, particularly in England, where it tended to be performed in intimate, often domestic, surroundings. The musical language of the English madrigalists was far more adventurous than that of Palaestrina for example, and Bach's most inventive music can be found among keyboard works such as *Das wohltemperiertes Klavier* and *The Art of Fugue*, rather than in his church cantatas.

The stylistic evolution of European music owes much to the great ecclesiastical buildings which are the natural ancestors of today's concert halls. As music became an established art in its own right, it outgrew its servility to religious patronage, but, although now inappropriate for sacred surroundings, the profane still aspired to grandeur, and so new secular temples dedicated solely to the Art had to be built which would be large enough to accommodate a burgeoning number of devotees. The modern symphonic repertoire owes much to the acoustics of great secular buildings, epitomised perhaps in the Grosser Musikvereinssaal in Vienna, the now-replaced Neues Gewandhaus in Leipzig or the Concertgebouw in Amsterdam.

Marvellous though these buildings are, they were not conceived specifically as acoustical masterpieces; rather it is the music which developed to suit their acoustical qualities. One of the great myths perpetrated by the ill-informed ascribes acoustical success to the intuition of by-gone architects working empirically without the benefits of modern research technology. I join with more enlightened opinion in submitting that the acoustical success of the now legendary

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older buildings came about more by accident than by design, and that the myth that old buildings somehow "got it right" arises largely from the fact that the ones which didn't have either been demolished or have long-since ceased to be used as concert halls.

EXAMPLE AND EXPERIENCE

Although inevitably the nineteenth-century music which forms the core of today's concert repertoire tends to sound well in the better nineteenth-century buildings, this does not mean that today's solutions lie in the architectural emulation of those buildings.

Many modern halls have acoustics that are more than a match for their nineteenth-century forbears, achieved without compromising the other expectations of modern audiences. Out of the sixty or so halls I have visited to date I have selected a few which to my mind demonstrate what can nowadays be achieved through enlightened thinking and the careful application of modern technical resources. Against these I will also refer to some of the near disasters which have resulted from misconception or acoustical constraints.

The Berliner Philharmonie has now already achieved legendary status on a par with the best of the older halls. This is partly due, it's true, to its association with the Herbert von Karajan bandwaggon - hardly reticent in the art of hype - but it is none-the-less a fine hall which reflects credit on its principal architect, Hans Scharoun, and his acoustical advisor, Lothar Cremer.

This auditorium has some 2,200 seats, divided up into in raked blocks of around 300 seats each. Contrary to conventional practice, the blocks surround the platform and this helps to reduce the distance between the furthest audience rows and the podium, even though much of the audience is now seated behind the orchestra. This is not necessarily a bad idea, however, because provided acoustical diffusion is good the public can get every bit as much visual enjoyment from facing the conductor as from facing the players - a fact which I'm sure has not been lost on von Karajan!

The main acoustical advantage of breaking-up the audience seating into smallish blocks is that the parapets of individual blocks can serve as reflectors for adjacent blocks, and none of the seats is far from a reflective surface. This ensures that on the whole strong first reflections arrive at the listener almost simultaneously with the direct sound, thus providing desirable reinforcement. In the Berliner Philharmonie the top surfaces of the parapets also play an important part by providing reflections in the horizontal plane for the seats overlooking them, while the polished stone fascias of the tiers immediately behind and to the sides of the platform serve as reflectors for the orchestra itself. The collective effect of all these reflections makes for near-ideal reverberation characteristics.

This layout is likened to the arrangement of terraces in a vineyard, and it has since been copied elsewhere, notably in the new and lavish Suntory Hall in Tokyo and in the recently-built Gewandhaus in Leipzig, both of which rank amongst the best of modern halls. In contrast the Münchner Philharmonie at Gasteig in Munich has a layout which makes for a forbidding sense of vastness, particularly from the

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rearmost rows, and the acoustical treatment is aggressively obvious as such. It is hard to believe that this hall and the Berliner Philharmonie have a very similar total volume. When I attended a concert in the Munich hall I found myself at first agreeing with the critics who denigrated its acoustics, but as soon as I shut my eyes and relied on my ears alone it was clear that the sound was on the whole very good and that the critics had been unduly influenced by powerful psycho-acoustical factors.

In the Berliner Philharmonie diffusion is aided by the profile of the ceiling which resembles the inside of a large tent - again we have in this a feature which has been copied in Japan, this time in the superb Symphony Hall in Osaka. In Berlin the ceiling also incorporates 136 pyramid-shaped Helmholz resonators to damp unwanted bass resonances. Convex Plexiglass "clouds" - adjustable reflective panels about two metres across - have been suspended above the platform to reduce the effective height of the ceiling above the orchestra, and thereby to help performers hear themselves and eachother. Such devices have been widely used around the world, notably in the Victoria Concert Hall in Melbourne and in the concert hall of the Sydney Opera House, both of which have extremely high ceilings above their platforms.

The volume of the Philharmonie allows a generous ten cubic metres per seat, and the sound is at once spacious and warm without loss of clarity. However, despite the claims made for it, this hall is not entirely without defects. When I heard a concert given by the Vienna Philharmonic Orchestra playing Bruckner under Gerd Albrecht, I was mildly disturbed by spurious high-frequency reflections from behind me, obviously coming from the façades of the more remote seating tiers. This is a common danger when there is a proliferation of reflective surfaces to the rear of the audience, and clearly great care must be taken when determining the correct angles for such reflectors. A similar defect was noticeable in the Leipzig Gewandhaus, while in the Brahmssaal of the Kongresszentrum at Karlsruhe and in the pretty awful Salle Pleyel in Paris reflections from the rear were annoyingly strong.

My experiences have convinced me that the secret of good acoustics lies in the careful design of reflecting surfaces, rather than in the resource to absorption. Absorption is by definition wasteful of essential musical energy and the audience already soaks up a lot of sound on its own. When high-frequency reflections from the rear of an auditorium pose a problem some absorbative treatment may be necessary, but another method has been used very successfully in the Electric Company's Recital Hall at Nagoya in Japan, where computerised ray-tracing methods, courtesy of the Yamaha Acoustical Research Laboratory, dictated a horizontally convex profile for the rear wall and even for the glass window of the technical control room. Significantly this small hall, whose walls are faced with polished marble, is almost entirely devoid of any kind of absorbative treatment, although certain panels set into the walls can be rotated electrically to present absorbent faces when a cut in reverberation-time is deemed desirable - for example when the hall is used for conferences.

Imitation versus Imagination.

A hall which must be described is the recently completed Schauspielhaus in East Berlin. Here the authorities have gone to great lengths, as well as to considerable expense, to create a magnificent, not to say extravagant, incarnation of the ornate nineteenth century "shoe-box" hall.

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Impressive though it is in its vulgar way, with its gilded plaster-work, lavish imitation marble, opulent parquet flooring and sumptuous plush upholstery, it represents a reactionary approach which to me is quite unsuited to the spirit of the late twentieth century and the reasonable expectations of its audiences. The seating in the balconies is cramped and faces sideways, leading to cricked necks, sore knees and lop-sided sound, while the flat floor of the stalls plays havoc with sight-lines. The acoustics are rather like those of a swimming-bath, and the application of effective acoustical treatment has been proscribed by the rigorous adherence to period style. Ironically, although the hall imitates closely the style of the great nineteenth-century Berlin architect Karl Friedrich Schinkel, whose shell it inhabits, the original concert hall was less than half the size and occupied only a wing of the building. The new hall replaces what was originally a theatre, as the name Schauspielhaus indicates, and it is therefore almost entirely a sham. (At least the comparably resplendent Semper Oper in Dresden is a more-or-less genuine restoration.)

Compare this hall with the highly imaginative Alte Oper in Frankfurt. Here the similarly-shaped bombed-out shell of Richard Lucae's 1880 opera house has undergone loving external restoration, but inside it one now finds an imposing and uncompromisingly modern concert hall which defers not a jot to its parent. The interior of the auditorium itself achieves the kind of beauty peculiar to functional design, exemplified in the heavy polished-mahogany wall-panels which not only look superb, but which, in their intricate geometrical arrangement, clearly have a major acoustical function.

The acoustics are by the late Professor Heinrich Keilholz, and in keeping with the best modern practice the sides and rear of the platform are bounded by reflective walls some two-and-a-half metres high, the chorus seats occupying the tiers immediately above these. The visible ceiling of the hall comprises a network of metal grids which in turn support acoustically transparent fabric screening. The true ceiling is in fact several metres higher than this and the space between is acoustically coupled to the main body of the hall, whose effective volume is therefore greater than it looks. The grids are of course of great practical use for supporting lighting and other services. A vaguely similar arrangement has been used by Alex Burd in the largely excellent St. David's Hall in Cardiff.

If I have a subjective criticism of the acoustics of the Alte Oper it is that the bass response is inadequate - this is confirmed by the reverberation graph which shows a less-than-ideal tailing-off below 250 Hz. It is coincidental that the St. David's Hall also suffers to some extent from a similar defect, the result of constraints put upon Alex Burd by the hall's multi-purpose function. In the case of the Frankfurt hall the cause quite clearly lies in the deliberate, and to my mind excessive, use of bass absorbers. Many of the wall panels are hollow while others incorporate Helmholz resonators.

The figures for the Alte Oper also show a marked difference in reverberation-time between empty and full halls of well over half a second at 1000 Hz. This can be largely attributed to the polished hardwood floor which obviously contributes greatly to the reverberation-time, but which is substantially masked as soon as an audience is present. I will return to the matter of flooring a little later in the context of the Llewellyn Hall in Canberra.

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Problems and Dangers.
Two halls need specific mention because they amplify the negative effect of ill-judged acoustical design. Both halls incorporate concave surfaces and demonstrate spectacularly why these are so dangerous to acoustics.

The first is the Salle Pleyel in Paris, to which I've already referred. Here the enormously high side walls curve inwards at the top, while the ceiling rises in an unfolding concave arc from near vertical low down behind the orchestra to more-or-less horizontal at the full height of the auditorium above the audience. The acoustical upshot is a proliferation of irritating focal-point effects and sounds appear to emanate from all sorts of unlikely corners. Matters are made even worse by the wide slab-like vertical fascia of the balcony, from which certain sounds ricochet back towards the players, producing a double echo reminiscent of the Royal Albert Hall in its pre-saucer days. A less serious but similar effect in the otherwise excellent Meistersingerhalle in Nuremburg has been cured by hanging tapestry drapes over the balcony parapet.

The other hall is the new Kölner Philharmonie in Cologne. Here the whole building is basically circular, already problematical for the acoustician, and matters are exacerbated by having the orchestra play within a semi-circular surround. An attempt has been made to counteract this latter feature by breaking up the wall into smaller convex panels, but the net effect is still full of anomalies for the listener as players on the platform's left are sometimes heard coming from the right and *vice versa*. Furthermore, the reflective surround is so shaped that it favours those instruments close to it, such as brass and percussion. The strings and soloists on the main platform apron have no such help, and even that powerful pianist Peter Donohoe, whom I heard in Busoni's *Piano Concerto*, was inaudible at times. In turn he told me that he found it impossible to hear the rest of the orchestra properly.

A steel and glass cartwheel-shaped canopy is suspended above the platform, but this is quite obviously too low and all the wrong shape. Even the wedge-shaped glass panels radiating from its hub are concave. Consider too that the organ is placed to one side - not in itself a disastrous idea until one appreciates that organs are acoustically about 85 per cent absorbative. In this case the organ is placed on the left immediately behind the violins, already the most disadvantaged section of the orchestra in this hall.

Simple and Effective.
To end on an optimistic note: probably the best hall I encountered during my research was the Llewellyn Hall at the School of Music in Canberra, Australia. It is a comparatively austere building, built to a limited budget, but it satisfies musical criteria in a very special way. The sound is at once warm and precise; dramatic impact arising from contrasting musical textures and dynamics is enhanced; performers find it easy and rewarding to play in, and high-quality broadcast or recorded sound can be obtained with the simplest of microphone techniques - an acid test for many halls. The acoustics were designed by Gerald Riley, recently retired, of the Melbourne consultants Riley, Barden and Kirkhope.

Ironically, the Llewellyn Hall shares with the excellent Metropolitan Festival Hall in Tokyo the distinction of being a multi-purpose hall, such purpose being the only way the School of Music was able to justify the building of an auditorium to its

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financiers. It was nevertheless clear to Riley that the prime purpose was for music, and he made fulfilling the demands of music his prime objective. Unlike the St. David's Hall, both these halls get round the problem of multi-purpose use by resorting to variants of the movable acoustic shell, so common in the United States, where outside the metropolitan cities virtually all halls have to serve a variety of purposes.

It is Riley's belief that reverberation-time alone is no measure for a hall's overall musicality. Good diffusion and short first-reflection delay-times are at least as important, and in designing the Llewellyn Hall Riley and the architectural firm Yunken Freeman worked closely together in order to achieve optimum results in these aspects.

The auditorium seats around 1300 and has an internal volume of 8,800 cubic metres - around 6.8 cubic metres per seat - not including the fly-tower dictated by the demands of opera productions. Because of such use, and because of the hall's relatively small capacity, an average reverberation-time of 1.5 seconds with the hall fully occupied was deemed desirable. On paper this may seem on the short side for large Romantic orchestral works, but the reverberation curve shows that the time rises at low frequencies to give 1.9 seconds at 100 Hz and 2.5 at 50 Hz. This characteristic, when coupled with a tailing-off above 2.5 KHz which Riley considers necessary in the pursuit of a mellow sound, ensures that in practice the sound is so well balanced and so rich in texture that no lack of reverberation is felt by either performers or audience.

I heard the Melbourne Symphony Orchestra play Mahler's *Fourth Symphony* in the hall and found the sound to be magnificent. My wife Margaret Field was the soprano soloist in the last movement of this work and described the hall as one of the best she had ever sung in. The conductor Hubert Soudant and the leader of the orchestra Robert Scott were equally unstinting in their praise, commenting on the ease of achieving good ensemble and the lack of any need to force tone. Some four years earlier the B.B.C. Symphony Orchestra performed in the hall during their Australian tour, and we obtained first-class recorded results from a very simple microphone array.

In achieving such commendable acoustics, Gerald Riley used various devices:-

The bare concrete walls initially fan outwards from the proscenium, but then change direction to become almost parallel, thereby helping to provide good cross-reflections which Riley considers essential. To assist diffusion the wall surfaces are broken up by substantial pilasters which look rather like buttresses but don't actually reach the ground.

The ceiling was kept fairly low in order to make the time-delay between direct sound and first ceiling reflection as short as possible, and flat wooden "clouds" are suspended from the exposed girder framework forward of the proscenium in order further to assist diffusion; not, it must be stated, in order to provide early reflections - the usual purpose of such devices. These clouds are spaced apart sufficiently widely to ensure that the reflective surfaces above them remain acoustically active. Upstage of the proscenium a further row of clouds serves to deflect downwards some of the sound which would otherwise disappear up the enormous fly-tower.

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In order to ensure acoustical consistency with the hall full or empty, the floor beneath the auditorium seating is carpeted. It is Riley's contention that the presence of such carpeting has little or no effect when all the seats are occupied, and there is an added benefit in marked reduction of audience noise from foot-shuffling and the like.

On viewing the stage when it has been set out for concert use, one notices immediately the huge vertical reflector behind the orchestra. Constructed from dense timber and having a plain flat surface, it serves very effectively to project orchestral sound forwards, thereby greatly improving clarity and also enabling the players to hear themselves and eachother. When I questioned Gerald Riley about his choice of so simple a structure, he pointed out that a flat surface ensures a single direct reflection path between any two players and between any player and any member of the audience. Contrast this to the unsatisfactory performance of the heavily sculptured panels surrounding the platform of London's Barbican Hall.

In the Llewellyn Hall projection is also aided by a simple reflector attached, Bayreuth-style, to the top of the proscenium arch and by side reflectors in the wings. The on-stage reflectors can all be moved forwards and backwards on rails, while each side reflector can also swivel about its vertical axis. All the stage reflectors are immensely tall, matching the full height of the proscenium.

In front of the platform is a conventional orchestra pit, for use in opera productions. Its floor can be raised or lowered hydraulically. Initially it was intended that the floor should be raised for concerts, but it was found that the sound was better when it was fully lowered - presumably because in the raised position it tended to serve as a bass absorber. This means that nowadays players and soloists near the front of the platform need a good head for heights, since the unprotected drop is a good twelve feet!

The Llewellyn Hall is a supreme example of how success can be achieved through the clear identification of objectives and the sound application of acoustical logic. That the whole of the complex, which also incorporates a 300-seat recital hall, cost the Australian Government a mere one-and-a-half million Australian dollars in 1980, does great credit to the collaborative expertise of its architectural and acoustical designers.

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Principal concert halls visited to date for the purposes of this research.

Australia: Canberra: Llewellyn Hall; Melbourne: Robert Blackwood Hall, Victoria Concert Hall; Sydney: Opera House.
France: Paris: La Salle Pleyel; Studios at the Maison de la Radio; I.R.C.A.M.
Federal Germany: Bayreuth: Festspielhaus; Berlin: Philharmonie, S.F.B. Studio 1; Frankfurt: Alte Oper; Karlsruhe: Kongresszentrum; Köln: Philharmonie; Ludwigshafen: Staatsphilharmonie Rheinland-Pfalz; München-Gasteig: Philharmonie; Nürnberg: Meistersingerhalle.
German Democratic Republic: Berlin: Schauspielhaus; Dresden: Semper Oper, Kultur Palast; Leipzig: Gewandhaus.
Japan: Hiroshima: Yubin-Chokin Hall; Matsumoto: Harmony Hall; Nagoya: Electric Co. Recital Hall; Osaka: Symphony Hall; Tokoname: Civic Hall; Tokyo: Htomi Memorial Hall, Metropolitan Festival Hall, NHK Hall, Suntory Hall.
U.K: Most major halls.
U.S.A: Greenvale, N.Y.: Tilles Center, Long Island University; Philadelphia, Pa.: Academy of Music; Orlando, Fla: Bob Carr Performing Arts Center; New York, N.Y.: Avery Fisher Hall, Carnegie Hall; Sarasota, Fla: Van Wesel Hall.

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