Proceedings of The Institute of Acoustics

ACOUSTIC CONSULTANCY: AURAL CRAFTMANSHIP WITH SCIENTIFIC PRETENSIONS

J.G. Charles

Bickerdike Allen Partners, 121 Salusbury Road, London, NW6 6RG

PROLOGUE

When awarding the Tyndall Medal, the Institute of Acoustics warns recipients that they are required to give a lecture to members on a topic of their choice . As this year's recipient is an acoustic consultant, you will not be surprised to learn that he has chosen to discuss the quality and effectiveness - if you like, the state of the art - of acoustic consultancy today. Four totally different case studies have been taken to exemplify this: aerodynamic noise, vibration isolation, noise impact on the community, and auditoria acoustics.

But first the role of the acoustic consultant needs to be defined. What is he, and what is his function? He is thought to be someone who can be hired to provide a client with confidential advice, usually within a limited time and always within a limited budget. It is often assumed that his wisdom is unbounded and that in any case he has sufficient tools of the trade to resolve any problem referred to him. This is seldom true. I would prefer to amend the definition thus: an acoustic consultant is someone who will advise a client to the best of his ability within the constraints of his own craftsmanship and the limited scientific knowledge available within his profession.

A new aggravation for the practicing consultant is the developing tendency for aggrieved clients to seek legal redress for deficiencies as soon as a project has been completed rather than painstakingly try to sort out and remedy all the 'snagging' items. The result is that the consultant is under pressure to ensure that his advice is accurate, although the database and scientific or empirical prediction methods are generally far too unreliable to indicate that there is anything other than just a good chance of an acceptable result.

Table 1 reflects the lack of availability of adequate noise and vibration prediction methods over a selected range of consultancy tasks. To understand the tabulation, take item 1, electrical power transformers. The noise arises due to vibration of the transformer core due to magnetostriction. It is not possible to predict accurately from magnetostriction parameters, the noise of a completed transformer; therefore in my view there is no accurate scientific prediction method. In contrast, due to many measurements on completed transformers, relationships between radiated noise and power rating and other parameters have been established, therefore for transformers of similar design it is possible to calculate with reasonable accuracy the noise prior to manufacture, ie to make an adequate empirical prediction. Similarly when designing a transformer the principles are known, but the effect of every detailed aspect of construction is not accurately quantifiable without building it and testing it.

If this is too specialised an example, let us consider sound insulation from my neighbour above. It is known that improvements can be achieved by building an extra ceiling on separate framing below the existing floor. There is no scientific prediction available, and in this case no empirical prediction method which could be used to quantify without measurement the effect of the extra ceiling or of placing absorbent in the cavity, or of making the new ceiling heavier.

It is at this point that the acoustic consultant is often expected to give definitive and preferably quantitative replies. And this is where the difference between a science-based discipline and a craft with scientific pretensions becomes acute. The layman, dizzily impressed by the use of decibels, one third octave bands and such like, naturally expects that the prognosis will be numerical and accurate, not qualitative and qualified.

But it is not my intention to dwell on the difficulties facing the consultant; I will illustrate now some and then suggest how the profession can help to overcome them.

My first case study concerns aerodynamic noise; the consultancy spanned two worrying weeks, but had a happy and remarkably unscientific ending.

AERODYNAMIC NOISE

The scenario is a car production plant, where three heat exchangers (one large, two small) have been incorporated into an extensive paint-spraying facility.

During the commissioning period, production staff had been dismayed to notice that the noise near one exchanger in particular , under which people were expected to work, was extremely unpleasant - a noise level of about 97dB(A). Something had to be done about it urgently, since if the new paint-spraying facility was inoperable, the entire car production process would be brought to a halt.

An urgent visit to site was arranged to confirm the consultant's initial desk-bound reaction that there was no way that a heat exchanger, which involved no power-driven equipment, could produce such a high noise level. It was clearly a simple matter of silencing a noisy fan somewhere in the heat exchanger air circuits.

On site, the scale of the problem became evident; the car plant was enormous. The fan was located as anticipated - a large centrifugal type with backward-curved aerofoil blades, giving $7m^3$/sec against 2KPa

- but the surprise was that near the circuit ductwork the noise was much greater near the heat exchanger; there must be some responding resonance in the exchanger's structure.

Happily the consultant's so far erroneous preconceptions did not prevent him from measuring the noise near all three heat exchangers. And even more happily, at a subsequent meeting with operating staff someone said "Why don't you come back when it really makes a noise - when we run the exchangers with hot gas flow?" This is the sort of remark which world-weary consultants tend to ignore; but in view of the professionally disconcerting fact that most people with normal hearing are able to make a competent acoustic analysis, the site visit was extended to measure the noise with the hot gas being circulated. The change in noise level was remarkable.

At this point, the paint-spraying installation needs to be described. Warm air is passed through the oven to dry the cars quickly; this air, which is full of paint solvent, is then incinerated and produces a very hot exhaust gas. This passes through a heat exchanger tube, over which the air coming into the paint-spraying booth is taken so as to pre-heat it. In both cases the air circuits are driven by large centrifugal fans. The suspect circuit in this instance was the air flowing at 10 m/s over the heat exchanger tubes, not the air flowing inside the tubes.

Figure 1 contains a sketch of the installation and details of the heat exchanger elements. Each exchanger has banks of ellipsoidal tubes with short conical needles approximately 25mm high, 3-6mm in diameter, spaced on a 13mm grid across Figure (1b). There is an array of 10 parallel rows of tubes, their long direction horizontal and normal to the inlet flow of cold air. The two smaller exchangers are 0.68m wide, 1.15m high, and 2.16m deep; the larger exchanger has slightly longer tubes, 1.04m, and 12 of them as opposed to 10. Figure 1a illustrates the installation, which consists of batteries of heat exchangers receiving the cold air from a Y section. After its fan-driven circulation, the air is drawn away to the drying ovens.

Measurements near one of the heat exchangers indicated an extraordinarily high noise level of 241Hz, with certain other strong discrete components. When the exchanger was heated up, the maximum frequency increased to 289Hz (Figure 1c).

And so ended the first site visit. The consultant, his preconceptions in ruins, returned to base for a quiet re-think. As a start, elementary predictions were made of possible resonances in the panels of the heat exchanger unit, the tubes, and vortex-shedding frequency from the tube array, and finally the simple horizontal and vertical acoustic resonances within the air in the unit.

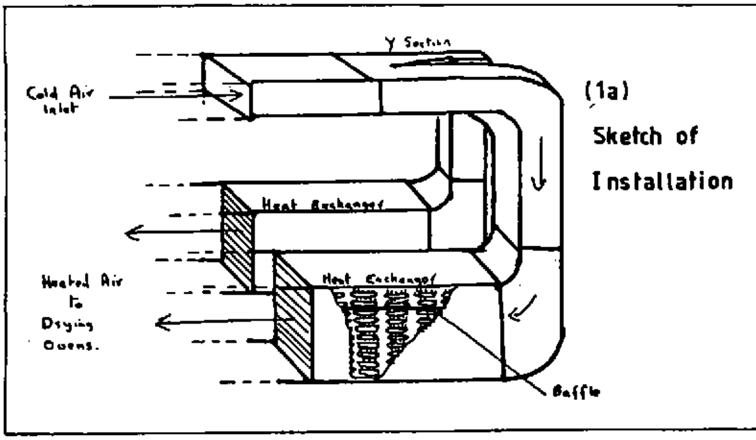
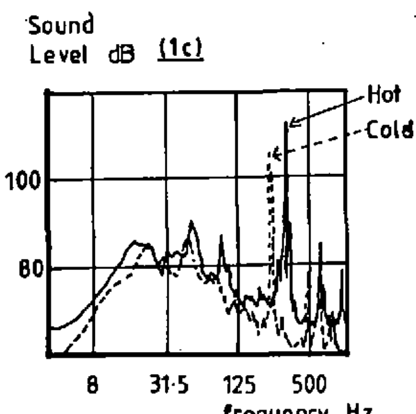
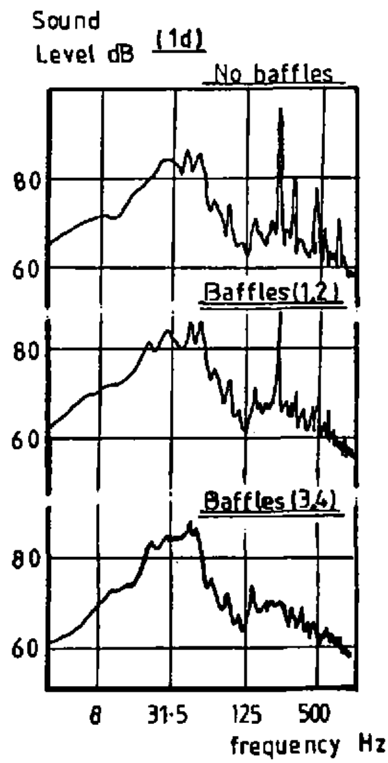


Figure 1 AERODYNAMIC NOISE

(1b) TUBE





The only theoretical explanation of the changes in frequency of the peak sound level with temperature, and which approximated to the frequencies measured during the first visit, was that some resonance was occurring in the air across the direction of the tubes. The predicted frequency was 245Hz compared with 241Hz measured on site with the exchanger running in cold condition. A second visit was arranged to test this hypothesis and to try to eliminate the problem.

Accompanied by the now anxious client, the consultant, armed with lengths of sheet metal, metal cutters, and sound and vibration transducers, set off to investigate one of the small exchangers.

The effect of flow velocity was checked by blanking off its front end; the noise could be reduced by 26dB by reducing the flow by 30%. The consultant was considerably interested in this result -the client less so, in that it seemed to have little relevance to his pressing needs. But at least it showed that the problem was related to flow velocity rather than fan noise. Accordingly it was decided to insert baffles across the front of the heat exchanger in both directions to see if this would cause the noise to reduce. It did not. Clearly an experimental break-through was called for.

Small thin strips of sheet steel were cut and pushed into the heat exchanger,all 2.16m of it, between the small needle-like projections on the heat exchanger tubes. Two complete vertical surface baffles were created between the tubes on one exchanger, and then another baffle was formed across the air circuit of the other exchanger. When the circuit was reactivated, it was immediately clear that something had changed. In fact the frequency had decreased from 234 to 223Hz, but the sound was still relatively noisy; the overall level had dropped from 96 to about 88dB(A) (see Figure 1d).

The client, much encouraged, was all for putting in more baffles and resumed his steel-cutting with enthusiasm. However, the consultant was wondering why the frequency had changed and whether there was much point in painfully stuffing more steel into this heat exchanger. But there was no denying the empirical evidence that there had been useful change (which had even been theoretically inferred), so the exercise was continued.

Eventually three baffle plates were inserted into one exchanger, and four into the connected exchanger. (Four hands were cut to ribbons in installing strips of steel 2.16m long and 50mm wide.) The tonal noise reduced by nearly 30dB, with no reduction in flow velocity (Fig 1d). The process was repeated on the other heat exchangers and the noise problem was solved. The management were delighted, and the paint-spraying operation started on time.

With hindsight, it is clear that the logical approach was adopted, and that the process of achieving the required result was only semi-scientific. It is also clear that the effect could not have been foreseen nor its amplitude predicted. The lesson to be learned is to collect as many facts as possible and listen to what people have to say, whether or not they are 'experts'. It is also relevant to note the recent work by R.D.Blevins, (1), on similar resonance effects in heat exchangers in a controlled test laboratory situation.

ISOLATING SUBWAY VIBRATION

About a year ago, the new Hong Kong Academy for Performing Arts[2] was commissioned and is now flourishing. It was built on a Site provided by the government near a helipad and a 6-lane busy urban highway. Even more problematically, the Mass Transit Railway (MTR) ran underneath the site, with trains passing every 3 minutes through tunnels about 20m below ground level.

At an early stage in the design process, it was decided that it was not financially viable for the whole building to be vibration-isolated. However, it was agreed that the Orchestral Recording and Rehearsal Hall (ORRH)[3] should be designed to be a room floating on springs, isolated from the vibration of surrounding building elements. The hall's dimensions were 30m long, 14m high, and 18m wide, see Fig 2(a). The Lyric Theatre next to it was not to be specially vibration-isolated, but all possible measures to investigate vibration-induced noise were to be taken. Here I am dealing with the problems which arose with the ORRH, where special vibration isolation measures were adopted.

Because of the initial decision taken to isolate it, little attention had been given to determining any existing vibration incident on the hall other than the frequency of structure-borne vibration caused by the MTR (Figure 2(b). On that basis, a mounting frequency of 10Hz was selected giving, theoretically at least, ample isolation.

However, as the hall's construction neared completion, it was abundantly clear that noise from the MTR was audible. As far as the client was concerned, the consultant had got it wrong. Personal reputation and confidence hovered perilously on the brink of oblivion.

The first action was clearly to monitor and measure the offending noise. The trains were inaudible when the site was busy, but when it was quiet and there was also no services noise, considerable peaks were recorded when trains passed underneath: 58dB in the 63Hz octave and 51dB at 125Hz. The consultant was convinced that the 'isolated' inner skin was connected somewhere to the unisolated containing structure of the Theatre block and advised that there should be a full inspection to identify and remove any rigid connections.

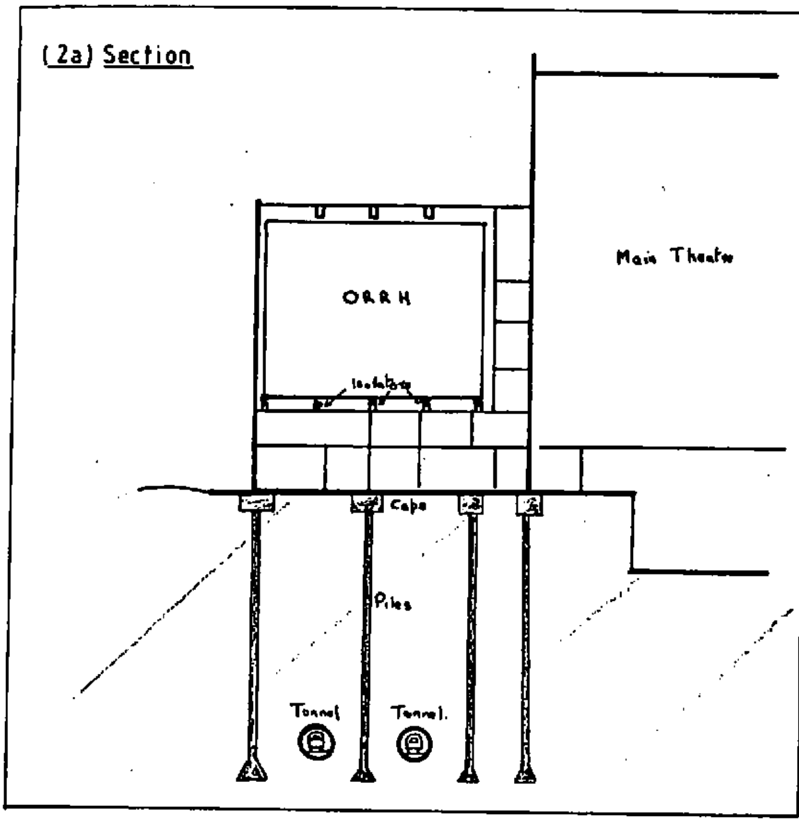
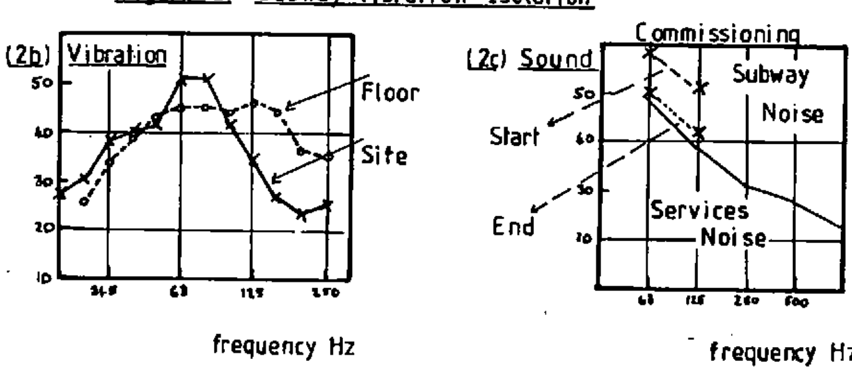


Figure 2 Subway Vibration Isolation



A few were found and rectified, but the audibility of the trains persisted. The consultant was asked to consider whether there were any shortcomings in the original design. The supplier of the isolating mounts were brought in for discussions and subsequently asked that the mounts be inspected insitu to ensure that the specified loadings had been achieved. They had not. None of the mounts was loaded to give the static deflection specified, so that the resonant frequency of the mounting system was about 13Hz instead of 10Hz. Despite this, and despite the fact that only limited data was available about the level of vibration incident on the building underneath the ORRH, it was clear that the mounts were slightly compressed and should be providing sufficient isolation. Further extensive noise and vibration measurements were made, in particular within the cavity between the isolated 'floating box' and the rigid structure. As anticipated, numerous small bridging elements across or jammed into the cavity were revealed : rigid pipework for the sprinkler system, electrical conduit and trunking, steelwork, blockwork, rubble and even door entrances where the lobby vibration isolation was bridged. It was decided that all these items must be attended to and all openings in the inner shell completed before further tests were made.

With the date of handover imminent, a mount was checked by the manufacturer to confirm its actual performance. This was deemed satisfactory. Meanwhile the on-site problems remained unresolved. Discussion then began about the lateral restraint pads which had been put in, in theory just to touch, to prevent the inner box rocking. This is standard practice where a building is liable to be affected by external forces; in this case they had been put in at the manufacturer's suggestion as a safety precaution. The consultant was concerned that if the pads were just touching but unloaded, they would have no isolating function and would in fact transmit any vibration from the outer to the inner shell. At this desperate point, an element of luck crept in. The loading difference on the pads that would result from the temperature variation between the hot weather at that time and the cooler period when they were installed was computed; there was likely to be a deflection of about 2mm. On site, 6 pads were measured and the average actual deflection was 2mm. Six that could be reached were slackened off and the noise from the MTR trains reduced by about 3dB at both 63 and 125 Hz. Subsequently all the remaining restraint pads were slackened and removed with a further improvement in noise reduction.

Three days were then spent inspecting virtually every inch of the cavity after special access holes had been cut into it. This confirmed the satisfactory isolating performance of the pads, the integrity of the inner shell, and the absence of significant bridging elements. However, a number of minor items had to be painstakingly removed and refitted and elements of the services ductwork re-routed. During all this attention to minute detail argument continued as to whether the now considerably reduced level of train noise would actually disturb users of the hall and whether attending to such apparently trivial defects would have any demonstrable effect on such a gigantic room. The consultant took the view that as the existing isolation was still much less than what should have been achieved, all bridging items, however miniscule, must be rectified.

When this had been done and the services system was operational for the first time, further measurements were made. Taking an average of 10 train movements, with a background noise level of 46dB, the measured level of train noise was 50dB in the 63Hz octave. In the 125 octave, the background was 38dB and the train noise 42dB.

The consultant still found that thetrains were still slightly audible above the services noise when listening alone in the unoccupied hall, Figure 2(c).

However, a significant improvement had been achieved by concentrated attention to detail, and the hall has since been used for music rehearsal, training, and digital sound recording. It came as a surprise that the recording engineers had not been aware of any noise from the trains.

During the course of this consultancy, it became clear that there was not a sufficiently accurate prediction method of either vibration propagation into and through a complex building or of the effectiveness of building vibration isolators. The general principles were clear enough but knowledge of any detailed effect was insufficient. Empirical information, such as that vibration levels often increase due to building resonances was found, but the magnitude of the effect was not predictable. In contrast the vibration attenuation from lower to higher storeys of the building, often quoted as 1-3dB/storey(4) was not found; in fact some tests showed higher levels at upper levels.

At the recent ICA congress in Toronto, J.G. Swallow(5) and T.J.B. Smith, R. Walder and C.D. Mathews(6) presented the results of careful scientific studies that will help the future design of vibration isolators.

In many projects, it is impossible because of economic constraints to adopt a policy of taking all reasonable empirically-based measures to produce the required result plus an adequate design safety factor. Suppose, for instance, that it was decided that all party walls should be built to a numerical requirement. (In view of the evidence that using apparently adequate constructions caused half of the party walls constructed to fail(7), this might be no bad thing). A 5dB safety factor would certainly be attractive; it would mean using a party wall of Dntw 57 so as to be sure to meet Dntw 52. As it is, one often uses 53-56 Dntw construction to meet the same requirement. However, given the constraints of the current climate the consultant needs to be rather more accurate.

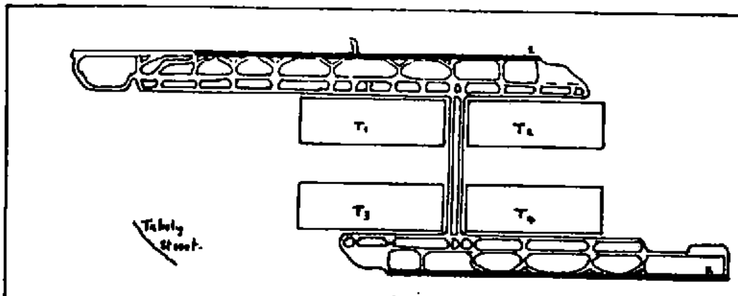
Some time ago, it was necessary to persuade a Client to increase the volume of his proposed concert hall by 15%, on the basis of a prediction of reverberation time (a parameter which tells little of the acoustic properties of a concert hall) and using a prediction method with little more than ± 15% accuracy. The economic implications were considerable and the data on which the advice was based were unreliable, the result luckily[8] was successful.

AN AIRPORT AND COUNTRY LIFE

The construction of London's third airport at Stansted in Essex is now underway. A few years ago, when the siting of the airport was still in question, the consultant was instructed to evaluate on behalf of the local community and their councils the impact of noise resulting from the construction and use of the airport on the basis of an annual passenger throughout ranging from 15 to 50 million, Figure 3(a). Much detailed prediction was needed, as well as special tests of aircraft manoeuvres, to demonstrate to the long-running Public Inquiry the likely degree of impact of the proposed new airport[9].

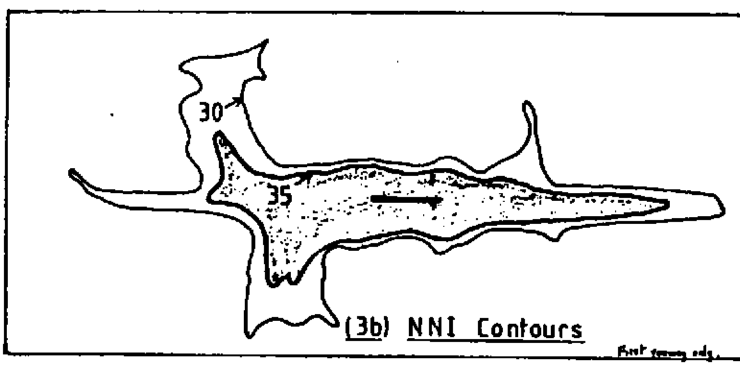
This was a situation where the database was complex and contradictory and where one had to struggle to maintain one's personal convictions in the face of continual criticism. One matter under discussion - it is still being discussed by those reviewing BS 4142 - is the importance of background noise in assessing the impact of new sounds upon an environment - in this case, the effect of noise arising from a large international airport on a rural area much quieter than those surrounding other major airports in the United Kingdom. Around Stansted there are no concentrations of population or industry, nor at that time any major transportation routes.

It was therefore decided to adopt a lower criterion for the low annoyance threshold (30 instead of 35 NNI, Figure 3(b))of people exposed to aircraft noise to allow for two effects - firstly, the background noise and secondly, the 'green field' factor. To allow for the 10dB lower level of background noise, the criterion was reduced by 2-3 NNI. This moderate precaution sparked off a prolonged and often heated exchange of technical information. At the first presentation to the Inquiry, 35 technical studies, 9 official policy references, and 9 practical cases of impact assessment were reviewed[10]. These generally, although not consistently, supported the importance of background noise. Subsequently 4 field studies [11-14] and 4 laboratory studies [15-18] were chosen to evaluate aircraft noise which concluded that for a 10dB increase in background noise, the impact in NNI reduced by 3-10.

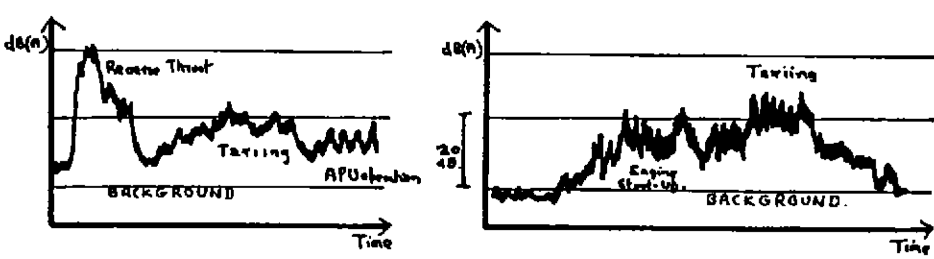


(3a) 50mppa Airport Plan

Figure 3 An Airport in a Quiet Area



(3b) NNI Contours



(3c) Sound Histories

Despite these results the opposition still postulated that the latest (unpublished) study proved the reverse. The consultant maintained that even if it did, this did not invalidate previous studies. The unpublished study might not reveal the effect of background noise but that did not necessarily mean that it had not occurred. The various expert witnesses were unable to agree on this matter and the Inspector was left to reach his own conclusions. I quote part of his findings[19].

".....There is no doubt that the background noise in much of the area is appreciable lower than around Heathrow and part of the Gatwick area, and it seems to me that background noise can be of importance when it has any masking effect in relation to other noise. When other noise is well above the background noise the position is different and background noise has little relevance when considering subjective response. Nevertheless I accept that there is something in the argument that some regard should be had to the 30NNI contour in the case of Stansted because of the more quiet invironment that obtains......".

Subsequently the airport development was approved, and in a few years we may find out whether or not the impact is greater than expected. However since then research has continued, and I am pleased to note the findings of C.G. Rice and K. Izumi [20] in 1984 who, in Heathrow [21] and their own laboratory study concluded that aircraft noise tends to be less annoying in high than in low traffic noise backgrounds.

However, the matter is not yet settled. Diamond, Walker, Critchley and Richmond[22], reporting in their study near Glasgow airport some of the findings from the CEC harmonising studies on the impact of environmental noise around airports, did not consistently find such an effect. When account is taken of the proportion of people surveyed expressing high annoyance with aircraft noise, most of the Dutch studies demonstrate slightly more annoyance in lower residual noise zones than in sites exposed to the same aircraft noise but with high residual noise. Half the French results are similar, and the latest Glasgow results have one group of data in support of the proposition, and two with contrary findings.

I have spent some time elaborating on this topic, because it illustrates well two common problems in consultancy: first which of our research colleagues to believe, and second whether to continue to search for the noise nuisance lodestone, by which I mean a simple noise criterion which will allow the consultant complete his noise predictions and state with some confidence that a development will not unduly disturb the community.

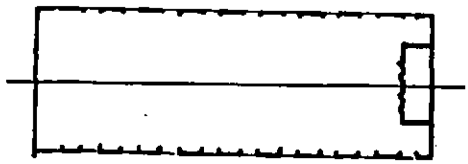
SPECIFYING A CONCERT HALL

About year ago a government agency asked for a detailed acoustic specification for a concert hall to be prepared as part of a building contract to be let. This, they assumed, would guarantee a good result.

Such a straightforward approach would be advisable if an adequate quantitative theory of concert hall acoustics had been evolved. But to date it has not, and in this example some of the factors taken into account and deliberated upon by the acoustic consultant faced with such a task are recounted. Before establishing the parameters finally adopted two important questions need to be raised and discussed: first, the wisdom of insisting on a traditional 'shoe box' shape for the auditorium, (eg the Vienna Musikveneinssaal), as rectangular shapes have long been held to be inherently better and less likely to fail. The second question was whether to use an electroacoustic system to produce a variable acoustic, which could possibly remedy any basic design defect.

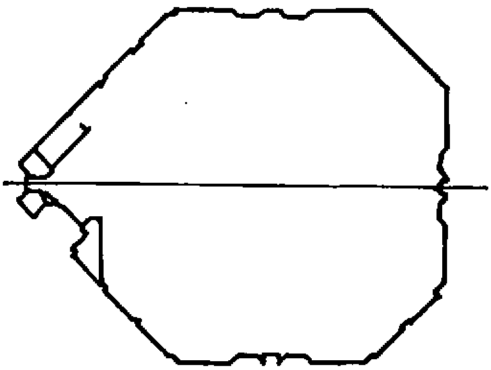
Although the rectangle has much to recommend it, good conditions for music has been achieved in numerous other room shapes. The plans of several non-rectangular auditoria used successfully for music are illustrated in Figure 4 . The consultant also recalled studies carried out in four rectangular halls in the United Kingdom, because of complaints of poor acoustics. Therefore, it was not considered valid to urge the designer of the new concert hall to copy past examples.

The decision about an electronically-derived acoustic was not so easily reached. A recent study by Ando[23] has indicated that the optimum acoustics for music varies between and even within pieces of music. For multi-purpose concert halls to approach optimal conditions it is necessary to "1) adjust the delay and amplitude of early reflections by electroacoustic equipment and control the absorption coefficiant of side walls; and 2) control reverberation time by using reverberators and by changing acoustic materials of several boundaries in the hall". This may be an extreme view,but many would agree that nowadays a concert hall has to deal with pop music, conferences, and many other activities as well as the vast range of serious music, and that the 'optimum' varies for each activity. For instance Reichart [24] has proposed and has been supported by many, that for his Clarity Index the value of Romantic music should be in the range -4.6 - -1.6dB, whereas for Classical music -1.6 - +1.6dB, only with variable acoustics could that be achieved. It appears therefore that in principle variable acoustics would be desirable if optimum conditions for all types of music are sought. An electroacoustically designed hall could be adopted instead of the usual practice of setting a natural reverberation time at 2 seconds, which will cope well with



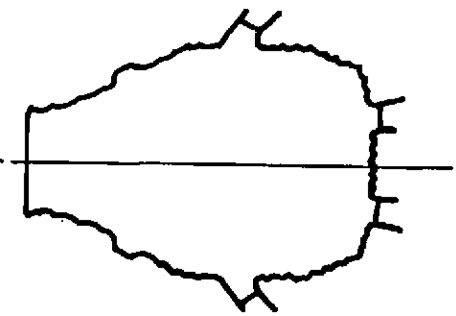
Musikvereinssaal Vienna

Figure 4 Concert Hall Plans



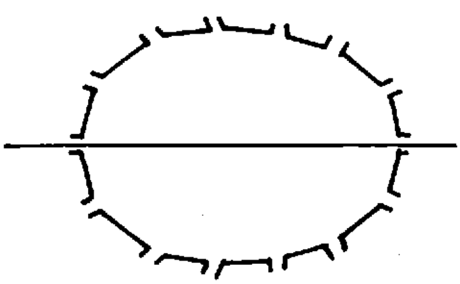
Musikcentrum Vredenberg

Utrecht

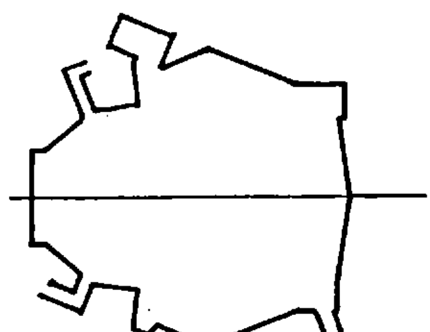


Joseph Meyerhoff Symphony Hall

Baltimore



Town Hall Christchurch



St Davids Hall Cardiff

most music but not with cinema or pop music. The natural reverberation could be set at 1 second, suitable for cinema and pop, and increased to whatever was suitable when the serious music was performed. An advantage of the electroacoustic design would be that instead of having to create a huge volume of air to produce a high natural reverberation time, smaller and less costly halls could be produced which used electronics to recreate the desired acoustic effects.

However, the track record of electroacoustic systems is so far not well documented although there is some information about the effectiveness of Assisted Resonance Systems (installed in eleven halls[25]) and the Multi-Channel Reverberation System[26] in extending the reverberation time. While this parameter is useful, it neither encompasses all the attributes necessary for a good concert hall, nor establishes the need to adopt the radical electroacoustic approach.

A recent project reported to the Institute [27,28] improving the acoustics of the Central Hall of York University, where an Assisted Resonance System had been installed. Due to cost constrictions, it only operated within the frequency range 70-922Hz but it caused a change in reverberation time, and effected the loudness and clarity of sounds in the hall Table 2. More surprisingly, it changed not only the late energy in the hall but also the early sound energy. But to return to the specification project, it was decided that the electroacoustics option was as yet insufficiently advanced to be totally reliable.

The specification therefore required:

a) Quietness

- Background noise shall contain no distinguishable tonal or impulsive characteristics.
- At any seat, continuous background noise from mechanical services shall not exceed NC20.
- At any seat, with background noise from other sources, peaks of noise shall not increase the continuous background noise level by more than 1dB in any octave.

b) Reverberation Time (RT)
(halloccupied)

Reverberation time (RT) in seconds at frequencies (Hz)

63	125	250	500	1000	2000 (Hz)
2.4	2.4	2.2	2.0	2.0	1.8

c) Other Acoustic Parameters

Early Decay Time (Edt) (29) Table 3

To be within 10% of (RT) values.

Clarity (Ratio of early (80msec)/Late Energy) (30) Table 4

To be in the range 0.0 - 2.0 on average, and within a small range about the hall.

Total Sound Level (31) Table 5

To be greater than 2.0, with a small range allowed in the auditorium.

Despite these relatively clear numerical criteria, all of which could be met in an auditorium, the acoustics still might not be deemed optimum. To try to overcome this the following qualitative notes were added:

a. There shall be no echoes, or flutter echoes

b. There shall be adequate diffusion of sound at all frequencies.

c. There shall be adequate distribution of reflections, particularly lateral.

d. There shall be no coloration of sound.

e. There shall be an adequate performing space in which musicians can hear themselves and each other.

If anyone ever actually built an auditorium to this specification, a good concert hall should be produced. The main areas of concern are the lack of an adequate quantitative description of diffusion, a readily usable parameter for lateral sound, and, perhaps of most importance, an adequate detailed comprehension of the parameters necessary for a good orchestral platform.

This example illustrates once again the lack of an adequate data base for this kind of consultancy work. There is clearly a need for more research, with the objective and subjective results published in the form of a consistent set of parameters for real applications.

EPILOGUE

These four examples have illustrated different aspects of acoustic consultancy work. I believe they indicate that existing knowledge may readily be applied to help solve problems but that it is often insufficient to cope with the technicalities of such problems, so that the consultant has to fall back on his craft. This has often provided sufficient in the past. However, now we are moving into an age where the actions and decisions of the acoustic consultant, as with practitioners in other professions, are liable to become the subject of legal retrospective inquiry. It would seem that either less consultancy advice should be given or a better and better proven database and prediction technology will be required.

My belief is that more and better consultancy advice is required at the start and throughout major projects, and to bring this about I offer the following suggestions to the relevant bodies involved:

1. To the training institutions. All students of acoustics should spend a period in consultancy as part of their training; and specialist post-graduate courses should be arranged for re-training!

2. To fellow consultants. We should feedback into the profession our experience and results (by persuading the Client to not insist on confidentiality). I cite as an example on how to communicate the excellent book by the late Dr V Jordon [32]. The purpose of this feedback would be to inform the profession of problems so as to allow researchers to incorporate appropriate information into their studies, and to progress the subject by contributing ideas based on practical experience. There is a large quantity of useful data and experience that needs to be made generally available.

3. To our research colleagues. Real buildings and real machines should be used in any theoretical or laboratory research. I cite the work of Professor Richards[33] on impulsive noise in the laboratory and in the factory.

4. To the government. I would remind them that voters have ears, and hope that the Institute's work in the Noise Council will be heeded.

5. To our Institute. Please keep up your leading role i our developing profession. More technical discussion of topics at 10A meetings would be beneficial, as I know from passed experience of organising meetings for the Institute, when I often failed to assign sufficient time in the programme for adequate technical discussion. In my view, this leads to confusion rather than enlightenment.

6. And finally to myself. I suggest that I continue to relish the challenge and variety of the practical application of acoustics and the inherent continuous process of learning.

ACOUSTIC CONSULTANCY : AVAILABILITY OF
SUFFICIENT QUANTATIVE TECHNOLOGY

CONSULTANCY TASK defined by Machine or Building Type	Availability of Adequately Accurate Technology			
	Prediction		Fundamental Design	
	Scientific	Empirical	Principles	Details
Electrical Power Transformers	-	x	x	?
New Layout of Cathedral Organ/Choir	x	x	x	?
Airport Noise Impact on Schools	-	?	x	?
Sound Propogation in Steel Houses	?	?	x	?
Lead Ball Mill	-	-	?	-
Noise Reduction in Kegging Plant	-	?	x	?
Stage Design for Performers	?	?	?	-
Ground Noise Aircraft Emission	-	-	?	-
Noise Reduction of High Speed Mincer	-	-	?	-
Reverberation Time in CCTV Studio	x	x	x	x
Acoustics of Debating Chamber	?	?	?	?
Underground railway vibration to above	-	?	?	-
Effect of Background Noise on Impact	-	?	?	-
Vibration Isolation of Studio	?	?	x	?
Electroacoustics System for Theatre	?	?	?	?
Noise Reduction of Explosive Oats Gun	-	-	?	-
Acoustics of museums	-	-	?	-
Airport Noise Incident on sideline Hospital	?	?	?	-
Intelligibility in Children's Theatre	?	?	?	?
Noise Nuisance of swimming pool pumps	-	?	?	-
Induction motor noise	?	x	x	?
Heat Exchanger noise	-	-	?	-
Cinema Acoustics	x	x	x	x
Control of Damper Noise	?	?	?	-
Facade Insulation against aircraft noise	?	?	?	?
High Pressure Compressors	-	-	?	-
Sound Insulation in Student's Hostel	?	?	?	?
Acoustics of Libraries	-	-	?	-
Press Shop Noise Control	-	?	?	?
Exclusion of Lorry Rumble from Houses	-	?	?	-
Road Vehicle Pass-by Testing	?	?	?	-
Mounting Terraced Houses	?	?	x	?
Vibration Attenuation in Ship Structures	?	?	x	-
Cider Bottling Noise	?	?	x	-
Sound Conditioning in Offices	-	?	?	?
Noise Impact of Lorry Park	-	-	?	?

Contd/..

ACOUSTIC CONSULTANCY:AURAL CRAFTMANSHIP WITH SCIENTIFIC PRETENSIONS

CONSULTANCY TASK	Prediction		Fundamental Design	
	Scientific	Empirical	Principles	Details
Nuclear Gas Circulators	-	?	?	?
Community Response to Diesel Testing	-	?	?	?
Audience Conditions in City Hall	-	?	?	-
Concrete road surface, noise impact	-	?	?	-
Noise reduction of V.A.V. units	?	?	?	?
Acoustics of Control Rooms	-	?	?	?
Noise emission from steam dumping	-	?	?	?
Stage Lift Vibration	-	-	?	?
Noise control for Fume cupboards	-	-	x	?
Electroacoustic system for Chapel	-	?	?	?
Vibration damage in historic buildings	-	?	?	-
Infra Red Milk Homogenizer Noise	-	-	-	-
Sound Emission from Bridge Structures	-	?	?	-
Noise emission from sewerage plant	-	?	?	-
Impact Sound from Dance Studio	-	-	?	-
Inaudibility in College Dining Hall	?	?	?	?
Cooling Tower Noise	?	?	?	-
Vibration Propogation through Foundations	?	?	?	-
Specification of Opera House Acoustics	-	?	?	-
Traffic Noise Propogation in urban areas	?	?	?	?
Aerodynamic Noise of rotors	?	?	?	-
Sound Insulation between Music Rooms	?	?	?	?
Standby Gas Turbines	?	?	?	-
Auditoria Acoustics for Audience	?	?	?	?
Structural response of Tunnel Linings	?	?	?	-
Plant room noise breakout	?	?	?	-
Intelligibility in Conference Auditoria	?	?	?	?
Noise emission of Aggregate Yard	-	?	?	-
Electroacoustic System for Prayer Hall	?	?	?	?
Noise emission from incinerator plant	-	-	-	-
Flanking sound assessment	?	?	?	-
Aircraft Maintenance Noise Emission	-	-	?	-
Intelligibility in a Circular Church	?	?	?	?
Noise Propogation from Motorway Intersection	?	?	?	-
Sound Insulation of Moveable Floor	?	-	?	-
Impact Insulation of floating floors	-	?	?	?
Open plan office acoustics	-	-	?	?
Noise Control of Performance Power Amplifier	-	-	?	-
Noise nuisance of water pump	-	-	?	-
Acoustics of pop studio	?	?	?	?

* N.B. Scientific, according to theory laid down in exact science, relating measurable non acoustic parameters to acoustic value; Empirical, based on observation of similar circumstances, not theory supported.

: (x) adequate data base, (?) some data base, (-) insufficient data base

Parameter	Frequency Band, Hz			
	125	250	500	1000
Reverberation Time				
A.R. off	1.4	1.2	1.2	1.2
A.R. on	1.8	1.6	1.4	1.4
Early Decay Time				
A.R. off	1.6	1.1	1.1	1.1
A.R. on	2.3	1.6	1.3	1.3
Clarity				
A.R. off	+1.5	+3.9	+3.8	+3.5
A.R. on	-1.5	+1.2	+2.5	+2.8
Total Sound Level				
A.R. off	2.7	4.0	5.3	5.5
A.R. on	3.8	4.9	5.8	6.2
Background Sound				
A.R. off	47	38	31	26
A.R. on	48	38	31	26

(See Reference 28)

Table 2 : EFFECT OF AN ASSISTED RESONANCE SYSTEM

N.B. System has 72 channels, and operates in frequency range 70 -922Hz only, installed at University of York. Values measured by Dr. M. Barron, University of Cambridge and W. Stevens of AIRO Ltd.