

50 Years of Control Room Design

by Jan Voetmann

Introduction

Sound control room design is an interesting part of small room acoustics and represents most of the problems from small room acoustics in general: Frequency-balanced reverberation time, proper distribution of room modes, low-frequency reproduction, sound source and receiver positioning, etc.

It should be recalled that the function of the control room is twofold, which is often overlooked:

On one hand the control room is the “tool” that – together with the monitor loud-speakers or vice versa – should illustrate or auralize the sound engineer’s (and producer’s) efforts in the creative process of the new recording or music production. This process encompasses putting tracks together, adding sound effects, balancing the mix, creating “space” around the instruments and the vocal, etc.

On the other hand, the control room should also mimic the acoustics of an average living room when checking of the final result of the recording, simply because most musical productions, whether on CD or in broadcasting, are aimed at the listening environment of a living room. For the same reason a number of investigations has been dealing with the acoustics of the living room.

This paper attempts to give an overview of sound control room design over the last 50 years, from the control rooms in broadcast and recording industry in the 1950’s up to today’s standard listening rooms aimed at detecting differences in modern bit reduction systems. Different and sometimes quite controversial “schools” popped up during the period and will be described. Basic acoustical design considerations of these schools will be discussed and examples of characteristic designs shown.

The paper will concentrate on the room acoustical aspects of the control room. Neither sound insulation, nor HVAC, nor control room equipment (except a little about loudspeakers) will be discussed.

A note on the reverberation time should be mentioned here. Some acousticians claim that the term reverberation time should be or already is earmarked to the situation where a stationary, diffused sound field is built up and after seconds interrupted. The decay time of the first 60 dB after the interruption is by definition the reverberation time. A stationary, diffused sound field is not being built up in a control room because of the heavy sound absorption, so it is not possible to talk about reverberation time in this situation.

Listening to a bass drum kick in two different control rooms with and without adequate absorption of low frequencies gives you two very different perceptions. So what are you listening to, reverberation time or decay time?

From the author's point of view the best measure of the perception of the impulse response of the room is the reverberation time (or maybe: the early decay time). But it is also crucial to look at the normal modes of the room, and realize that *the decay of the sound is the decay of the eigentones of the room (or the room modes)*. All other tones not being eigentones will disappear immediately when the sound source is interrupted. So having this in mind, the term reverberation time will be used here as one of the important metrics to characterize the room.

Control room design in the 1950's

It is characteristic that most of the development of control room acoustics took place in the USA, and that the interest in building better control rooms began in recording studios for pop music at the time of the introduction of stereo recordings in the mid-fifties. From pictures of that time the control room was a small acoustically untreated or randomly treated room, typically placed in the corner of the studio or as an excrescence on the studio box.

The author did not find anything about the acoustical conditions of these early control rooms, only vague descriptions of the acoustics of the studio, and without measurements. But it should be remembered that in those times acoustical measuring equipment was rare, heavy, not portable, expensive and mainly belonged to acoustic laboratories. So, for many reasons this kind of equipment was common to the studios, and therefore very little documentation exists.

A small number of great, dedicated designers showed up at the time, and around the recording sessions they were doing nearly everything by themselves. They spent all their time and efforts in order to get the recordings sound as fine as possible, inventing new gear, building their own mixing consoles as well as reverberation chambers and microphone preamplifiers, creating new sounds effects, etc. They based their judgment mainly on what their ears told them. Documentation in the shape of acoustical measurements was not backing their judgments, or at least it has not been possible to find such documentation.

Sound absorbent materials had been documented through laboratory measurements for many years, and those measurements were used as basis for the design of at least the studios. Most of the absorbers of the time were either perforated plates of wood with mineral wool behind, or fiberboards with holes drilled into the board ("Cellotex"). These absorbers were typically mid-frequency and high-frequency absorbers, and the documentation rarely went below 125 Hz. So, the room behavior regarding low-frequency reverberation time was more or less disregarded and beyond control.

At that time stereo was becoming the new recording technique, and it started a genuine interest in design of a new type of control room. *Symmetry along the median plane* through the room became an important issue in order to keep the stereo picture stable, and many of the old control rooms could not be redesigned because of this. It was time for interesting experiments such as the horn-coupled control room designed by Bill Putnam, and also Mike Rettinger was active as a designer and also an author of a number papers and books about studio and control room acoustics.

A New Generation of Control Rooms

At this time a new generation of control rooms popped up, mainly because of the attention on stereo reproduction. One of the important designers was Tom Hidley, engaged in building new studios early in the 1960's for major American recording companies and with a keen eye

to the acoustics of the control room. He has published very little about his design ideas, but in a rare interview he relates to the time, when he was working as a sound engineer in Hollywood. The company staff often went to the flat roof of the building to spend the leisure time between recording sessions. They installed a set of well-known professional monitor loudspeakers on the roof, so they could relax and listen to music. In the interview Hidley explains that these loudspeakers, playing in an open hemisphere, to him was the best sounding loudspeakers he had heard, and he wanted this impression to be found in the control room.

In this statement we have a description of an interesting acoustic situation. The loudspeakers are emitting sound in an almost perfect 2π -space with the roof floor as the only reflecting surface. *And with no reverberation at all.* When this situation is transformed to a real room, we are looking at a semi-anechoic room which is not desirable for several reasons. One reason is, that it is practically impossible to realize within the size normally reserved for a control room. Another reason is the earlier mentioned second purpose of the control room, namely to act as a kind of living room enabling you to evaluate how the final production will sound in a “real” room. The sound perception of the semi-anechoic room is simply too far from our daily experience.

Hidley’s interpretation of the sound perception on the roof was realized in a series of control rooms, with the following common features:

- Absolute symmetry along a median plane in the room to create a stable stereo image
- No reflections coming from the back wall
- No reflections coming from the ceiling
- Monitor loudspeakers built into and flush mount with the front wall of the room
- A short reverberation time of the control room down to and including low frequencies (the 63 Hz-octave band)

The latter was already mentioned by designers such as Bill Putnam and Mike Rettinger, and this might be the most important single acoustic parameter of the control room.

For unclear reasons early reflections along with the direct sound from the monitor loudspeakers in the front of the room were accepted and recommended by the Tom Hidley. One very practical reason is of course the window to the studio, as it is widely preferred to have visual contact between the artists in the studio and the sound engineer and producer in the control room. No specific explanation of this substantial deviation from “the acoustics on the roof” situation has been found. Some descriptions are discussing the importance of diffuse early reflections from the front end of the control room, but not why. Exactly this point was later heavily discussed by a group of other control room designers.

In his early designs Hidley introduced a reflecting canopy above the mixing console. The reason for this never became clear either, and the canopy was removed in later designs.

In order to obtain as much sound absorption in as broad a frequency range as possible Hidley created his famous “bass traps” consisting of elements of mineral wool hanging vertically side by side at a height of maybe 2-3 meters. The effect can be compared with the effect of the mineral wool wedges of an anechoic chamber. The wedges create an impedance matching between the air and the rigid boundaries of the room, so there will be no (or very little) reflection from the boundaries back to the room. Because the length of the bass trap (or of the wedge) along the direction of the sound the effect can be extended to rather low frequencies, e.g. 50 Hz.

A peculiar detail is the name “bass trap” as the absorber is not especially effective at low frequencies; it is in fact a broadband absorber, just like the sound wedge. The bass traps were never documented by laboratory measurements, maybe because of the difficulties of doing laboratory measurements at such low frequencies. An attempt to measure the bass traps was done in Denmark in the late 1970’ies by means of a large plane wave tube of concrete in the basement under the Danish Broadcasting Corporation in Copenhagen.

In 1982 Hidley was commissioned by the same Danish Broadcasting Corporation to design a new control room for the concert hall, called Studio 1. The concert hall was inaugurated in 1946, and the original control room was very small and unsymmetrical, typical of that time. Another larger space for the new control room was found, but without direct vision to the concert hall. Hidley’s ideas were modified by the house architects in order to make the room fit into the overall interior design of the (protected) building.

All the characteristics of a Hidley control room can be found here. The front wall with room for built-in monitor loudspeakers (they were later replaced by free-standing monitors, and the remaining holes in the front wall were filled with sound-absorbing material). The front part of the side walls includes both glass elements (daylight) and a stone wall giving diffuse reflections (!), and a cupboard on the opposite side wall was covered with a glass door in order to obtain symmetry. Bass traps have been installed above the ceiling to a height of approx. 2.5 meters, thus obtaining effective absorption down to low frequencies. This is also the case in the rear part of the room, where curtains are hiding bass traps as well.

The control room has a very flat reverberation time as a function of frequency, and the room was very favourably reviewed by the sound engineer’s right from the beginning. Most of the productions are classical music.

Later Hidley got another contract from Danish Broadcasting to design a new studio with variable acoustics for “modern” multitrack pop music productions. In this case two of the original old studios were reconstructed and combined into one, and a new control room of the latest design was included. The studio complex was inaugurated in 1984.

In this control room we find again some Hidley characteristics: The built-in loudspeakers in the front wall, the (hidden) bass traps in the ceiling and in the rear part of the room. But some modifications have been introduced. The original reflective front wall and front part of the side walls are now to some extent absorptive. And part of the rear of the side walls are now made reflective, rendering sound reflections back to the sound engineer in a diagonally fashion, meaning that reflections from the left monitor will hit back from the right, rear part of the room.

Why was that? To try to understand this we must go back a number of years to around 1978. At that time Hidley and his company Westlake Audio had built a series of highly successful studio complexes for major clients, both independent studios and large recording companies. But triggered by a new and revolutionary measuring technique called Time Delay Spectrometry, a completely new control room design appeared, and everything was changed once more.

TDS, Time Delay Spectrometry

In order to quantify the “sound quality” of the control room the so-called “house curve” is often used. By this a pink noise signal is fed to the monitor loudspeakers (one at a time) and picked up by an omni directional microphone at the listener’s position. The microphone signal is processed through a 1/3-octave spectrum analyzer, and the resulting curve showing

the sound level as a function of frequency is the “house curve”. Ideally this curve should be flat up to 1-2 kHz with a slight roll-off towards higher frequencies. The actual “house curve” is influenced not only by the loudspeakers, but also by the position of the loudspeakers and the microphone because of the modes (the eigentones) of the room. This is the background for introducing (sometimes substantial) equalizing of the signal fed to the loudspeakers. This procedure is sometimes misleadingly called “room equalizing”. To minimize the need for equalizing loudspeakers flush mounted with the front wall are often preferred, although with obvious practical disadvantages.

The use of the house curve introduces a serious problem because the use of a steady-state signal, which means that time-varying details cannot be detected, and the direct sound from the loudspeakers cannot be separated from the early reflections.

In contrast to this Time Delay Spectrometry is based on a time-varying signal, a sinusoidal sweep, fed to the loudspeakers. The signal is picked up by the microphone and analyzed by means of a narrow-band filter, which tracks the sinusoidal sweep in such a way that the filter is “open” exactly when the instantaneous tone in the sweep arrives at the microphone. Depending on the time delay between the instantaneous frequency of the sweep and the centre frequency of the narrow-band filter, different parts of the combined signal of direct sound plus reflections can now be separated and shown graphically.

This new measuring technique was invented by Richard Heyser in the late 1960’s for other purposes, but now it was used by Don Davis and Chips Davis among others to analyze the house curve in different control rooms. And in control rooms with hard, sound-reflecting front walls as in Hidley’s design, they could show that early reflections created “bumps” in the house curve leading to a less-than-optimum situation for the mixing engineer. In other words acoustical comb filtering was the result.

The Live-End-Dead-End Control Room

Around 1979 Chips and Don Davis introduced a completely new design concept and named it LEDE, Live End Dead End. The idea was, contrary to common practice at that time, to make the front end of the control room as non-reflective as possible, thus enabling the mixing engineer to hear only the sound from the loudspeakers. Because an anechoic control room is not desirable, reflections had to be reintroduced in some way. These reflections should not be specular, they argued; otherwise one would end up with the same disadvantages (comb filtering) as with reflecting front walls. Necessary reflections should come from the rear part of the room and be diffuse.

There are several ways of obtaining diffuse reflections, but an idea introduced by M.R. Schroeder in 1975 and originally intended for concert halls appeared to be very useful for the new control rooms.

Another aspect of the LEDE principle was the request for a minimum size of the room, especially a minimum depth of the control room. This caused sufficient delay of the arrival time of the early reflections at the mixing engineer’s position was the explanation given. Also in this design the overall request for room symmetry along a median plane as well as a controlled reverberation time down to low frequencies was emphasized. The live-end-dead-end principle quickly became successful among designers and engineers, and a lot of control rooms were made based on the principle.

The psychoacoustic theories behind the live-end-dead-end design have been much debated, especially the interpretation of the Haas effect into how you in the control room can hear the

sound being recorded in the studio. The Haas effect was originally a result of research of the audibility of a single echo, with two loudspeakers in front of the listener, one loudspeaker radiating a speech signal and a second loudspeaker radiating a delayed version of the same sound. The experiment was a mono signal experiment, and the relevance to the live-end-dead-end design was not clear.

In some papers it was recommended to let reflections come back diagonally from the rear of the room, and maybe Hidley (see above) got his ideas for Control Room 3 of Danish Broadcasting from there. Anyhow, from the pictures it is obvious that some-thing has changed drastically compared to his original design.

The “Reflection Free Zone” Principle

In continuation of the live-end-dead-end principle – or maybe as an extension – the “reflection free zone” concept was introduced by another group of designers (and manufacturers of diffusors) around 1984 as a logical step further. Based on a purely geometrical basis, the idea was to form the front part of the walls and the ceiling, in a way that all reflections were passing round the mixing area, thus letting the direct sound of the loudspeakers radiate unaffected. The approach is only valid for rather high frequencies, but as the goal was to maintain a stable stereo image, which is related to a frequency range from approximately 500 to 5000 Hz, the idea seems to be justified.

Interesting enough, thinking back, a large number of international top hits of that time were produced in studios and control rooms designed by Hidley, and suddenly a new control room design based on more or less complete opposite ideas was the only appropriate way. The situation was more or less triggered by the new TDS measuring technique, though interesting enough this was not connected to human sound perception. To the author’s knowledge no listening tests were made, except of the type where the designer and his client walk into the new control room making their judgment regarding the sound quality.

Documentation was typically made by means of a measuring technique able to reveal variations in the spectrum, which may or may not be perceived by the listener. As one critic puts it, the actual measuring situation corresponded to “a listener with one ear without the pinna, deaf on the other ear, and lying on one side!”

The real situation is, of course, a little bit different, namely: a listener with two ears with pinnae on either side of the head, and with a head and a body. A dummy head measuring system would come much closer to the real listening situation, but proper analysis methods and more psycho-acoustic understanding is needed.

The Control Image Design

Up to about 1990 most of the development of acoustic design of studios and control rooms took place in the USA. It was driven by and large by the big recording companies, in Hollywood and New York. In Europe the development took place mainly at the national broadcast corporations, which at that time had fine research laboratories and expertise.

Yet, there seems to be no original contribution to control room design within Europe until Bob Walker from the BBC came up with a new control room design around 1992-1993. His idea was to get a zone around the sound engineer without disturbing early reflections, more or less like the Reflection Free Zone design mentioned above, but without introducing huge amounts of sound absorbent material and the consequently very short reverberation time. Bob

Walker's design goal was a reverberation time closer to the living room standard, 0.3 to 0.4 seconds, and early reflections entering the listening zone should be down 15-20 dB within a time window of 20 msec.

The approach was purely geometrical, introducing a circle around the mixing position, placing the two monitor loudspeakers in front of that position and preventing any reflected sound rays from entering this circle. What shape of the adjacent surfaces could then be expected?

By means of a CAD computer program it became possible to draw up these surfaces, and some interesting new shapes appeared. They were modified into realistically shaped side walls, front wall and ceiling, and a test room was built at the BBC based on these principles. Free-standing loudspeakers are standard in BBC control rooms, so the design was meant to work in this case, where most of the design principles described above required or recommended loudspeakers to be built into the front wall.

To prevent this new design concept from being mixed up with the Reflection Free Zone principle it was named Controlled Image Design, CID. A number of control rooms based on this design were built by the BBC, and measurements done with a MLSSA-system. MLSSA (pronounced "Melissa") is a measuring system with more or less same attributes as Time Delay Spectrometry, but using controlled impulse trains in order to enhance the signal/noise ratio of the measuring situation. MLSSA documented the concept of CID and showed that the design goals were essentially met.

To the author's knowledge this design has not been implemented outside the BBC, although it contained some interesting viewpoints, especially by not requiring huge amounts of absorption material, which takes up a lot of space (and rent!). Maybe more important: Controlled Image Design room renders an acoustical perception closer to a real living rooms as opposite to control rooms with their very uneven absorption distribution and extremely low reverberation time.

The Non-Environment Control Room

During all the years where design of control rooms has been discussed, it has always been raised as a problem, no matter what design philosophy you preferred, that the sound of the recording/production changed more or less, when you moved from one control room to another (also within the same design concept). This, of course, leads to speculations of a design of a neutral space, letting you listen to the pure sound from the monitor loudspeakers without sonic influence from the room itself.

A recording situation being more and more international, meaning that the tape, the hard disc or the bit stream of the recording being passed from one studio to the next, adding tracks, effects etc. renders an increasing demand for preserving the sound of the recording during this process.

In order to make a final solution to the problem, Tom Hidley together with Philip Newell came up with a quite controversial proposal around 1991, where anything left of real room acoustics was set aside for the goal of having an absolutely neutral acoustical environment, the non-environment.

Despite earlier research pointing out that sound engineers preferred a "real" room (yet with a short reverberation time) contrary to an anechoic room, the non-environment proposed semi-anechoic conditions, where the only room surfaces left were the front wall and the floor,

acoustically speaking. The remaining walls and the ceiling were made (nearly) totally sound absorbent. Hidley re-introduced the “bass traps” (still “broadband absorbers”), and they will work down to around 40 Hz with enough space available. It has been claimed that they can be effective down to 20 Hz, but documentation of this has never been published. The bass traps are installed in the ceiling, in the side walls and in the back wall.

Not much documentation of the rooms has been presented so far, but the reverberation time must be non-existing. A number of the rooms have been built in England and Portugal by the original designers, and the sound of the rooms is being enthusiastically described, but the fact is that very few have been built; maybe because of the complicated and very costly design. The author is in line with the non-environment designers that the “absence” of acoustics in this type of room will probably preserve the sonic characteristics of the recordings much better, when taking them from one non-environment to the other.

Standard Listening Rooms

It seems that no real improvement or new design ideas in control room design have been introduced since the beginning of the nineties. Most of the development of small room acoustics has been focused on “well-behaved” listening rooms for studying loudspeaker configurations in multi-channel environments such as “home theatre” or 5.1 loudspeaker setups.

Another important application of controlled listening environments has been in the development of bit-reduction algorithms. In this case very small sonic differences – called transparency – between the bit-reduced signal and the original signal have been studied. From intense collaboration between industry and broadcasting a new standard for listening rooms was introduced, partly based on earlier work and standards for listening rooms in broadcast corporations and cooperating research institutions.

The final result is the EBU Tech. 3276, “Listening conditions for the assessment of sound programme material: monophonic and two-channel stereophonic” from 1997. This standard includes detailed requirements for a listening space for this type of research. All parameters discussed above are quantified in this standard: room dimensions and ratios, tolerance limits for reverberation time as well as room response, time window and level of early reflections, and background noise limits. The basic shape of this listening room is the box shape.

The EBU Tech. 3276 standard is the basis also for rooms for controlled listening tests with test panels for quality assessment of reproduced sound (e.g. loudspeakers) or for product sound quality (e.g. household machines).

Experience in using this standard as design criterion for new control rooms is sparse.

Summing Up

Looking at control room design during all these years it seems to have been quite easy to introduce controversial ideas in the field, and also to get these ideas accepted as long as some overall principles are maintained. One overall principle is to keep strong symmetry, which is related to the balance of multi-channel recordings, another principle is to have a controlled, short reverberation time down to low frequencies. The importance of early side wall reflections has yet to be discussed.

Over the years a small number of “schools” with quite different backgrounds seem to have dominated the main road of control room design. Besides these trends a large number of “individual” designs have been carried out.

There seems to be only limited documentation of the acoustic properties of the rooms, and most of the design has been based on assumptions or theories from quite distant and different fields, where the positive effect for the actual application has not been verified. Many of the designers were autodidact with limited theoretical knowledge within fields as e.g. room acoustics or psychoacoustics, and intuition has been a driving force. This need not be a limitation for designing good rooms, and many examples show that.

Documentation of the listening experience in different control rooms by means of a test panel could be very elucidating in order to select facts from myth. One way could be to record appropriate program material with a dummy head in a number of control rooms of interest and subjectively rank them according to preference by a listening panel. Recent experiments on transforming a listening experience to a remote listening panel by means of a dummy head have shown very encouraging. This has been the case e.g. in HiFi car audio design.

Also the developing of measuring systems based on dummy head recordings together with a proper two-channel analyses based on recent research results within subjective listening experience and room acoustical attributes might be the future for documenting the sound quality control rooms (and other acoustic rooms).

Conclusive Remarks

It has been the purpose of this paper to present different acoustical design ideas for control rooms during 50 years, in which period almost all major development in recording techniques has taken place. The author has been through a number of papers in order to make this overview as complete as possible and must be excused for any omissions or overlook.

It is hoped that this presentation would inspire fellow colleagues to dive into the field and come up with better explanations or ideas in order to quantify the overall sound quality factors in these small, but demanding spaces.

It has been interesting to collect and select the information presented here. Any correction, elucidation, or new information will be received with gratitude by the author.

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