

BALANCED NON-ENVIRONMENT CRITERIA FOR CONTROL / MASTERING ROOMS AND FOR MUSIC, A/V, GAME SOUND, & DUBBING THEATER 2.0 (STEREO), 5.1, 7.1, & DOLBY ATMOS™

John H. Brandt

John H Brandt Acoustic Designs

<http://www.jhbrandt.net>

Introduction:

Let's review the purpose of the control / mastering room:

The purpose of a control room for sound (any format) is to provide a clear, accurate, detailed representation of the recorded material in order to allow critical mixing/mastering decisions to be made.

A control room must **NOT**:

a. Add any sound character.

A room that has character is one in which the reflections, resonances, and absorption contribute to an effect. This effect is a change in the way that sounds are heard in that room which is different from other rooms that are used for the same purpose. For example; a recording of a ball bouncing on the hardwood floor of an indoor auditorium would instantly be recognizable as such. In contrast, noise created in any part of a Balanced Non-Environment room will not be recognized as coming from any particular room. Also due to the non-character of a Balanced Non-Environment room, excellent & un-colored recordings can also be made right in the control room.

b. Try to emulate domestic listening conditions.

It has been suggested early that a control room, mastering room, or critical listening room roughly duplicate the 'average' home listening condition in order to make proper EQ, pan, and level adjustments so that they will sound similar in any listening environment. [2] The author disagrees.[10] This does not make rational sense. It would be like asking a graphics artist to work on a display that had its color adjusted to 'vivid' or 'extreme color'. I know of some incredibly talented engineers who could actually pull this off, and do so, but that is not the point of this paper.

- c. Have early reflections or image-enhancing diffusion/diffraction - unless said diffusion covers the full frequency spectrum from the Schroeder frequency of the room up to a minimum of 5 kHz and provides a minimum attenuation of -20 dB. Therefore any diffusor used on the side walls or reflection zone areas must use a prime number of at least 101.

While an audiophile listening room or concert venue may be enhanced using side reflections and/or diffusion, [9] this is not a desired feature of a mixing or mastering room.

- d. Have room noise above NR-10. [6], section 2.6

Noise Rating curves
Octave band sound pressure level values in dB re. 20mPa.

NR Curve	Frequency Hz								
	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
10	62.2 dB	43.4 dB	30.7 dB	21.3 dB	14.5 dB	10.0 dB	6.6 dB	4.2 dB	2.3 dB
15	65.6 dB	47.3 dB	35.0 dB	25.9 dB	19.4 dB	15.0 dB	11.7 dB	9.3 dB	7.4 dB

- e. Have inferior isolation as to permit external noise to enter and degrade the NR-10 rating. [11], [12]

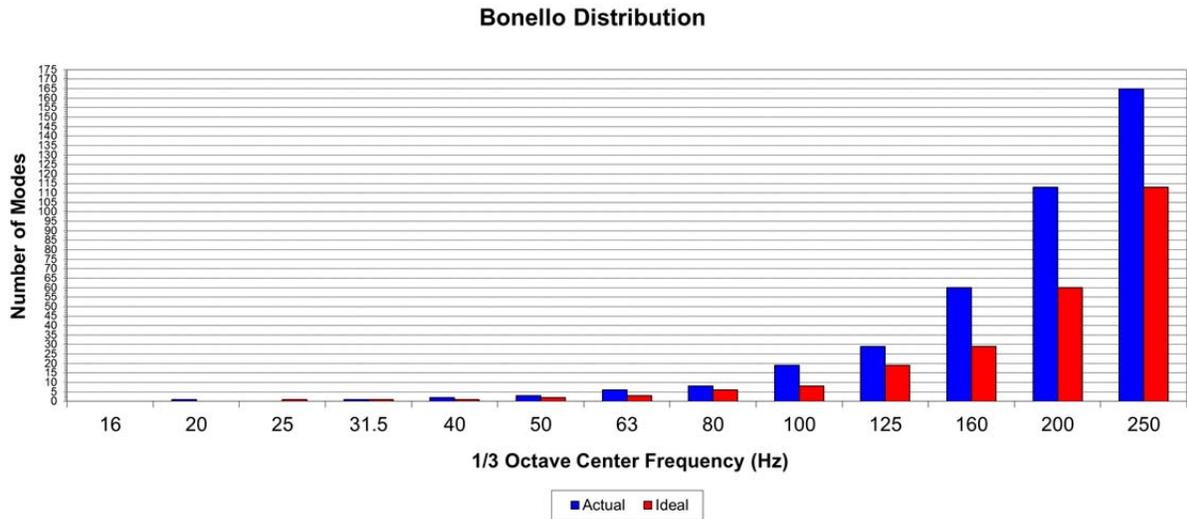
The most important, and sometimes difficult, issue in the design of the optimal control room is low frequency **control**. Low frequency optimization or the lack thereof is the major acoustic design flaw in most rooms, in the author’s opinion, that are used to mix music and film. It is this degree of acoustic control such as will allow the engineer to recognize and adjust the low frequency balance in the program material that ultimately displays the quality of the mix room.

The quality of a control, dubbing, or mastering room is displayed as a room in which one can produce a mix or product that translates to other rooms, theaters, venues, homes, and vehicles. Real world mix translation is the *Holy Grail* of design goals, because if you can produce a mix that sounds great on any system, anywhere, you definitely have hit potential. When an engineer is able to work quickly and repeatedly produce excellent results, it is a direct reflection on the quality of the work environment and acoustics.

Dimensions:

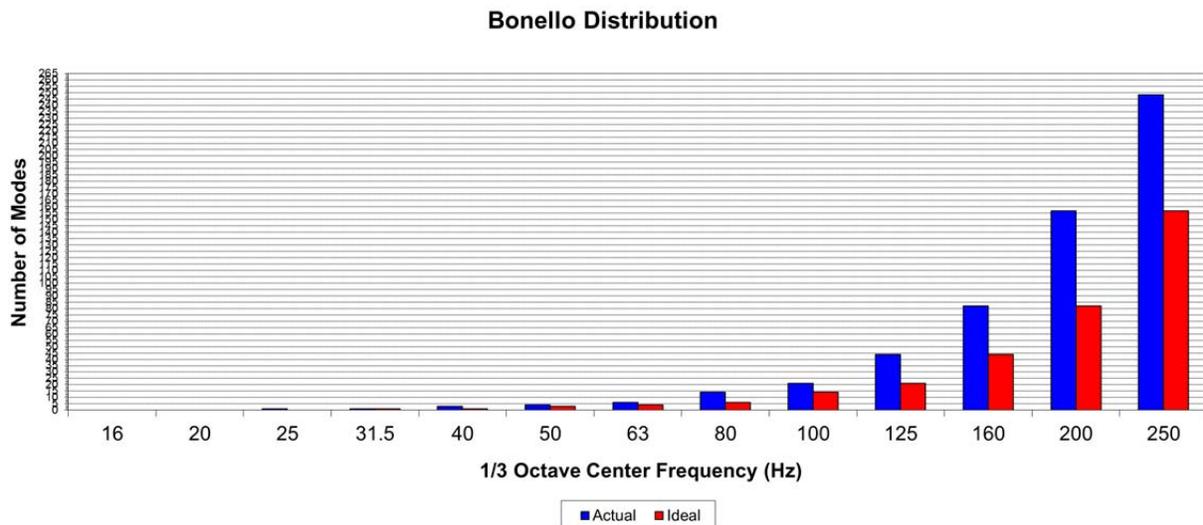
To qualify for Balanced Non-Environment certification the room must have a minimum volume of 120 cubic meters [4200 cu. ft.]. The ideal volume shall be ~200 cubic meters. The interior room shell must conform to a calculated ratio that is close to those proposed by L. W.

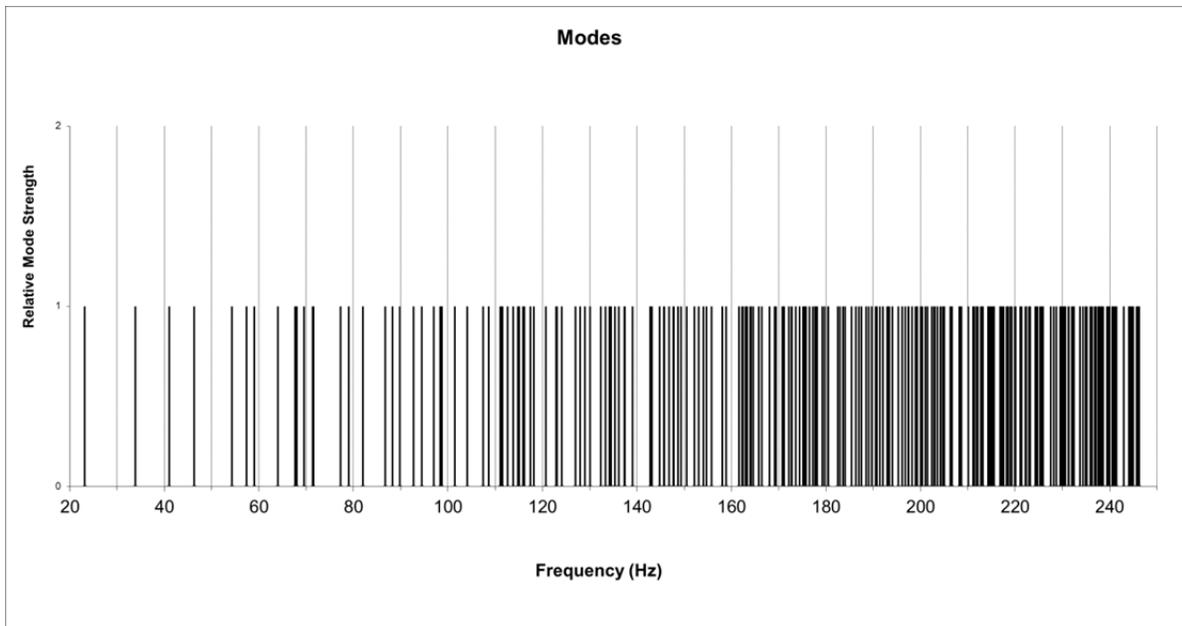
Sepmeyer, M. M. Loudon, or Richard H. Bolt, and is translated to the nearest prime numbers. For example; L. W. Sepmeyer ratio of 1 : 1.6 : 2.33 beginning with a finished ceiling height of 3.2 meters will result in dimensions: Height = 320, Width = 512, Length = 745 which, when converted, will result in prime numbers as; Height = 317, Width = 509, Length = 743. This room will have volume of 120 cubic meters.



The resulting interior enclosure will pass Bonello Distribution down to the 31.5 Hz 1/3 octave band. Uneven modal support in the very low frequency bands can be further smoothed by the deep trapping provided for in these criteria.

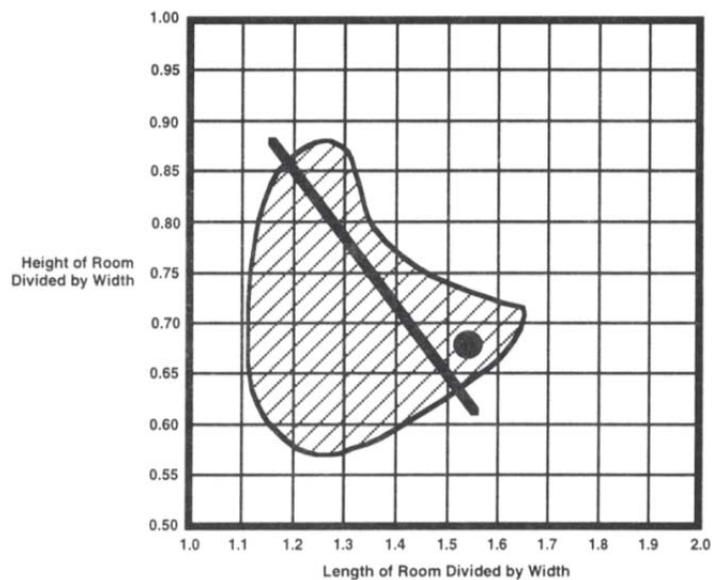
If a 'no-holds-barred' approach is requested, further refinement of the dimensions results in an 'ideal' room within the Bolt ratio of 1.00 : 1.26 : 1.59, resulting in dimensions; Height = 479, Width = 607, Length = 761. The room volume will be 221 cubic meters. The Bonello distribution chart below shows a 'pass' in all bands. This room will have a good response down to 25 Hz and below. After treatment the pressure zone will begin at/around 22 Hz. If non-ported or infinite baffle design speakers/subwoofers are utilized, room response down to 10 Hz is possible.





As shown above, the modal distribution of this room is very even all the way down to the lowest octave.

It should also be mentioned here that the 'best' ratios, as adopted by Dolby Labs for certification, are from Richard H. Bolt shown in the next drawing, and as stated in the Dolby certification documents, "Room ratios should be within the shaded area shown in the figure below and ideally close to the straight line."



Reflections:

Reverberation and reflections must be eliminated in any control, mixing, or mastering room.

However, a sense of ambience and the perception that one is 'in a room' are important parameters for a comfortable and fatigue-free environment. This is one of the reasons that LEDE and RFZ designs are so widely used. These rooms still sound like rooms. But the problem with only reflection control is the small 'sweet spot' and poor low frequency translation. If the mix engineer moves out of the 'zone', or moves about in one of these rooms, the optimal response is gone because there is far too much room sound (diffuse field) to really determine what's going on in a particular mix until they sit back down precisely at the mix position. Too often, this difference in frequency response and balance will cause confusion when the engineer is making critical decisions. This will cause more fatigue and delays in project completion.

The LEDE/RFZ criteria require a fairly high energy return to satisfy the ISD termination. The author of this paper maintains that these reflections create audible degradation of the signal, regardless of the location of the reflecting surface.

It should also be noted that today's production requirements are using less and smaller tracking areas compared to the past, therefore sizing a control room based on the tracking room is practically irrelevant. Therefore, how does one satisfy the provision:[15] "There is an effectively anechoic path between the monitor loudspeakers and the mixer's ears which extends for at least 2 – 5 ms beyond the studio's initial time delay gap."? - In the authors opinion it would be better to make the ITD gap of the control room as large as practically possible.

The sound received (source and reflected, time-delayed) by the ears is processed at a very high level by the brain, and subsequently filtered. But this is added brain stress in an 'already-stressful' work environment. Let us remove the need for this brain process and allow the engineer to focus his or her energies on mixing without subconsciously compensating for the errors in frequency response.

The acoustic designer's job is to create a space where the artist / composer / engineer / producer, can work. The spaces that are created are meant to make the job easier, faster, more accurate, and MORE FUN. Why not create a mix/mastering environment that shows all of the flaws in the program material so that the engineer is able to their job quickly, accurately, and enjoy doing it?

I believe, like Tom Hidley, that control rooms and mastering rooms should have no sound of their own and they should all be similar in response. They should add absolutely nothing to the source material. This is especially important in today's market, when work is done in many studios to complete a project. In each facility, the engineers should be able to hear exactly the same things so that there is good communication and understanding between producers and artists.

However, one of the main issues with the non-environment approach, as experienced by many, is that it can feel unnatural. This unnatural quietness can be discomforting to the subconscious, which in turn creates fatigue. Another issue is the requirement of a large space the greater amount of which is taken up with bass trapping. Adequate trapping can be applied to meet the ITB and EBU guidelines [3,4,5,6] within a reasonably sized space and within a reasonable budget using the Balanced Non-Environment design approach.

Control Room Design Chronology to 2000:

- 1935** - WGN Radio studio - large control room
- 1946** - Bolt – Note on Normal Frequency Statistics in Rectangular Rooms
- 1957** - Putnam - Capitol Tower studio - small control room
- 1962** - Berenek – Music, Acoustics & Architecture
- 1967** - Heyser – Acoustic Measurements by Time Delay Spectrometry
- 1969** - John Storyk designs Electric Ladyland studio
- 1969** - Tom Hidley designs first 24-track studio
- 1973** - Veale – The Environment Design of a Recording Control Room
- 1975** - Schroeder – Diffuse Sound Reflections by MLS
- 1977** - Rettinger – On the Acoustics of Control Rooms
- 1979** - Bonello – A New Criterion for the Distribution of Normal Room Modes
- 1979** - Don Davis and Chips Davis – The LEDE Concept for the Control of Acoustic and Psychoacoustic Parameters in Recording Control Rooms
- 1981** - Puddie Rogers - Pinna Transformation and Sound Reproduction
- 1982** - Hidley / Newell introduce the Non Environment control room
- 1983** - RPG introduce the QRD diffuser
- 1983** - Techron introduce the TEF System 10 portable TDS analyser
- 1984** - D'Antonio – The RFZ/ / RPG Approach to Control Room Monitoring
- 1991** - Newell – The Non-Environment Control Room
- 1993** - Walker (BBC) - Controlled Image Design - A new approach to the design of Control Room Acoustics for Stereophony
- 1996** - Andrew Parry - Early Sound Scattering
- 1998** - EBU Tech 3276 published

The **BALANCED-NON-ENVIRONMENT** Control Room

This design criteria is called the **BALANCED NON-ENVIRONMENT**, but not because control room design can be a balancing act, but because a balance is needed between the extremes of LEDE and NE - as well as the importance of a balanced frequency response in any critical monitoring environment.

It is a fact that LEDE evolved around the Urei 811C, 813C and 815C type monitors. The frequency response of these speakers were far from flat even when flush-mounted. In most of Tom Hidley's NE rooms, Westlakes, TAD, and Kinoshita monitors were used which offered a much better frequency response.

However, all of these monitoring options featured horn-driven midrange and HF and this is the main reason why it was said about the NE design, "*This type of room often has a limited area where the sound is best*"[14]. – Is, in the author's opinion, due to the narrow dispersion angle of the horn-loaded drivers.

Solution

1. Wide dispersion drivers coupled with soft-flush mounting in the control room front wall.
2. In addition to a modified NE criteria treatment application, we position attenuating diffraction/diffusion arrays in a way that will keep energy in the room longer WITHOUT interfering with the source signal. The room remains non-environment from the source to the mixer's ears.

This does two things;

- a. Remove the foreign (anechoic) environment.
- b. Broaden the sweet spot / mix area.

Most of our BNE rooms boast an extremely large mixing zone and it is said by many that the entire room is a sweet spot (perceived). The diffusion elements used do not return any sound higher in level than -20 dB and are time delayed by at least 20mS, relative to the source material.

The front walls of our rooms are designed to be absorptive with slat grating and mains are soft flush-mounted. Near-field monitoring is critical to starting and balancing a mix, therefore the near-field speakers must be able to perform optimally in our rooms along with the flush-mounts, when used.

The example below (Fig 1) shows a typical double shell room construction; room-in-a-room. The wall panels are constructed using wood 2 by 6s (38 mm by 152 mm), 3 layers of Sheetrock® brand Firecode® Core 5/8" (16 mm) Type X Gypsum Panels, 2" (50.8 mm) gap between wall frames, stud cavities and air gap filled with lightweight fiberglass insulation. This system will provide a panel resonance (lowest) of 15 Hz with useable sound isolation down to 22 Hz.

The interior room (shell) is dimensioned L = 6880.2 mm (270-7/8"), W = 4886.325 mm (192-3/8"), H = 3815.425 mm (150-1/4").

The primary room resonances will be; L = 25.0 Hz, W = 35.2 Hz, H = 45.1 Hz.

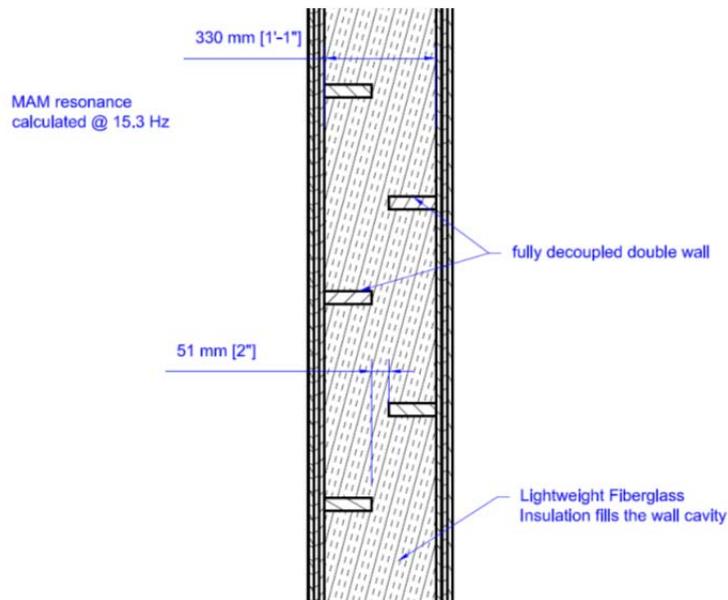


Fig 1

Typical BNE treatment plan (Fig 2) showing Flush-Mounted custom monitor:

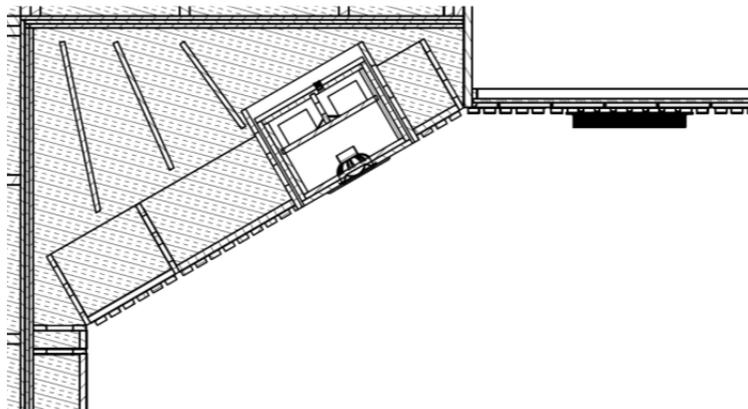


Fig 2.

The *Balanced Non-Environment* control/mastering room design criteria:

1) There is a low-frequency symmetrical outer shell and large enough to provide modal support of all the notes on a keyboard. (at least to 27.5Hz)

2) The low-frequency outer shell is complimented by a symmetrical inner shell, determined by ratio & prime numbers, which provides isolation mass-air-mass construction where the crossover frequency between the outer shell and the inner shell is equal to the square root of 2 (1.414) times the lowest modal frequency of the room. The room should be symmetrical relative to the vertical plane on the mid-perpendicular of the stereo base, and the floor area should preferably be in the shape of a rectangle or quadrilateral with one pair of sides parallel. The ideal volume being close to 200 cubic meters [minimum volume 120 cu. m.] with a room length to support 20 Hz wave response (8.63 meters).

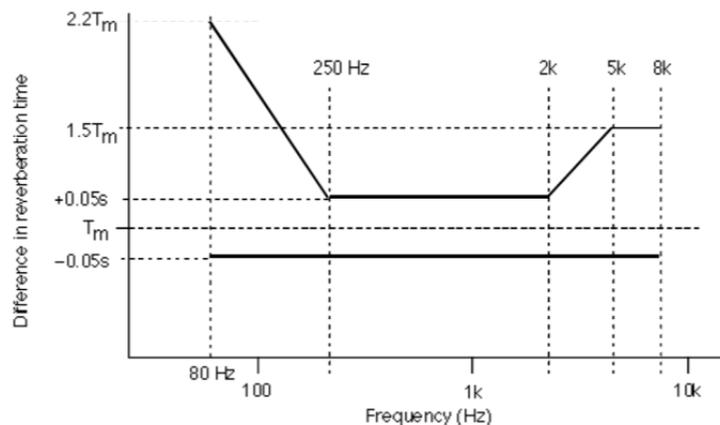
Note: symmetry is critical for left-to-right IACC – Inter-Aural Cross-Correlation or the absence thereof, depending on the application. It is most important to have left-to-right symmetry for frequency response balance irrespective of pan settings. [9]

3) Trapping and wave guides are integrated into the interior shell of the studio system and into the surface treatment to provide low-frequency damping to conform to AES [5], ITU[3], & EBU [4] standards;

$$RT60 = 0.25(V/V_0)^{\frac{1}{3}}$$

RT60 = nominal value T_m , computed as the average measured over the frequency range 200Hz-4KHz, which is linked to the volume of the room as the formula above, with V the volume of the room, and V_0 a reference volume of 100 m³.

NOTE: The low frequency absorption shall take into account the longest width mode (for side wall trapping), height mode (for ceiling trapping), and length mode (for front and rear wall trapping). The designer must also be aware of the cross-over frequency of the mam system interior partition so that low frequency trapping also complies with the formula above and agrees with the AES curve below. [5]



- 4)** There is an effectively anechoic path between the monitor loudspeakers and the mixer's ears, extending in time to at least 20 milliseconds after the source sound reaches the mixer's ears. Any sound returning to the mix position must be attenuated by at least -20 dB in level relative to the source signal at mix position.
- 5)** The Critical Distance (Dc) of the room will be at least the size of its smallest dimension. A diffuse field is to be avoided. See blog - CRITICAL DISTANCE, BASS TRAPPING, ETC. - link: <http://www.jhbrandt.net/critical-distance-bass-trapping-etc/>
- 6)** No early - early sound (EES) is present. This is sound that arrives at the mixer's ears ahead of the direct sound traveling through the air. All speakers shall be decoupled from the structure by any means that will ensure complete isolation at all operational frequencies.
- 7)** The front wall shall incorporate flush-mounted speakers in the treatment surfaces. The flush-mounted speakers are not mounted in a hard wall. The front surfaces of the room will be absorbers overlaid with reflection slats or similar into which the main loudspeakers shall be mounted. If the room is to be used for 5.1 thru Atmos, the spacing on the vertical slats must be based on a Maximum length Sequence (Binary) that matches the front wall from center to the side.
- 8)** All walls, ceiling, and work surfaces are so designed to provide a reflection free zone for all occupants of the room without measurable anomalies.
- 9)** Diffusion / diffraction shall be positioned to provide a room effect as one nears the boundaries. The diffusion/diffraction shall not interfere with the source material (reflections are at least -20 dB below source signal) and shall be designed to promote an even response in all parts of the room.
- 10)** A flat frequency response, in conformance with AES limits, should be perceived in the largest possible area (smallest room dimension) within the room.
- 11)** Background noise levels should be low and follow published recommendations (NR-10).
- 12)** The control room monitors should be able to reproduce the entire musical frequency range without distortion and be able to do this at various levels from very low to very loud.
- 13)** All electrical within the studio building shall provide for a zero loop area in the grounding connections between all audio wiring and all electrical wiring. An isolated ground system shall be installed and applied to all circuits to be used for audio purposes. Electrical wiring used for audio purposes shall incorporate twisted L & N throughout the building, as outlined in the Bill Whitlock - Jamie Fox AES paper. [8]

References:

[1] "Sound Reproduction - The Acoustics And Psychoacoustics Of Loudspeakers And Rooms" - Floyd Toole – Focal Press, 2008

[2] W. B. Snow, "Application of Acoustical Engineering Principles to Home Music Rooms," IRE Trans. Audio, pp.153~159(1957Nov-Dec.)

[3] "Subjective assessment of audio quality" - EBU Technical Review Winter 1997 - Hoeg et al. - link: [trev_274-hoeg.pdf](#)

[4] Rec. ITU-R BS.1116-1 1 - RECOMMENDATION ITU-R BS.1116-1 – "METHODS FOR THE SUBJECTIVE ASSESSMENT OF SMALL IMPAIRMENTS IN AUDIO SYSTEMS INCLUDING MULTICHANNEL SOUND SYSTEMS" – link: [R-REC-BS.1116-1-199710-S!!PDF-E.pdf](#)

[5] AES TECHNICAL COUNCIL - Multichannel surround sound systems and operations - Document AESTD1001.1.01-10 – link: [AESTD1001.pdf](#)

[6] "Listening conditions for the assessment of sound programme material: monophonic and two-channel stereophonic" - EBU Tech. 3276 – 2nd edition May 1998 – link: [tech3276.pdf](#)

[7] "Listening conditions for the assessment of sound programme material - Supplement 1" – link: [tech3276s1.pdf](#)

[8] "Ground Loops: The Rest of the Story" presented at the AES 129th Convention, 4-7 November 2010, San Francisco, CA, USA - Bill Whitlock - Jamie Fox – Link: [Whitlock-Fox+-+Ground+Loops+.pdf](#)

[9] "Architectural Acoustics - Blending Sound Sources, Sound Fields, and Listeners" - Yoichi Ando. AIP Series in Modern Acoustics and Signal Processing, 1998 Springer-Verlag New York.

[10] 19th International Congress on Acoustics 2007 - "ON THE USE OF A NON-ENVIRONMENTAL CONTROL ROOM AS A 5.1 SURROUND LISTENING ROOM"

[11] "Sound-Proofing: The Quest" JH Brandt, online publication 2013 – link: [Sound-Proofing](#)

[12] "How To Find How Much Isolation You Need" JH Brandt, online publication 2012 – link: [How To Find How Much Isolation You Need](#)

[13] "Diffuse Seminar, iRoom: Next Generation Critical Listening Room", by Dr. Peter D'Antonio of RPG Diffusor Systems, Inc. - link: [iRoom Blackbird.June 2006.rpg.pdf](#)

[14] A Study on Acoustics of Critical Audio Control Rooms - Bruno Fazenda 28/02/2001

[15] Beyond Control - Acoustics of sound recording control rooms – past, present and future - FAGO report nr: 03.23.G - B.J.P.M. van Munster 447662 - April 1 2003

See also:

Flush-Mount Speaker Systems and Control/Mastering Room Desks by JH Brandt.

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