UNIVERSITY OF TEXAS AT AUSTIN
ME 384N – ARCHITECTURAL ACOUSTICS

Survey of Audio Recording Environments

Dan Hemme

20 May 2013

TABLE OF CONTENTS

1. INTRODUCTION

Special considerations must be made when designing and constructing a critical listening space. Failure to take these considerations into account during design and construction will often lead to unsatisfactory performance of the room for its intended purpose, and subsequent renovations that are by nature both more expensive and less effective than treatment would have been had it been undertaken during original construction.

The first of these considerations is adequate interior room acoustics. A key metric of acoustical conditions is reverberation decay time (RT-60), defined as the amount of time necessary for sound intensity levels to decay 60 decibels, in other words to one-millionth of the sound power of the original signal. An optimal RT-60 value for a specific room depends on the volume and intended use of the room. The RT-60 in a given room is most often modified by installing or removing acoustically absorptive material from the room, although modifications can be achieved by other means (resonant absorption, bass traps, etc).

A second consideration is for sufficient sound isolation between the listening environment and adjacent areas. This may imply that noisy activities in the listening environment run the risk of causing a disruption to quieter activities in adjacent area, or that sound-sensitive activities inside the listening environment may be disturbed by noise sources in adjacent areas. Sound isolation can be maximized by providing a massive, and airtight, envelope around the room.

A third consideration is the need for low background noise levels in critical listening environments. This is important primarily because the dynamic range of program material will be limited if ambient noise levels are too high, and quieter portions will not be understood. It is especially critical to maintain low ambient noise levels in a recording environment, because high ambient noise levels can quickly accumulate over several tracks when multi-tracking audio; the noise floor on the resulting recording can be significantly higher than the original background sound level in the recording environment. In most common buildings, the dominant ambient noise source is the Heating, Ventilation, and Air Conditioning (HVAC) systems.

Undoubtedly, there are many other factors – including cost, structural needs, local zoning and sound ordinances, federal Americans with Disabilities Act (ADA) requirements, and countless others – that must be considered. Some of these considerations may necessitate compromises being made to the key design imperatives listed above. In these cases, the best must be made with the conditions available. The ultimate goal is to create a space that is usable for its intended function but not over-engineered.

EQUIPMENT & METHODOLOGY

Several critical listening spaces were surveyed, representing a variety of uses and levels of sophistication. Measurements at each location were made of reverberation decay time (in accordance with ASTM 2235 – Standard Test Method for Determination of Decay Rates for Use in Sound Insulation Test Methods), as well as sound isolation (if applicable at the individual venue, and in accordance with ASTM E336 – Standard Test Method for Measurement of Airborne Sound Attenuation Between Rooms in Buildings), and ambient sound pressure levels. As much as possible, measurements were taken in nearly empty rooms with other conditions as would be typical during production at the individual facility (ie. doors that are normally left open were left open, the HVAC system was at typical operating levels, etc.).

Sound level measurements were taken with a Larson Davis model 831 Class 1 integrating sound level meter with ½" random incidence microphone. Calibration to a known standard was accomplished immediately prior to and after the sessions to within+/-0.1dB. Broadband, octave and 1/3 octave data were gathered along with A and C weighted averages in terms of L_{eq} (average) and L_{max} (peak) readings. Pink noise was amplified through a QSC model HPR153i speaker cabinet containing a 1.4" high frequency compression driver and horn with a 15" low frequency driver with an integrated 600W amplifier.

Reverberation was measured by orienting the sound source towards a corner, and producing a diffuse field of pink noise at a high level (approaching 100dBA) in the room of interest. When sound levels reached steady-state the sound source was abruptly turned off, and the time rate of decay of the sound levels in the room was measured. The analyzer then measured the amount of time necessary for sound levels to decay 20 and 30 decibels, and used these values to calculate the amount of time necessary for sound levels to decay 60 decibels

(RT-60). The measured values are known as T20 and T30, respectively. Reverberation decay values based on the T30 measurements are considered more accurate than those calculated based on T20 measurements; for this reason T30 measurements are used for RT-60 values stated in this report.

Sound transmission between adjacent spaces was measured by producing a diffuse field of pink noise at a high level in the room of interest, and measuring the sound pressure levels in this room (Send) and in adjacent spaces (Receives). The difference between the sound levels on either side of a wall is analyzed to determine the effectiveness of the wall at blocking the transmission of airborne sound.

Sound isolation through a partition is assigned a Sound Transmission Class (STC) rating when measurements are made under laboratory conditions; the Noise Insulation Class (NIC) rating system is used for the purposes of this report. The NIC system approximates the STC system, but will account for defects inherent to the particular construction (flanking paths). The in-situ (NIC) rating for a given partition construction will most often be at least five points lower than the laboratory (STC) rating.

Ambient sound level measurements were taken at several locations around each of the facilities. Representative locations within the sound-critical rooms were chosen that were sufficiently far from any wall or other large surface, and measurements were made, over a period of around fifteen seconds each, while slowly and steadily moving the sound level meter such that the local area is as evenly sampled as possible. L_{eq} values are used for Noise Criterion (NC) calculations in this report.

EVALUATION CRITERIA

Measured conditions were compared to recommendations for the particular type of facility. Recommended reverberation times for rooms of various functions and sizes are shown in Figure 1.1, reprinted from Architectural Acoustics by M. David Egan. A similar chart that is more tailored to the types of venues that are of interest to this report is shown in Figure 1.2, reprinted from The Master Handbook of Acoustics, by F. Alton Everest.

The reverberation times indicated in Figures 1.1 and 1.2 are general guidelines. It is desirable for reverberation times in a recording environment to be somewhat variable, to best suit different styles of music. The reverberant response should also be fairly consistent throughout the recording environment for any given setup – modal room responses can result in unintended and undesirable result.

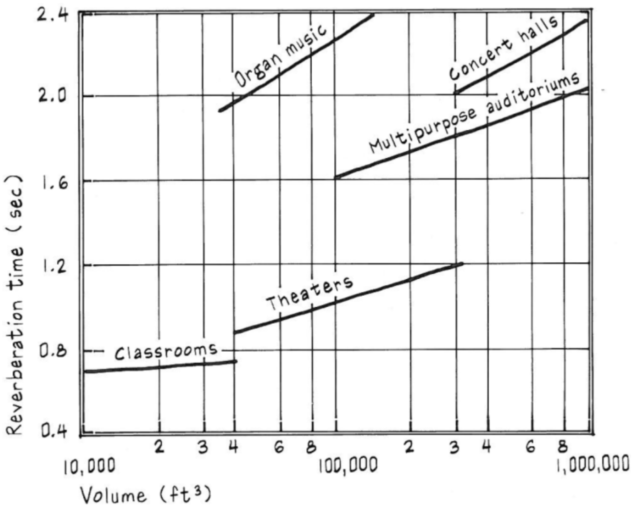

Figure 1.1- Recommended reverberation decay times for various types and sizes of rooms

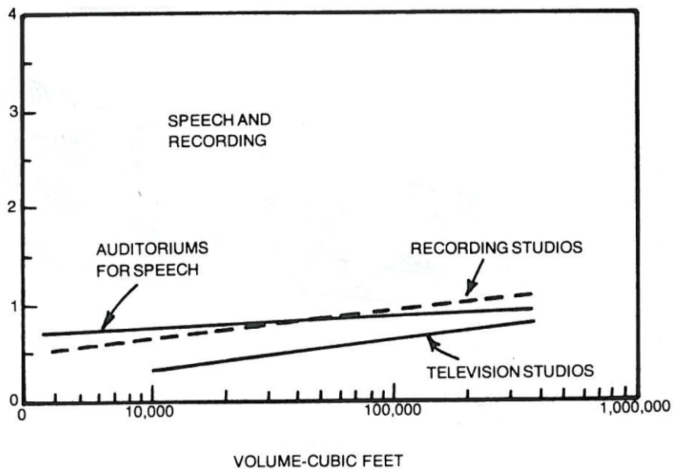

Figure 1.2- Recommended reverberation decay times for studios

Recommended ambient noise levels in rooms of various functions are found in the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) Handbook, Chapter 48 – Noise and Vibration Control, and are summarized for the purposes of this report as maximum NC-25 in audio recording environments (with NC-20 or below preferred) and maximum NC-30 in music performance spaces.

Acoustical considerations in Control Rooms are somewhat different than in Tracking Rooms. Many Control Rooms are constructed in accordance with the Live End Dead End (LEDE) design philosophy, which entails installing acoustical absorption to the front of the Control Room and acoustically reflective materials at the rear. The goal is to provide a reflection-free zone at the mix position, to ensure that the audio engineer hears only direct sound form the monitor speakers. Acoustical diffusion is often installed at the ceiling and/or rear wall to prevent distinct reflections.

Recommended levels of sound isolation for these types of facilities do not exist. In some cases walls are built similar to those at a THX certified theater, but more often these recommendations are found in the form of maximum permissible sound pressure levels in an adjacent room, or in the case of outdoor sound, maximum permissible sound levels at the property line. It is important to note that the common single-number sound isolation rating systems in use today (ie. STC and NIC) are biased toward frequencies in the human speech range, and do not adequately represent sound isolation for musical sources, which tend to have a more pronounced low-frequency component.

VENUE SELECTION

Four venues were visited for this report, each of which caters to a wide variety of musical styles. Austin Signal & East Austin Recording are recording studios, and Studio 1A & the Moody Theater have aspects similar to both live music venues and recording studios. All venues visited were built specifically to be a critical listening environment, with room acoustics, sound isolation and noise control being important design concerns.

The recording studios that were visited each are comprised of a larger Tracking Room, a smaller Control Room, and an Equipment Closet. Some facilities have one or more Isolation Booths and/or other areas. Portable isolation panels are used in most facilities visited, for acoustical isolation and/or localized absorption. All of the facilities visited are capable of recording several musicians simultaneously; both of the dedicated recording studios are also capable of recording instrumentation in several takes and overdubbing.

Most of the recording projects undertaken at each facility are started and completed at that facility, but this is not always the case. Occasionally, an artist will bring tracks recorded at one studio to add to and mix down at a different facility. The two ‘hybrid’ venues that were visited are both capable of capturing live audio, mixing it down to a stereo and/or 5.1 audio feed, and either broadcasting and/or saving the resulting mix for later post-production.

CONCLUSION

Four purpose-built sound-critical spaces were visited, with the goal of characterizing some of the acoustical parameters of the rooms. Reverberation decay times, sound isolation, and ambient sound levels were measured, and results were compared with recommended values for rooms of similar usage. Individuals familiar with the design and construction of each venue were interviewed regarding considerations made for room acoustics, sound isolation and noise control.

A direct comparison between the disparate facilities visited is not in the scope of this report, as the facilities vary widely in their intended use and niche in the market.

Thanks to Greg Enenstein for assistance during site visits and data analysis, and to Ken Dickensheets for supplying the measurement equipment.

2. AUSTIN SIGNAL

BACKGROUND

Austin Signal is a commercial recording studio located in a residential area of the hill country west of Austin. The studio opened for business in January 2012. During production sound levels in the Tracking Room can reach over 100 decibels.

The Tracking Room is a moderately large room (approximately 476ft^2, 6,200ft^3); the Control Room is considerably smaller than, and located adjacent to, the Tracking Room. Interior views of both rooms are shown in Figure 2.1. Floor plan and section views of the studio are shown in Figure 2.2. Note that these drawings do not reflect some changes made during construction, namely the size of the Isolation Booth shown at the top-right corner was increased by reversing the slope of the wall, as shown sketched in.

Figure 2.1- Austin Signal Control Room (top) and Tracking Room (bottom left and right)

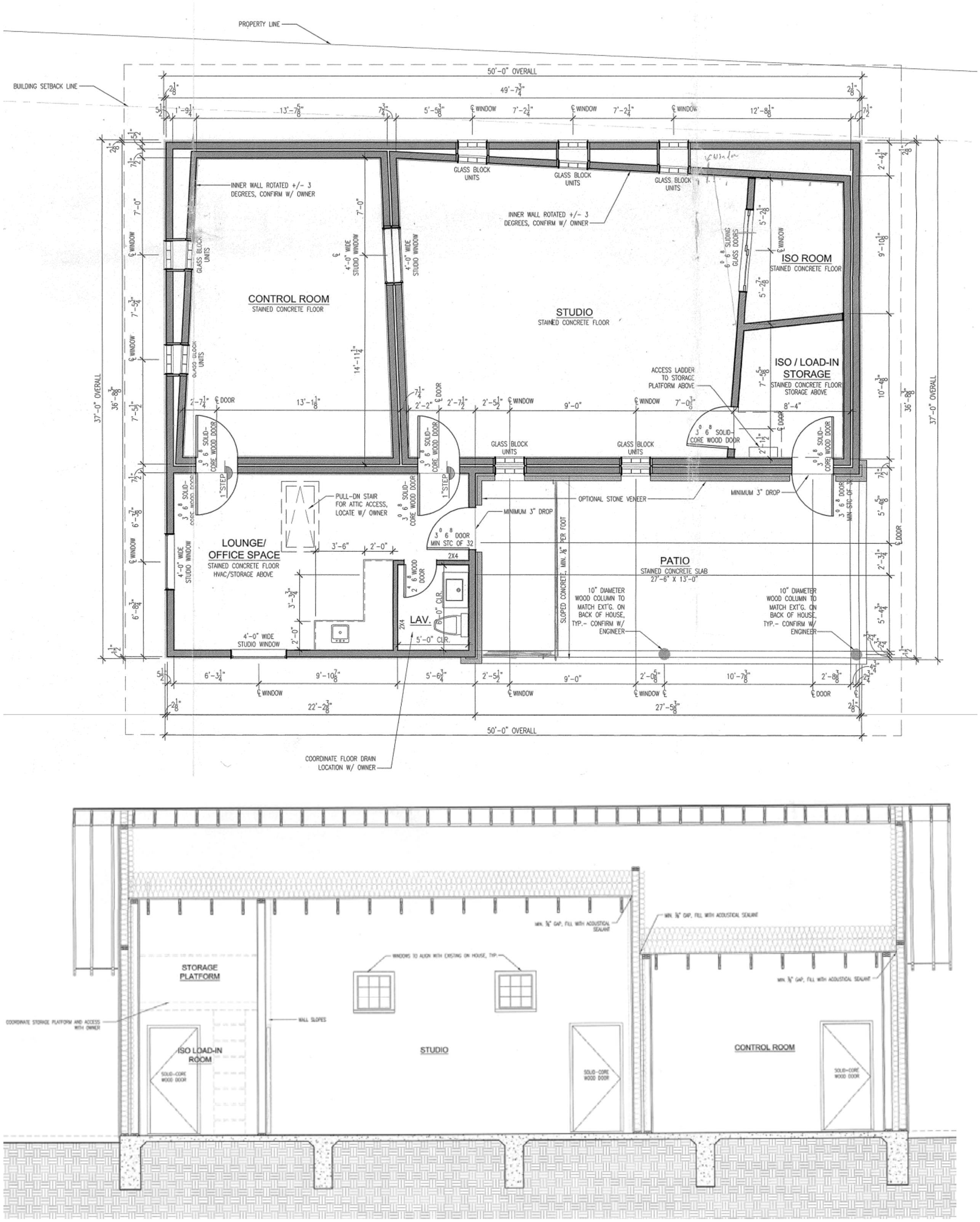

Figure 2.2- Floor plan (top) and Section (bottom) views of Austin Signal – note the splayed walls, and the room-within-a-room construction

ROOM ACOUSTICS

The finish floor in the Tracking Room floor is wood, built up from the concrete slab and accented with area rugs. The finish ceiling over the Tracking Room slopes from 11'-4" to 15'-0" above the finish floor. The ceiling is primarily finished with two layers 5/8" gypboard, with approximately 80ft^2 coverage of 4" thick absorptive treatment installed at the bottom of the rafters (see Figure 2.3), relatively evenly distributed throughout the ceiling area. Perimeter walls are finished with double layer 5/8" gypboard. Each wall surface is treated with 4" thick absorptive treatment, most of which is hung vertically from the ceiling, spaced approximately 4" from the wall, as shown in Figure 2.4. The installation of the absorptive panels does not approximate any of the typical mounting types; absorption values for type E-400 were used for calculations.

A portion of absorptive panels at the ceiling are installed with foil facing exposed under the fabric wrapping, and a portion of the panels installed at the walls are covered with artwork; these conditions may result in reduced absorption, especially at higher frequencies.

Reverberation time can be varied as needed. The windows between the Isolation Booths the Tracking Room can be covered with an absorptive panel if line-of-sight between the two areas is not critical and/or if additional absorption is needed. In addition to the fixed wall absorption, there are multiple gobos (portable isolation constructed of two layers 2" thick fiberglass, each adhered to a layer of plywood and separated from the other piece of plywood/

Figure 2.3- Acoustical absorption installed at the ceiling

Figure 2.4- Acoustical absorption at the wall is hung from the ceiling with an airspace behind

fiberglass by an airspace) that can be positioned as need to increase isolation or absorption at a particular area, or can be completely removed if desired. The gobos are designed to increase the amount of acoustical absorption in the Tracking Room by about 50% when deployed.

Walls throughout the studio are canted such that they are slightly off-perpendicular when viewed in plan; in most cases the walls are offset at 1:10, or walls on both sides of the room are each offset at 1:20, for a net effect of a 1:10 ratio. The non-parallel walls were a considerable difficulty during construction, but are necessary to address room modes and standing waves. It is also interesting to note that the decision was made to use two layers of gypboard at the walls and ceiling, instead of three, on the basis that creating walls that are slightly flexible will alleviate the need for targeted low-frequency absorption (bass traps).

The reverberant spectrum is fairly even throughout the audible frequency range; it was measured at 0.33 seconds, and calculated at 0.35 seconds, broadband, see Figure 2.5. At the time of our visit, there were 5 gobos set up throughout the Tracking Room. The discrepancy between measured and calculated values can most likely be attributed to discrepancies between materials and mounting types used in laboratory tests versus the installed condition.

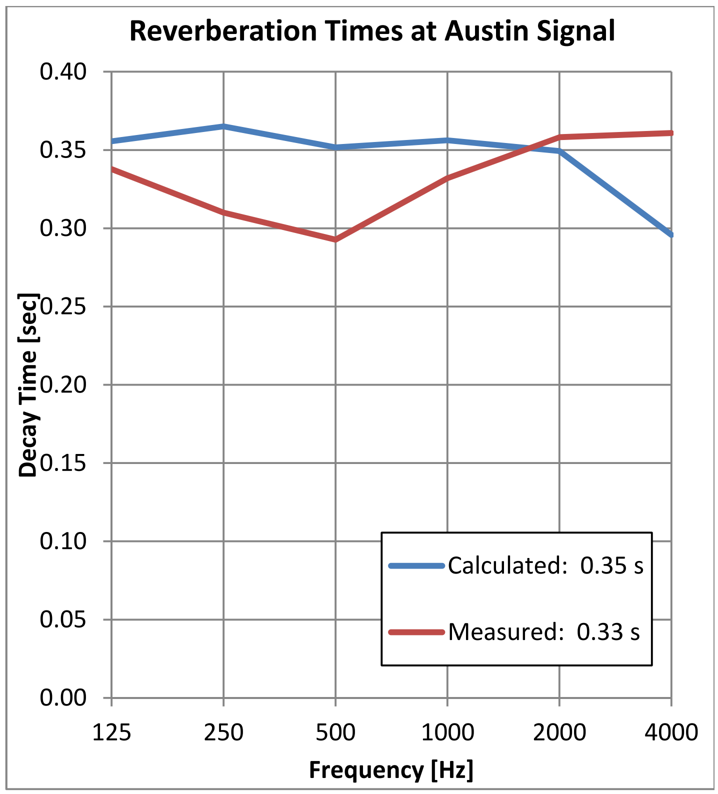

Figure 2.5- Reverberation time in the Tracking Room

The Control Room finish materials are similar to those in the Tracking Room (raised hardwood floor, double layer gypboard walls and ceiling with 4” thick absorptive panels hung spaced from the wall on either side of the mix position), with the thick absorptive wall treatment surface mounted on the front wall behind the console. The rear wall is a sliding partition finished with acoustically absorptive material; this partition separates the Control Room from a storage area which houses noisy equipment (console power supply, etc.), while simultaneously acting as a bass trap.

SOUND ISOLATION

Sound isolation between the Tracking Room and the Control Room was not as much of a design concern as interior/exterior isolation. The exterior walls at the Tracking Room are double wood stud construction, with a varying airspace between the interior and exterior sides. Exterior windows at the Tracking and Control Rooms are double glass block, with each face installed in one of the stud walls, as shown in Figure 2.6. In no instance are the interior and exterior sets of studs rigidly connected together. The roof structure, in the attic above the sound-critical spaces, includes R-30 batt insulation and two layers of 5/8" gypboard; this effectively creates a sealed vestibule between the Tracking and Control Rooms and the exterior. In addition, gypboard throughout the studio is 'firerock', which is approximately 25% more dense than standard gypboard.

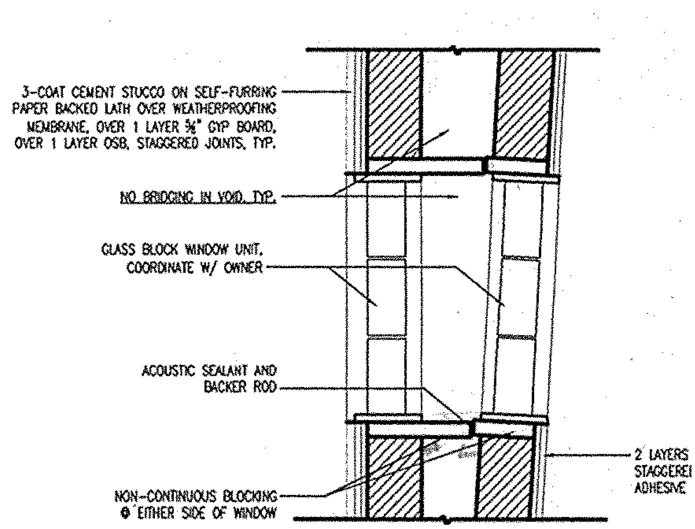

Figure 2.6 Detail of the glass block windows

The Tracking and Control Rooms are constructed as independent rooms within the building shell, rigidly connected to a monolithic concrete slab, but otherwise freestanding and not connected to adjacent rooms. Interior walls are constructed as double wood stud partitions, separated by a 2" air gap with two layers 5/8" gypboard is installed on both sides of the walls, and stud cavities filled with batt insulation. A 2" air gap was specified, instead of the more typical 1", to ensure that minor material irregularities in the wood studs would not cause the air gap to be bridged, especially considering the considerable ceiling height (and therefore the length of the studs). Junction boxes for electrical outlets and audio connections are all surface mounted, as shown in Figure 2.7, to minimize flanking paths through wall penetrations.

Figure 2.7- Surface mounted junction boxes

The interior doors throughout the studio are solid-core wood units, with perimeter seals and a bottom sweep. Doors between the Lobby and the Control & Tracking Rooms are installed in pairs, separated by an airspace. Doors between the Tracking Room and both Isolation Booths are a single door leaf. The window at the Control Room is a custom fabricated unit, with a layer of 5/8" laminated glass connected to one set of studs, and a layer of ½" laminated glass on the other side. Windows at the Isolation Booths are single layer laminated glass.

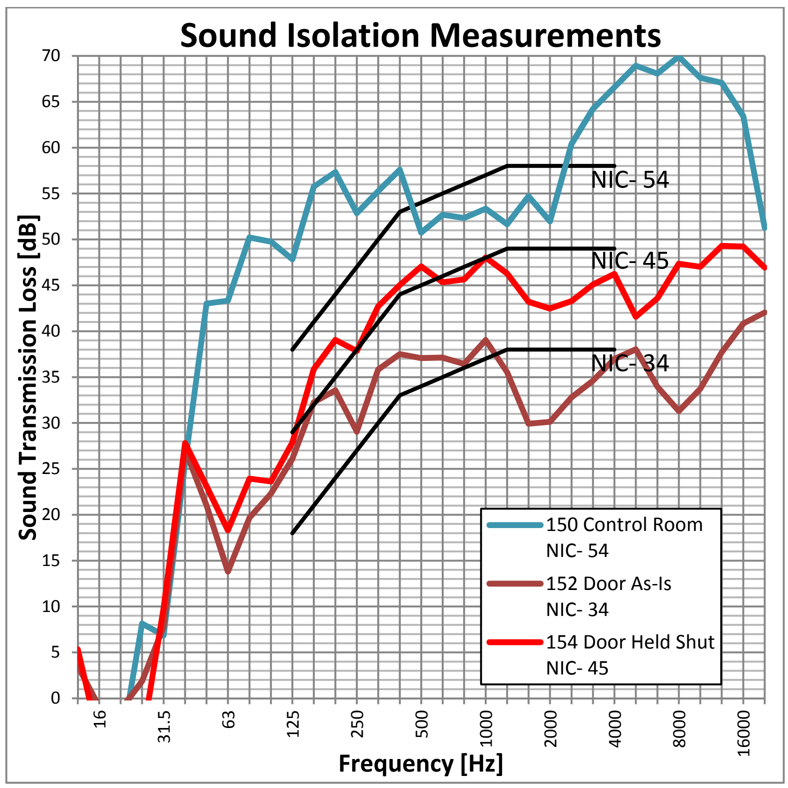

Figure 2.8- Sound isolation measurements between the Tracking Room and the Control Room, and between the Tracking Room and the Isolation Booth under two conditions

Sound isolation between the Tracking and Control Rooms was measured at NIC-54, which is fairly respectable considering this was not a major design concern. Isolation between the Tracking Room and Isolation Booths was tested under two conditions: with the door closed loosely – as would be typical during production, and with the door held firmly shut – as recommended for optimal sound isolation. Isolation under the two conditions was measured at NIC-34 and NIC-45, respectively, indicating that the doors are a significant weak link in the wall assembly. Figure 2.8 shows results of sound isolation measurements.

An attempt was made to measure sound isolation between the Tracking Room and the exterior; however, valid measurements were not possible due to ambient noise conditions. Only the extreme low frequencies of the pink noise were audible outside. It is interesting to note that during construction a drummer and bassist were brought in to rehearse inside the unfinished Tracking Room, in an attempt to find any sound leaks. To date, no neighborhood noise complaints have been reported.

NOISE CONTROL

A single HVAC system serves both the Tracking Room and Control Room. The fan unit is located in the attic space above the Lobby, and is attached to supply and return plenums constructed of acoustically absorptive fiberglass ductboard, with several flex-duct takeoffs serving the various areas in the Studio. A transition to ductboard is made where the ductwork penetrates the isolation wall around the Tracking and Control Rooms. No grilles or diffusers are used, and ductwork is slightly upsized to provide lower airflow velocities. Vibration isolation at the fan unit is accomplished with Styrofoam and semi-rigid fiberglass, as opposed to the spring isolators, or neoprene mats typically used for this purpose.

Ambient sound levels in the Tracking and Control Rooms were measured, with the HVAC system in operation, at 20.7dBA, NC-18 and 28.5dBA, NC-23 respectively (see Figure 2.9). In other words, conditions

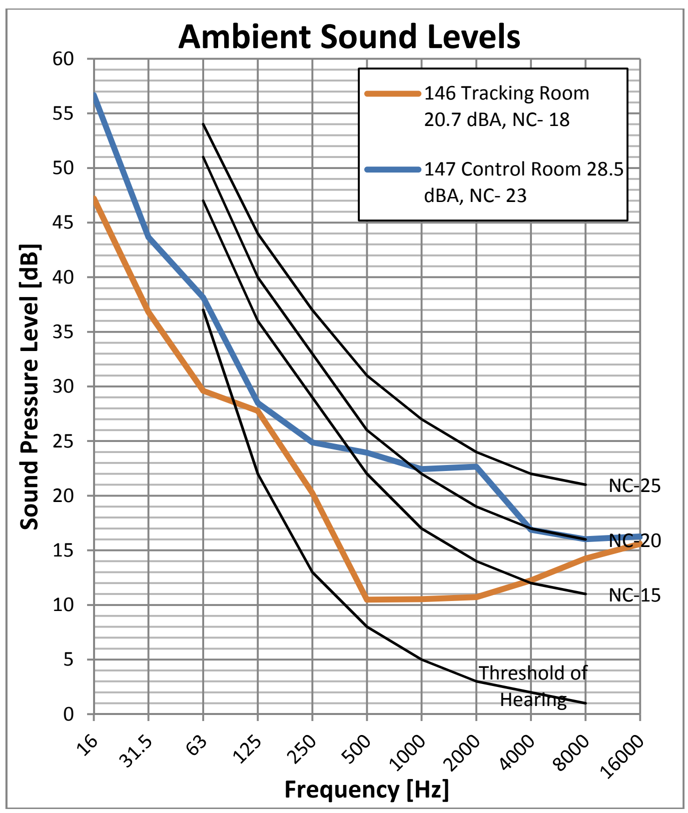

Figure 2.9- Ambient sound levels in the Tracking Room and the Control Room

are within recommended guidelines. The peak in the 2kHz octave-band seen in the Control Room is likely due to equipment noise.

CONCLUSION

In summary, the acoustical properties at Austin Signal are highly variable, and well suited for a wide variety of musical styles. Reverberation time can be modified through the use of gobos and area rugs. Walls are canted and the ceiling is sloped such that there are no parallel acoustically reflective surfaces.

Sound isolation within the studio was not a major design imperative, although measured levels were fairly respectable. A more pressing design concern was isolation between the studio and nearby neighbors; noisy activity in the studio has not been a source of neighborhood complaints.

Background noise levels in sound-critical areas conform to recommendations. The HVAC system does not produce a noticeable level of noise.

Thanks to Jon Niess and Greg Klinginsmith for their assistance in providing access to, design documents for, and answering questions about Austin Signal.

3. EAST AUSTIN RECORDING

BACKGROUND

East Austin Recording (EAR) Studio is a semi-private recording studio located in a residential area. The studio opened for business in 2007.

The Tracking Room is a fairly large room (approximately 675ft^2, 8,500ft^3) on the ground level. The Control Room is considerably smaller, and is located on the second level, with three large windows overlooking the Tracking Room. Interestingly, there is not a door at the Control Room; the stairway from the ground level entryway leads directly to the Control Room. The Isolation Booth is located off of the Tracking Room. The Machine Room is tucked behind the Isolation Booth, and houses a large equipment rack with the console power supply, power amplifiers, etc.; this room is served by a dedicated HVAC unit. The Control Room is shown in Figure 3.1, and several views of the Tracking Room and Isolation Booth are shown in Figure 3.2.

Figure 3.1- Interior view of Control Room

The decision to position the Control Room overlooking the Tracking Room was made late in the design, as a measure to increase the size of the Tracking Room. Issues that have been encountered due to the location of the Control Room include difficulties moving large pieces of equipment into and out of the Control Room, and the possible need for additional structural bracing below the console.

During production sound levels in the Tracking Room reach over 100 decibels; sound levels in the Control Room are generally much lower – estimated around 80 decibels for mixing, with occasional periods of higher volume levels.

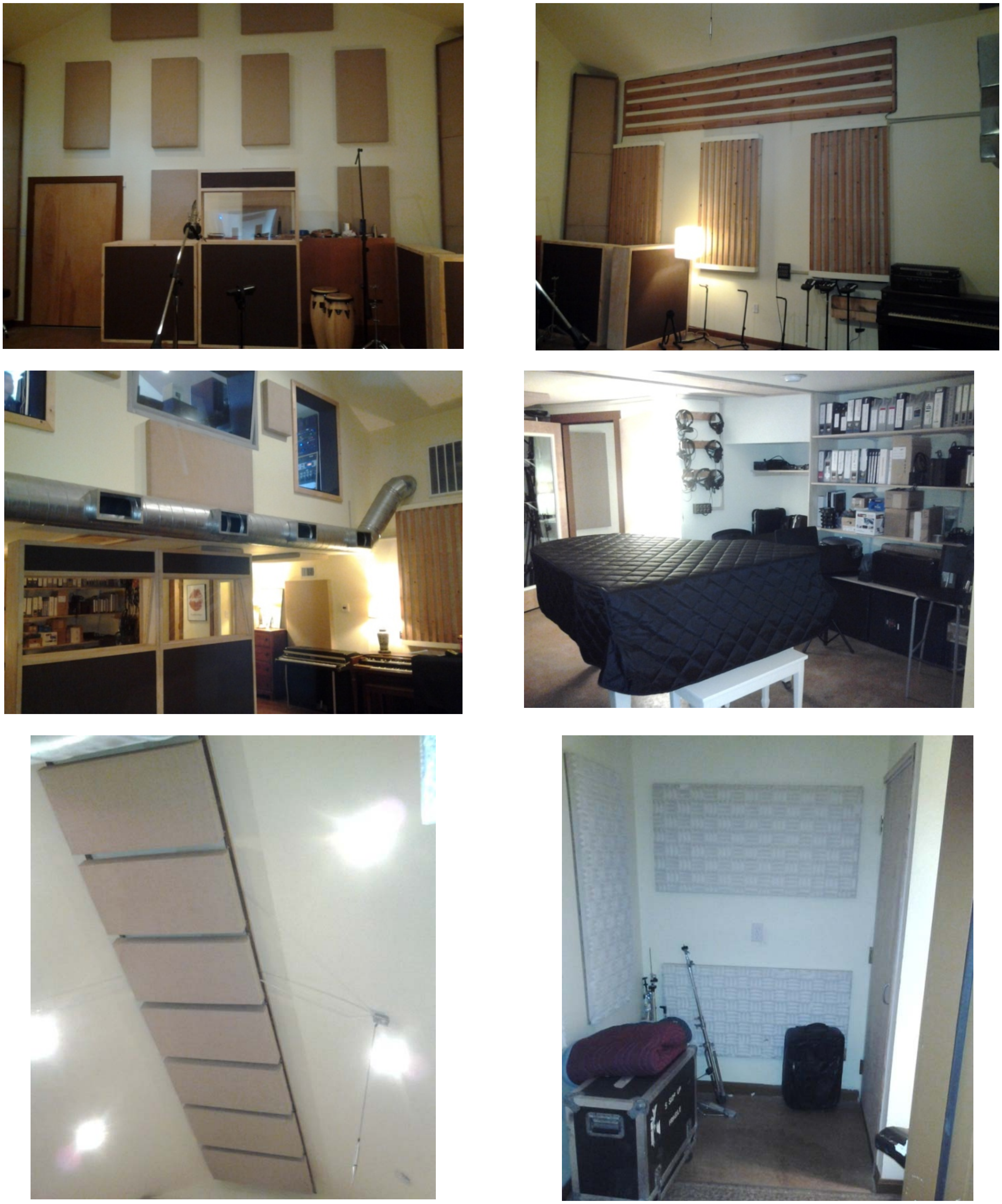

Figure 3.2- Interior views of EAR – Note the exterior door, plate reverb, and wall panels, top-left; bass trap and wall panels, top-right; wall between Tracking Room and Control Room, center-left; low ceiling area of Tracking Room, center-right; acoustical treatment at Tracking Room ceiling, bottom-left; Isolation Booth with door to Machine Room visible, bottom-right

ROOM ACOUSTICS

The Tracking Room floor is exposed concrete slab, accented with area rugs. The finish ceiling over a large portion of the Tracking Room slopes from 12’-0” to 18’-6” above the finish floor, where it meets at a peak; the ceiling is installed at 7’-6” above the finish floor at a smaller portion of the Tracking Room (below the Control Room). The ceiling is primarily finished with gypboard, but also includes a significant amount of 4” thick absorptive treatment at the peak. Walls are finished with double layer gypboard, and are relatively rectangular. Each wall surface is treated with 4” thick surface mounted absorptive treatment, and floor-to-ceiling bass traps are installed in two corners. There are multiple gobos (portable isolation constructed of two layers 4” thick fiberglass, each adhered to a layer of plywood and separated from the other piece of plywood/ fiberglass by an airspace – some gobos contain a plexiglass vision pane) that can be positioned as need to increase isolation or absorption at a particular area.

The Control Room is relatively rectangular, and is open to the staircase at the rear. The ceiling is sloped, and the walls are quite low at the sides. The ceiling and walls are finished with two layers 5/8”gypboard, with 2” and 4” thick surface mounted absorptive treatment relatively evenly dispersed around all wall and ceiling surfaces. The Control Room floor is hardwood. Interestingly, the fact that the Control Room is open to the stairs and Entry way seems to increase clarity in the lower frequencies; it seems that the coupled space acts as an effective bass trap.

Reverberation decay time in the Tracking Room was measured and calculated at 0.5, broadband. Figure 3.3 shows that the decay times across the audio frequency range is relatively flat. Note that some of the disparity between the

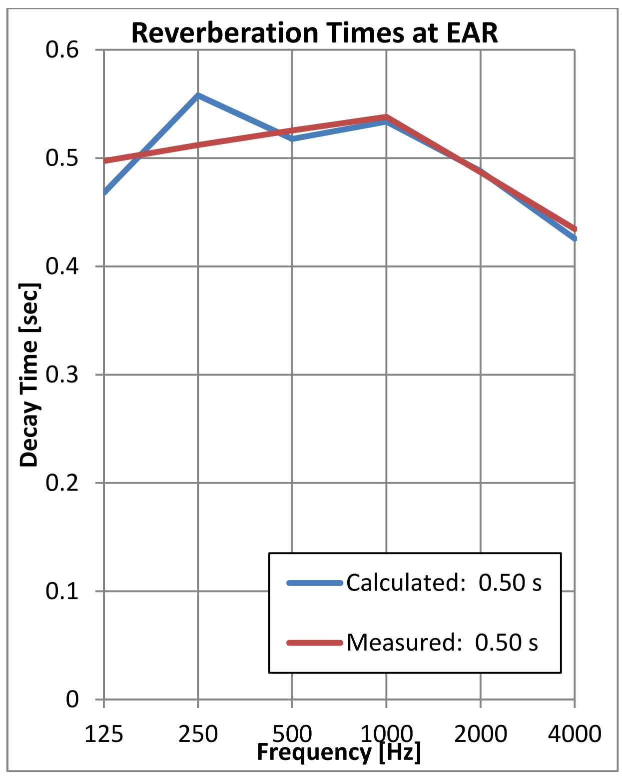

Figure 3.3- Reverberation time in the Tracking Room

measured and calculated reverberation times can be attributed to drums and a large plate reverb unit located in the Tracking Room that were excited by the noise source.

The reverberant spectrum is fairly even throughout the Tracking Room, with the notable exception that a distinct flutter echo can be induced near the point where the low-ceiling area meets the sloping-ceiling area. There are not any large areas of parallel acoustically reflective surfaces, but there are multiple smaller areas, that may be causing the flutter echo. The flutter echo is noticeable only when the room is quiet and lightly occupied; it is not an issue when sound levels increase and additional diffraction is provided by people, equipment, etc.

SOUND ISOLATION

The Tracking Room is isolated from the exterior by a sound isolation wall assembly that is more than 12" thick (see Figure 3.4), constructed of double wood stud walls separated by an air gap, with fiberglass batt insulation in the stud cavities, and faced with multiple layers of gypboard. The exterior doorway is fit with two solid-core wood doors – one on the exterior and one on the interior set of studs. There are no exterior windows in the Tracking Room.

Figure 3.4- Exterior wall is more than12" thick.

Isolation between the Tracking Room and the Control Room was not as much of a design concern as interior/exterior isolation. The doors between the Tracking Room and the entryway and between the Tracking Room and the Isolation Booth are solid-core wood with a double-paned lite. All studio doors include perimeter seals and bottom sweeps, although some seals were in better condition than others.

Two of the windows between the Control Room and the Tracking Room were field-fabricated of double layer glass separated by a large air gap. The largest window, in the center, was manufactured as a sound isolation window. There are also several standard, double-paned window units at the rear of the Control Room. Sound isolation through these windows has not posed an issue due to the previously mentioned low volume levels preferred for mixing.

Figure 3.5 shows the results of sound isolation measurements obtained by placing the noise source in the Tracking Room, and measuring sound pressure levels in the Isolation Booth, Corridor, and Control Room. Isolation between these areas was measured at NIC-34, NIC-22, and NIC-40, respectively. Note that in the case of the Control Room, this value represents sound isolation provided by the wall and floor/ ceiling structure. By most measures these isolation values would be considered very low for this type of facility. However, sound isolation between

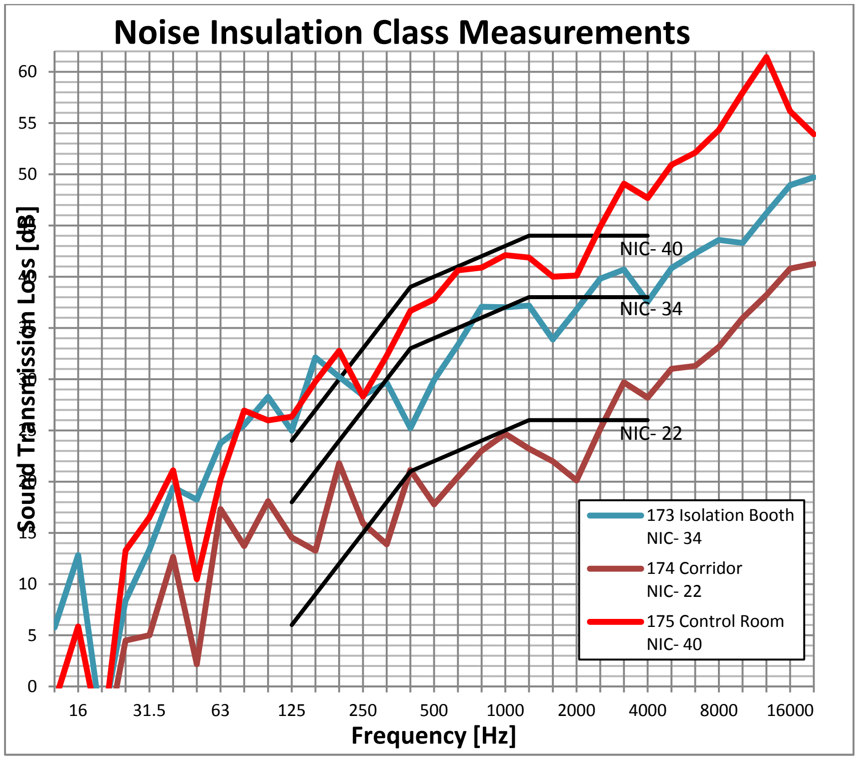

Figure 3.5- Results of sound isolation testing between the Tracking Room and the Isolation Booth, Corridor, and Control Room

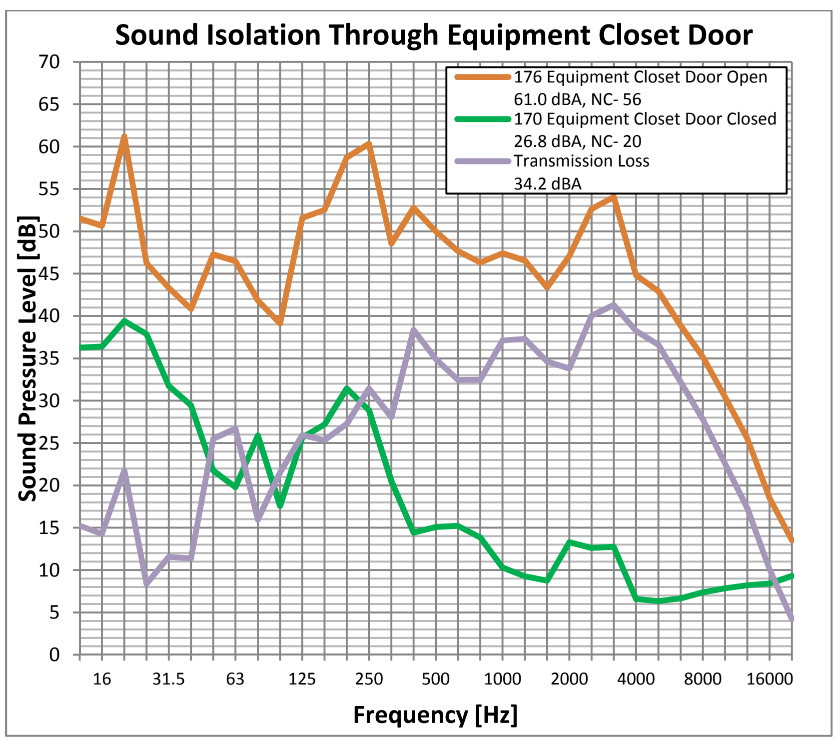

Figure 3.6- Sound isolation through Machine Room door

areas within the studio was not a major design concern. Operators at the studio are much more concerned with sound isolation between the studio and the exterior, which has not proven to be an issue.

The door separating the Isolation Booth from the Machine Room was constructed by laminating two solid core doors together, and applying seals to each leaf. The equipment stored in the Machine Room is fairly noisy, and without excellent isolation the fan noise would be picked up by sensitive microphones in the Isolation Booth. Due to the small size of these two spaces a valid NIC measurement was not possible, however sound levels were measured in the Isolation booth with the Machine Room door open and with it closed. Results of these measurements, shown in Figure 3.6, indicate the door provides over 34dBA of isolation.

NOISE CONTROL

The HVAC needs of the studio are served by two fan units – one each for the Control and Tracking Rooms. Both units are located outdoors, shown in Figure 3.7, with rectangular sheet metal ductwork running up an exterior wall before entering the building. It is not clear how much of the ductwork includes internal lining; supply ductwork in the Tracking Room was found not to include internal lining (see Figure 3.8), while return ductwork in the Control Room was found to be internally lined. Most of the supply air registers throughout the studio have been removed, as shown in Figure 3.9, and the replaceable filters used at return air grilles are

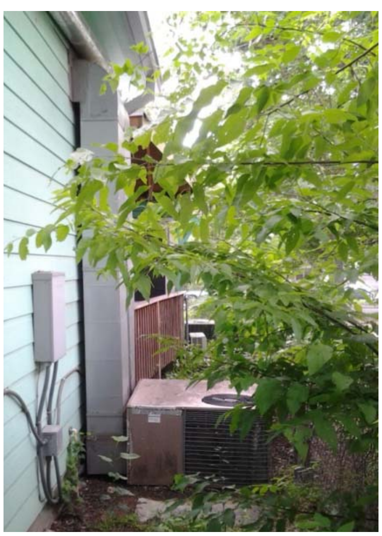

Figure 3.7- Exterior HVAC fan units with exposed ductwork.

Figure 3.8- Inside of Tracking Room ductwork, note lack of internal lining.

Figure 3.9- HVAC diffusers were removed throughout the studio.

Figure 3.10- Several noise producing appliances located in the Control Room

the inexpensive blue ones, as they have been found to present the least amount of static pressure drop, and hence the least amount of noise.

There are several non-HVAC related noise sources in the Control Room, including, a water cooler, a small refrigerator and a coffee maker (see Figure 3.10). The refrigerator was unplugged during our visit, as it was reportedly operating louder than typical.

Ambient sound levels in the Tracking Room were measured at 26.9dBA, NC-20 with the HVAC system off, and 40.8dBA, NC-39 with the HVAC system on (see Figure 3.11). In other words, conditions were within recommended guidelines with the HVAC system off, but were well above recommended levels, due to significant increases in the lower octave-bands, with the system on. The situation is

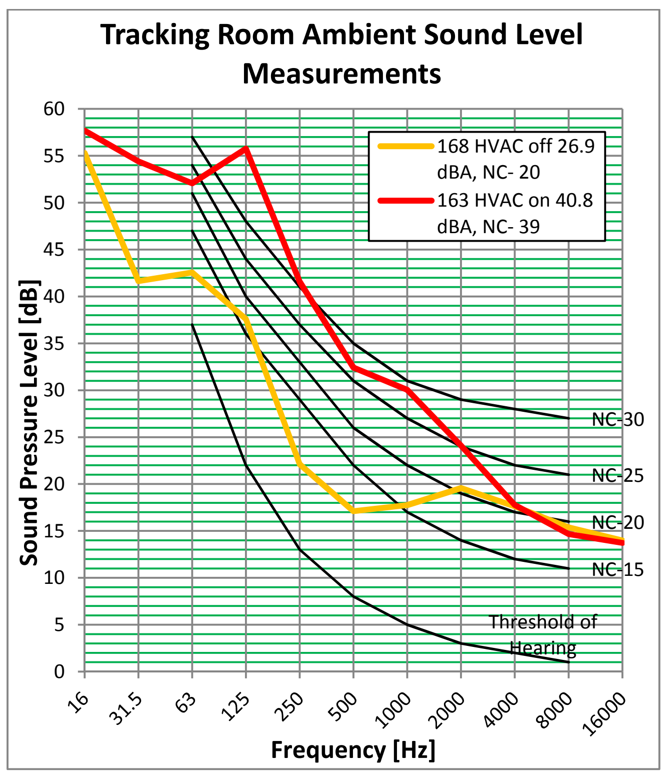

Figure 3.11-Ambient sound levels in the Tracking Room with the HVAC system on and off

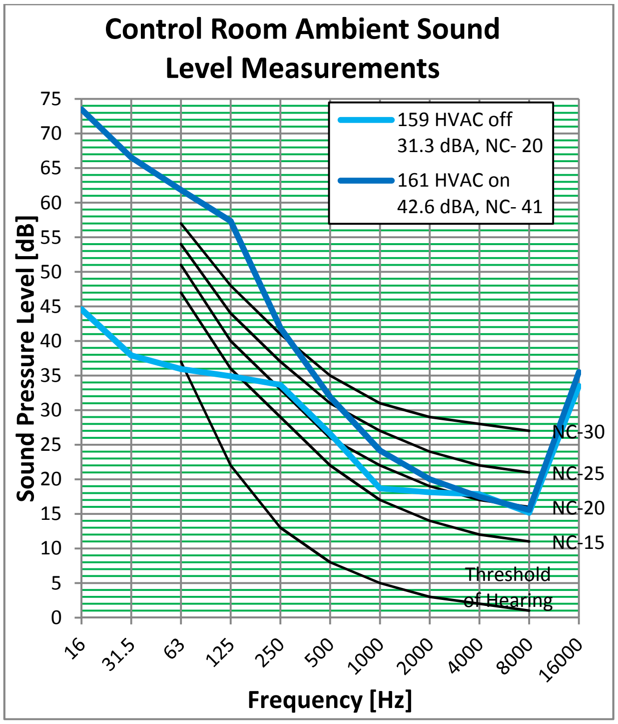

Figure 3.12-Ambient sound levels in the Control Room with the HVAC system on and off

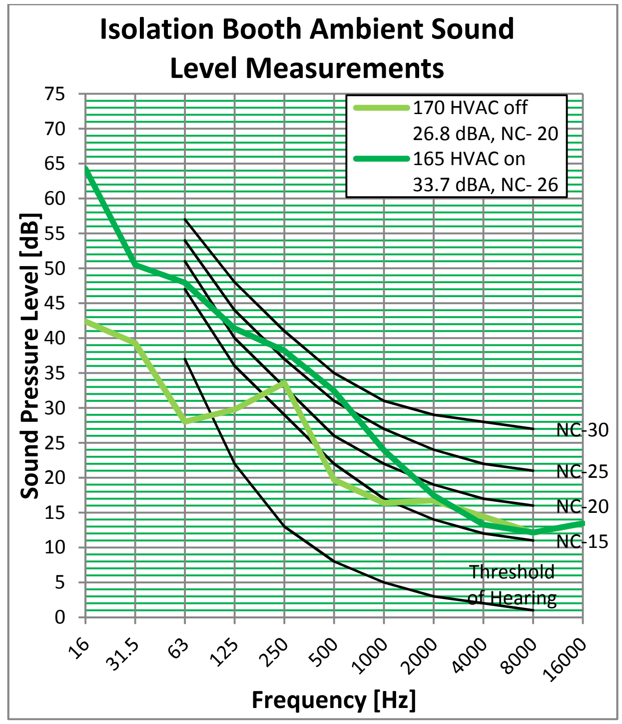

Figure 3.13-Ambient sound levels in the Isolation Booth with the HVAC system on and off

similar in the Control Room and Isolation Booth, as can be seen in Figures 3.12 and 3.13, respectively.

In order to get around limitations posed by an elevated noise floor in a sound-critical environment, the studio is often 'pre-chilled' overnight prior to a session, then the HVAC system is turned off during production. Another solution to this problem that was discussed during our visit was the installation of duct silencers in the supply and return ductpaths serving both units. Silencers can be selected using the data gathered at our visit, along with knowledge of operating parameters of the HVAC systems including airflow rates, duct sizes, and the static pressure that the system currently operates at.

CONCLUSION

In summary, the acoustical properties at East Austin Recording studio are more than acceptable. The only complaint expressed by users is a persistent flutter echo that is evident at one area of the Tracking Room. Reverberation time can be modified somewhat through the use of gobos and area rugs.

Sound isolation within the studio was not a major design imperative, and measured levels were not as high as generally recommended. A more pressing design concern was isolation between the studio and nearby neighbors, which was addressed with massive wall construction, and heavy exterior doors situated in pairs and separated by an airspace. To date, noisy activity in the studio has not been a source of neighborhood complaints.

Background noise levels in sound-critical areas conform to recommendations when the HVAC system is not in operation; when the system is activated sound levels increase significantly, particularly in lower octave-bands. This can be addressed by installing duct silencers in exterior portions of ductwork.

Thanks to James Stevens for his assistance in providing access to, and answering questions about East Austin Recording.

4. STUDIO 1A

BACKGROUND

Studio 1A is a live-to-air recording/ broadcast studio associated with Austin public radio stations KUT and KUTX. The studio is located on the first floor of the Belo Center for New Media on the UT campus, which also houses other areas associated with the radio stations, as well as a lecture hall and other areas not directly associated with the radio stations. The studio was commissioned in June 2012.

The Tracking Room is a relatively large room (approximately 1,230ft^2, 17,920ft^3), which can accommodate a live audience of approximately 60 people (see Figure 4.1). The Control Room is considerably smaller than, and located directly to the south of, the Tracking Room. Floor plan and section views of the Studio area are shown in Figure 4.2.

Representatives of the studio who were available to discuss the operations and construction with us were not sure what a typical sound pressure level in the studio during a session is, but this is expected to be between 90dBA and upwards of 105dBA, depending on the performers.

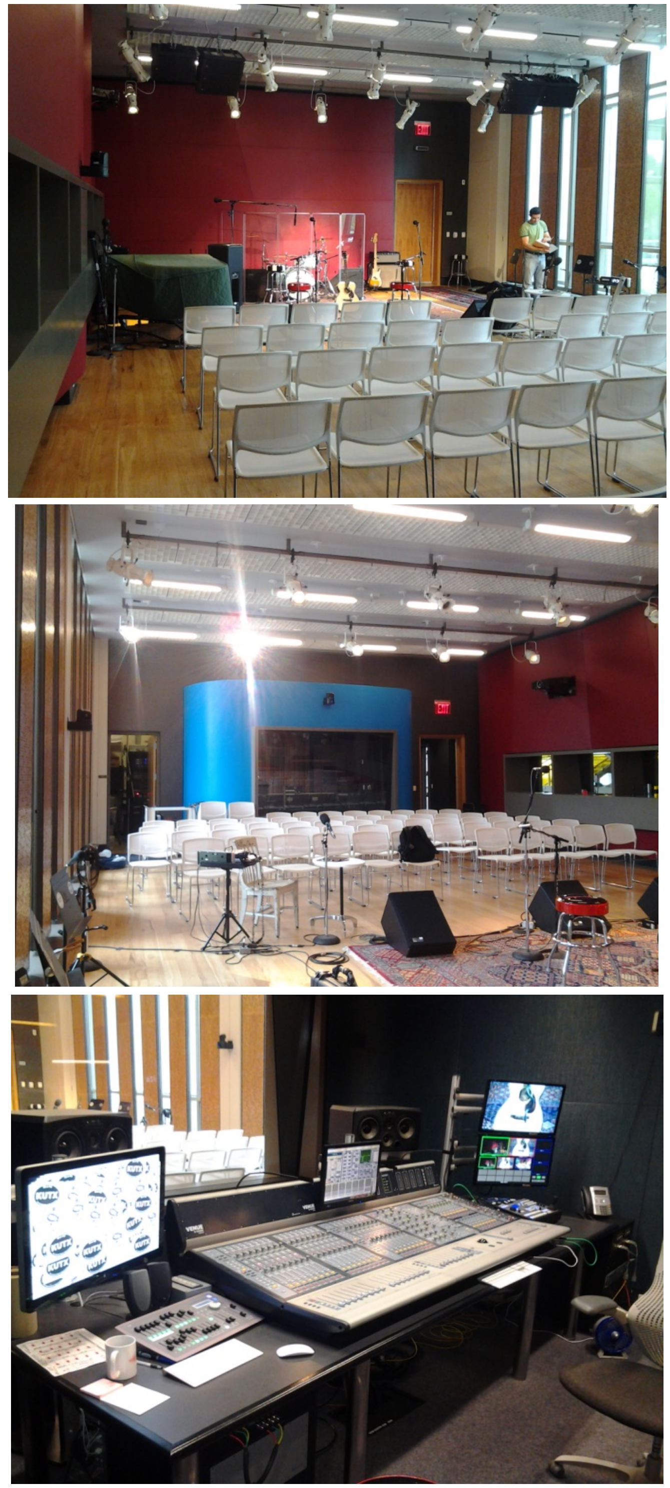

Figure 4.1-Interior of the Tracking Room from the northeast (top) and southwest (middle) corners, and the Control Room (bottom)

Studio 1A

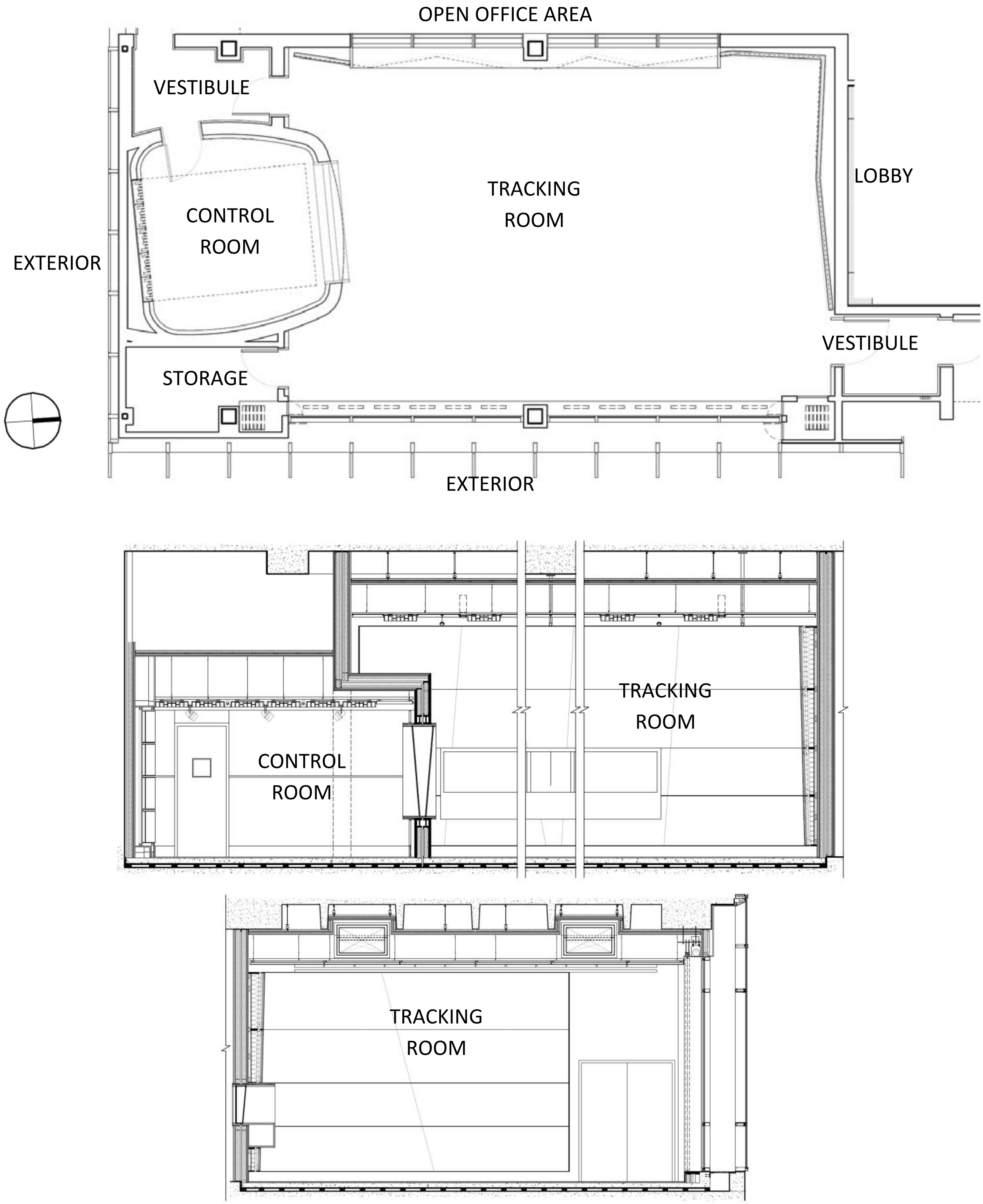

Figure 4.2-Plan and section views of Studio 1A – Note the irregularly shaped walls, and the thickness of wall assemblies surrounding the Studio Suite. Section views face west and north.

ROOM ACOUSTICS

The Tracking Room floor is made of locally sourced pecan wood, and is accented with several large area rugs around the performance area. The finish ceiling installed at 14'-4" above the finish floor, and is made primarily of gypboard with approximately 30% of the surface area covered by acoustical diffusers, shown in Figure 4.3, which serve to discourage flutter echo between the otherwise parallel and acoustically reflective surfaces of the floor and ceiling. The diffusers also provide a feeling of spaciousness in the room which is not typically found in a recording environment, but which provides for a more natural listening environment for the live studio audience.

Structural walls are relatively rectangular, but are faced on three sides by acoustically absorptive treatment ranging in depth from 2" to over 12", with the rest of the wall surfaces being primarily three layers of 5/8" gypboard, or sound isolation windows. The exterior window along the east wall can be covered with hanging variable acoustical panels, shown in Figure 4.4, which can be rotated to expose an acoustically reflective or absorptive surface; incidentally, there are not enough panels to completely cover the window, and the panels are often used by the video production staff to control natural light.

Figure 4.3- Ceiling mounted acoustical diffusers

Figure 4.4 Variable acoustic panels in the Tracking Room – absorptive side (left); reflective side (right)

At the time of our visit, there were 9 variable acoustic panels in place, with the absorptive surface exposed to the Tracking Room and 260ft^2 of area rugs in place.

Reverberation decay time was measured at 0.42 seconds, and calculated at 0.44 seconds, broadband. Figure 4.5 shows the decay times across the audio frequency range. Discrepancies between measured and calculated values are probably due to the variable thickness of the absorptive treatment; absorption values for 4" thick fiberglass were used for calculations, as this is the thickest treatment for which data was available.

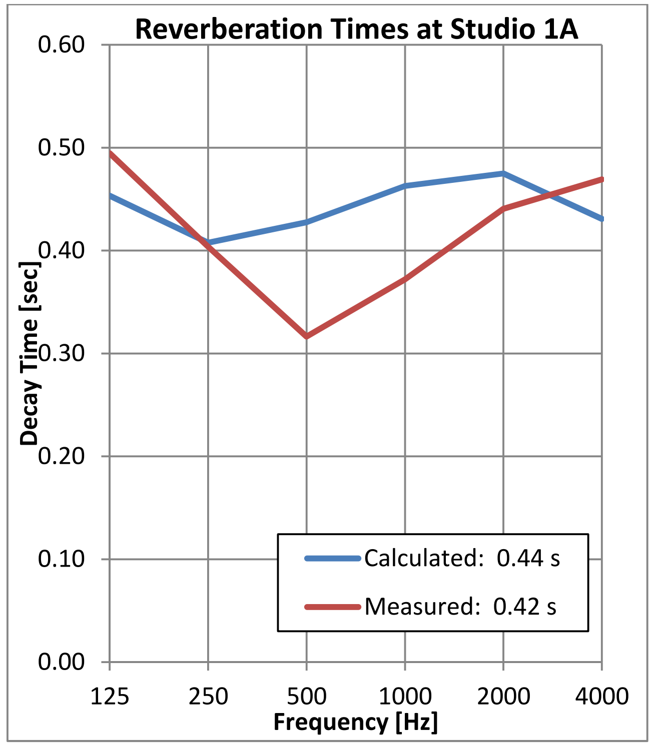

Figure 4.5- Reverberation time in the Tracking Room

The ceiling in the Control Room is installed at 9'-2" above the finish floor, and is composed of three layers of 5/8" gypboard with the area above the mix position covered by acoustical diffusers. There is absorptive treatment installed at the front and side walls, and a large diffuser installed on the rear wall. Figure 4.6 shows the rear wall diffusion in the Control Room.

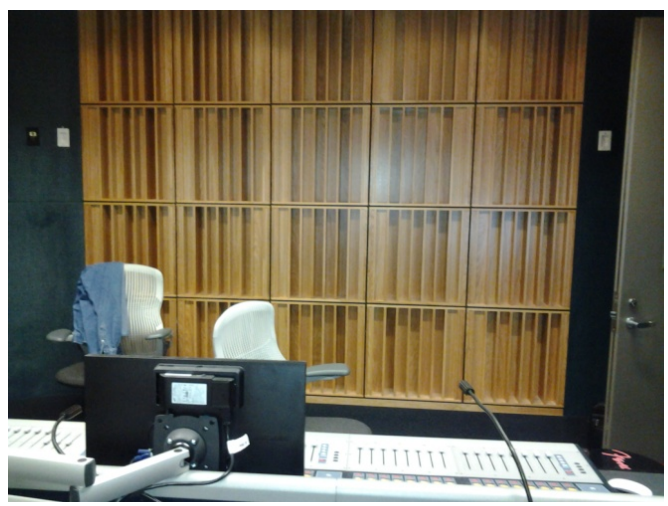

Figure 4.6- Interior of the Control Room showing the rear wall acoustical diffuser

<u>SOUND ISOLATION</u>

The Tracking Room is isolated from adjacent areas by the sound isolation wall assembly and Vestibules with interior lined with acoustically absorptive material to discourage the buildup of sound. Vestibule doors are heavy push-pull style units at Tracking Room side, and latching units at public side; this allows the doors to be securely locked from the outside, but prevents the doors from making a loud noise every time they close. All doors are solid-core wood, and include adjustable perimeter seals and a door bottom, as shown in Figure 4.7.

The Tracking Room is constructed as a room-within-a-room, including a 'floating' concrete floor slab isolated on neoprene pucks, a spring isolated ceiling system, and double steel stud walls, separated by a 1" air gap, around the perimeter with the exterior set of studs installed on the fixed slab and the interior set of studs installed on the floating slab. The windows at the Control Room and Open Office Area are double paned. Windows between the Tracking Room and the exterior are constructed as two separate curtain wall systems separated by an airspace that is more than 12" thick. See Figure 4.8 for architectural drawings of the sound isolation systems.

Figure 4.7- Adjustable door seals at Vestibule/ Tracking Room door – door closed (left) and door open (right)

Sound isolation between the Tracking Room and the 1st Level Open Office Area, the Lobby, the Control Room, and the exterior has been satisfactory; however an isolation issue has come to light between the Tracking Room and the 2nd Level Open Office Area. There seems to be an acoustical weak link at the exterior window system that allows sound to leak to the level above. So far this has been a minor issue, and the radio station staff has not further investigated or remediated this issue.

We made an attempt to measure sound isolation between the Tracking Room and the Control Room, but conditions did not allow a valid measurement; sound isolation was high enough, and ambient sound levels in the Control Room were loud enough, that the 'receive' measurement was not above the noise floor in the Control Room. We were not able to measure sound isolation between the Tracking Room and Open Office Areas or the Exterior due to background noise levels in these areas (ie. typical office noise during business hours and traffic/ pedestrian noise).

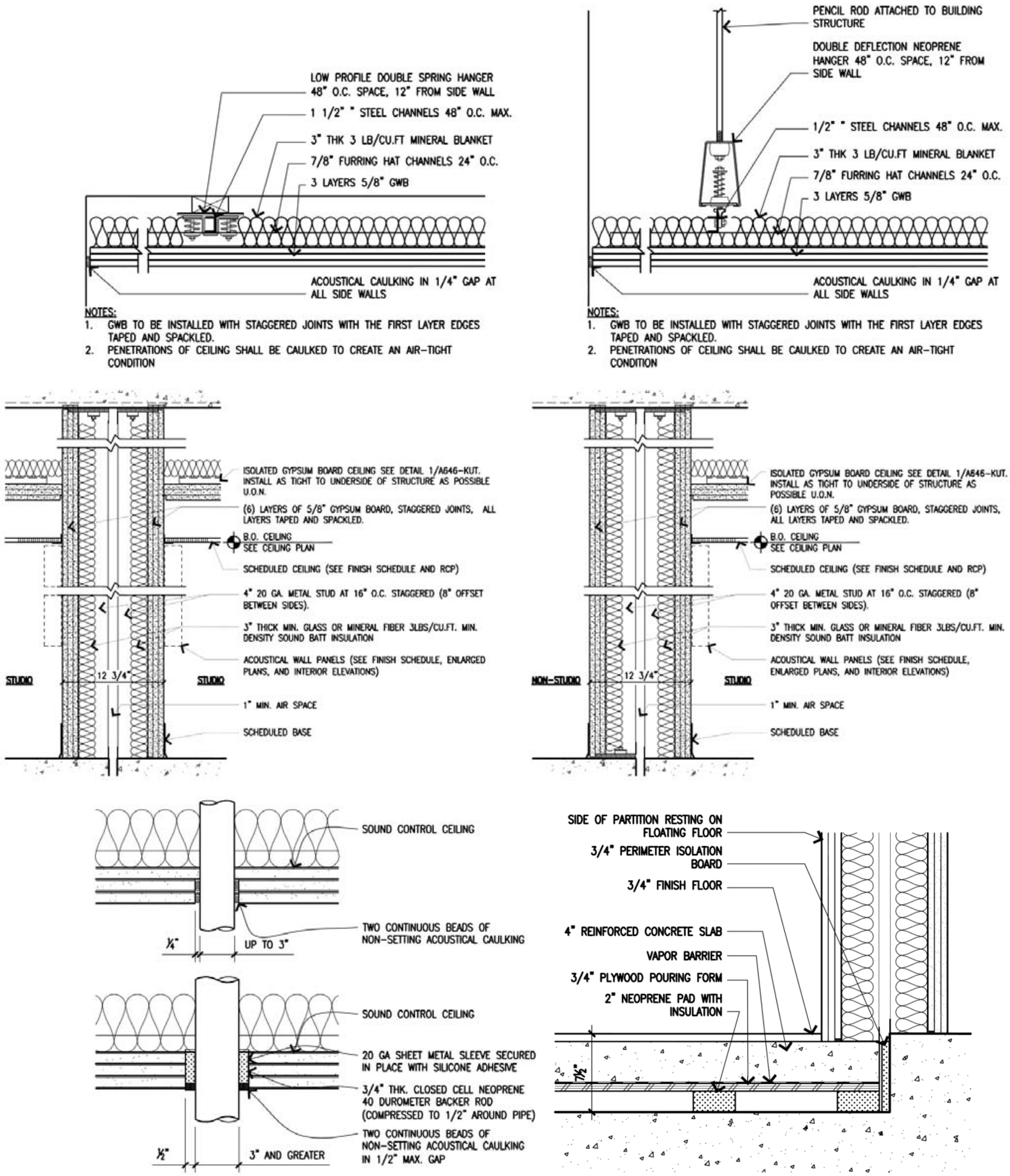

Figure 4.8- Sound isolation considerations included a floating floor, double stud walls, and spring isolated ceiling.

NOISE CONTROL

The HVAC system serving the studio was designed to produce noise levels no higher than NC-20; refer to Figure 4.9 for a layout of HVAC equipment in the Studio area. Low noise levels are achieved by serving the HVAC needs of the studio using a dedicated air handler unit (AHU), and locating this unit on the other side of the building to provide long duct paths – and increase the opportunity for sound attenuation – between the AHU and sound-critical areas. Ductwork in the Studio area is oversized to provide low airflow rates, and is internally lined to increase attenuation of fan noise as air flows through the ductwork. Air diffusers and grilles are selected to produce low levels of noise. The Tracking and Control Rooms are served by completely separate ductpaths so that cross-talk between the two areas is not possible through common ductwork. Keynote 4 in Figure 4.9 indicates internally lined air transfer boots in the shape of a ‘U’ or ‘Z’, which are designed such that a line-of-sight does not exist between the inlet and outlet; these boots provide significant sound attenuation, while allowing return air to flow back to the fan unit. The HVAC system operates continuously to combat the noticeable change in sound level when the system becomes active.

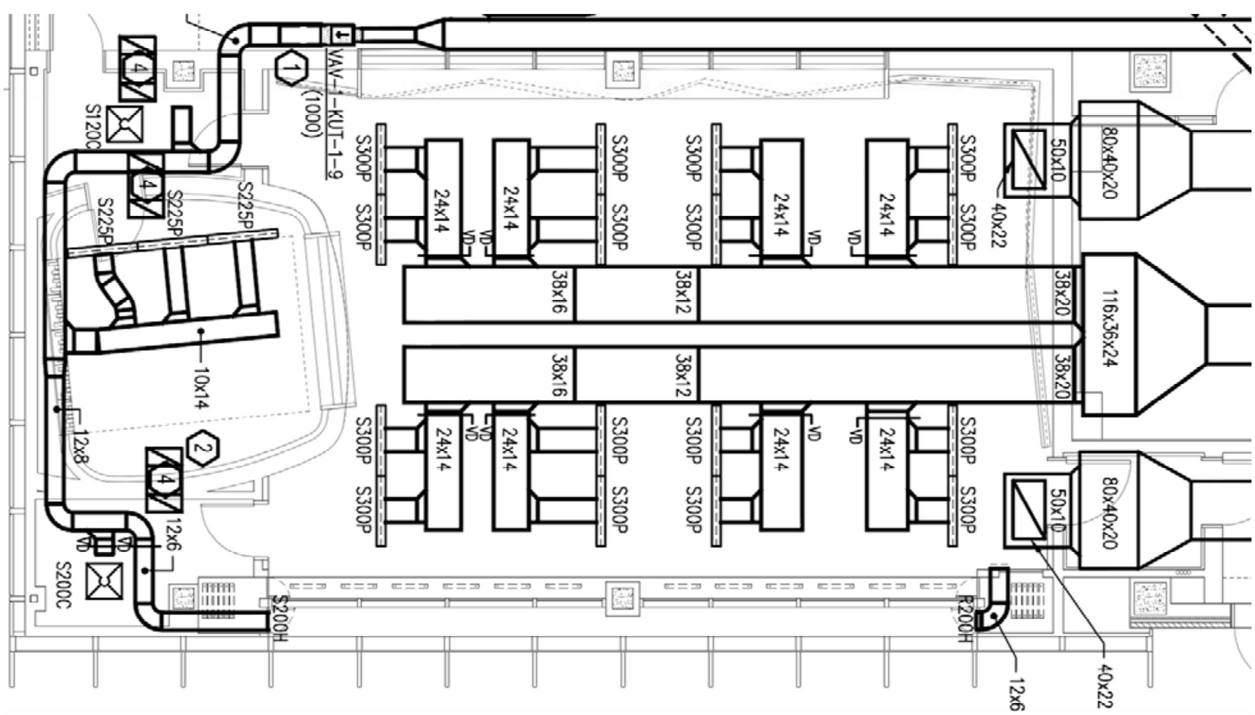

Figure 4.9- HVAC system layout in the Studio area

Figure 4.10 shows typical ambient sound pressure levels in the Tracking and Control Rooms. The ambient sound levels in the Tracking Room were measured at NC-31, 37.4dBA, dominated by fans in an analog-digital audio converter located near the performance area; in the Control Room levels were measured at NC-37, 42.3dBA, dominated by the five fans located on the rear of the mixing console. These levels are significantly above recommended levels, but it is important to note that HVAC system related noise is not noticeable in either room.

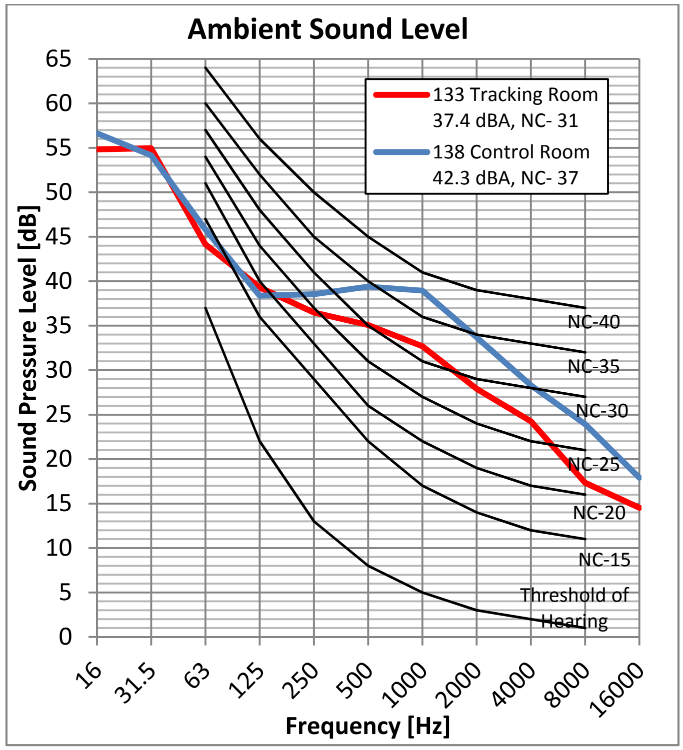

Figure 4.10- Ambient Sound Level Measurements

CONCLUSION

Overall, the acoustical properties of the Tracking Room, primarily the overall reverberation decay time, are highly variable. The recording/ broadcast engineer can optimize the conditions in the room and the feeling of presence and intimacy for the live audience based on the needs of the individual musical acts by altering the placement or orientation of the variable acoustical panels at the window and the area rugs, or removing these objects altogether. The extensive use of acoustical diffusers, with little acoustical absorption at the ceiling, creates a more reverberant space than is desired in most recording environments, but which works well in this case since the Studio often hosts a live audience.

Sound isolation between the Tracking Room and adjacent areas is by all accounts excellent, with the exception of a minor issue where sound from the Studio can be heard at a low level at the floor above. The double-paned windows at the Control Room and Open Office Area, and the massive window assembly at the exterior, work without complaint, although attempts to measure isolation at these areas were unsuccessful.

Ambient sound levels in the Tracking and Control Rooms were significantly higher than recommended for this type of facility, due primarily to cooling fans associated with the audio equipment. Great expense was taken, during the HVAC system design and construction, to provide extremely quiet conditions in the Studio area, and these efforts were successful in that HVAC noise is not noticeable in the sound-critical areas; however these efforts were somewhat in vain considering the noisy equipment that is installed inside the sound-critical areas. Equipment noise in the Tracking Room is dealt with by using close-mic techniques, portable sound barriers, etc.

Thanks to Peter Babb, Casey Cheek, Phil Hargrove, and Pawn Chulavatr for their assistance in providing access to, answering questions about, and supplying construction drawings for Studio 1A.

5. MOODY THEATER

BACKGROUND

The Moody Theater is a live music venue located in downtown Austin, known most notably as the home of the Austin City Limits (ACL) tapings, which are broadcast nation-wide on PBS television stations. The venue is located in a mixed use building which also contains a hotel, offices, retail and restaurant establishments, etc. The facility was commissioned in February 2011. The Moody Theater is used primarily for live musical performances; many – but not all – of the performances are recorded for ACL or other productions.

The facility includes the Theater, separate Audio and Video Control Rooms with associated Machine Rooms, a large outdoor Patio, and an extensive Back-of-House with storage and support areas for the Theater. The Theater is a large room (7,000ft^2 – footprint, 473,000ft^3), with three levels of seating (Floor, Mezzanine and Balcony). The Floor level seats around 800 people, the entire Theater seats 2,700. Views of the interior of the Theater are shown in Figure 5.1. The theater includes fourteen bars, each of which include noisy equipment (refrigerators, ice makers, etc.) There is a catwalk installed 50'-0" above the finish floor.

The Audio Control Suite is located on the Floor level in the Back-of House area down a corridor approximately 40 feet from a sound rated loading door to the Theater. The Control Room is separated from the Corridor by a Vestibule with sound-rated doors; interior views of this area are shown in Figure 5.2.


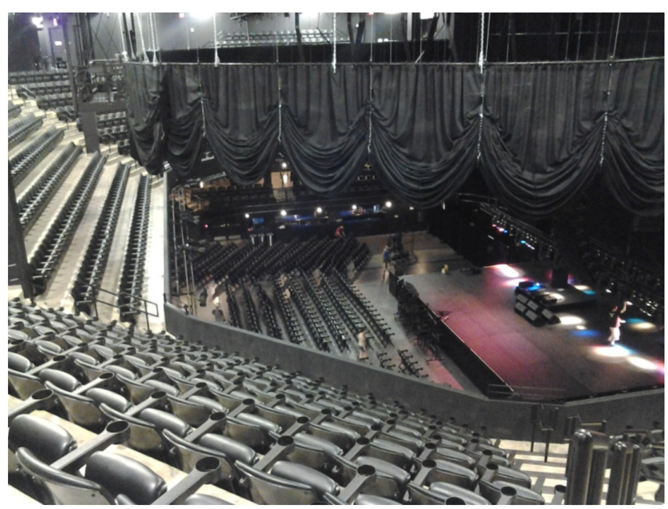

Figure 5.1- Views of the interior of the Moody Theater – stage from the Mezzanine level (left), stage from Balcony level (right)

Figure 5.2- Interior views of the Audio Control Suite – Vestibule, with Control & Machine Rooms visible (left), console and near-field monitors (right)

The FOH mix is sent to self-powered line array speakers, including a cardioid subwoofer array designed to keep extraneous low-frequency sound energy from the stage area and thereby make the FOH mix ‘cleaner’, suspended from the lighting truss above the stage area. Typical sound levels during production range from about 85dBA to 110dBA or above, depending on the event. For ACL tapings, the production staff prefers to keep levels as low as possible, but this is not always possible. For some ACL tapings, portable bleachers are situated around the Floor level, and the Balcony and/ or Mezzanine levels may be closed off with a heavy stage curtain.

<u>ROOM ACOUSTICS</u>

The Theater floor is made of cast-in-place concrete; the stage is of relatively light construction, and is built-up when needed and removed when not. The finish ceiling is exposed concrete deck at approximately 58’-0” above the finish floor. Audience seating at the Mezzanine and Balcony levels includes acoustically absorptive seats and backs. When temporary seating is installed at the Floor level, it includes padded seats and backs.

Structural walls are relatively rectangular, and are faced on all four sides of the Floor level with 2” thick acoustically absorbent treatment installed flush to the walls; treatment at the front wall extends higher than the Floor level, but otherwise no acoustical wall treatment is installed to wall areas at the Mezzanine or Balcony levels. The lack of acoustical treatment at the upper two seating levels leads to noticeably different acoustical conditions when these levels are open versus when they are closed off by the stage curtain. The stage curtain reduces reverberation decay time by effectively reducing the volume of the room, while significantly increasing the percentage of acoustically absorptive surface area, when deployed. Walls that are not covered with absorptive treatment are primarily concrete masonry units (CMU) or gypboard.

Surfaces at the rear wall were originally designed to include acoustical diffusion, but these materials were removed from the design due to cost considerations, and replaced with the previously mentioned absorptive material. There are plans to install additional absorptive treatment at the upper level seating areas at a later date.

The ceiling in the Control Room is gypboard; the floor is carpet tile at the perimeter and hardwood at the mix position. Most of the wall surfaces are faced with 2” thick acoustical absorption, installed flush with the wall surface. Hollow sections behind the rear corners of the room serve as bass traps.

At the time of our visit, portable seating (folding metal chairs with thin pads at the seat and back) was being set up for an upcoming event, and the stage curtain was retracted. Reverberation decay time was measured at 1.14 seconds, and calculated at 1.33 seconds, broadband. Figure 5.3 shows that the decay times at the lower end of the audio frequency range are significantly longer than middle and high frequency times, which are otherwise generally equal around 1.0 second.

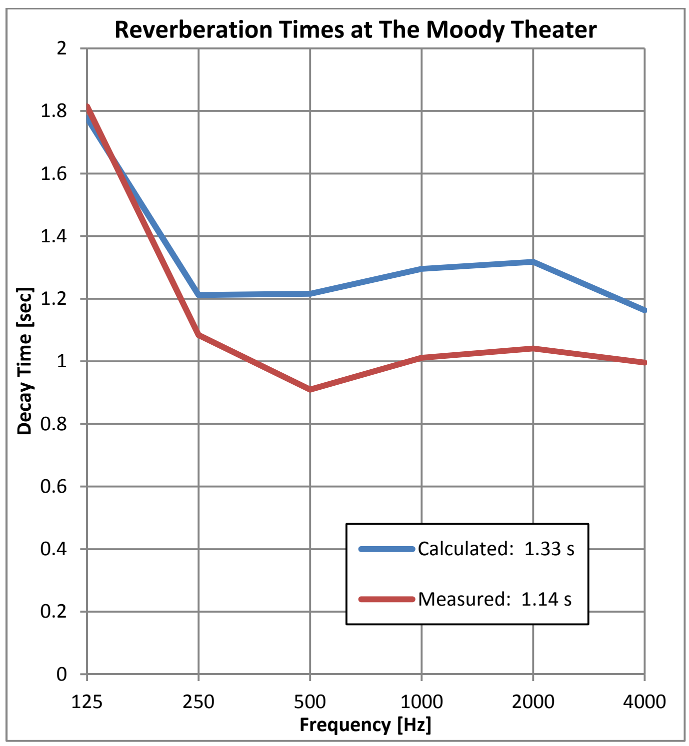

Figure 5.3- Reverberation decay time in the Theater

<u>SOUND ISOLATION</u>

Walls around the Theater are constructed of double layer CMU, separated by a 1” airspace. Sound isolation between the Theater and the exterior Patio is increased by vestibules fitted with heavy doors and acoustically absorbent wall surfaces. Isolation between the Theater and the Vestibule was measured at NIC-33, as shown in Figure 5.4. Sound level measurements were taken at the Patio, but the dominant source was traffic at the street below, and a valid isolation measurement could not be made. It is interesting to note that during construction there was reportedly jackhammer activity in the Theater that could not be heard on the Patio through the vestibules.

An isolated 'floating' floor is installed at the stage area of the Theater, extending part-way into the audience area on the Floor level. This is presumably designed to discourage vibration transfer from the stage to the building structure. After the facility was occupied, the gap between the isolated and fixed slabs was found to interfere with the portable bleachers, and the gap has since been bridged with sheet metal (see Figure 5.5). The details of how this was accomplished were not immediately available, but it is possible that the isolated floor has been rendered ineffective by bridging it to the fixed slab.

Sound isolation between the Theater and the hotel that occupies the same

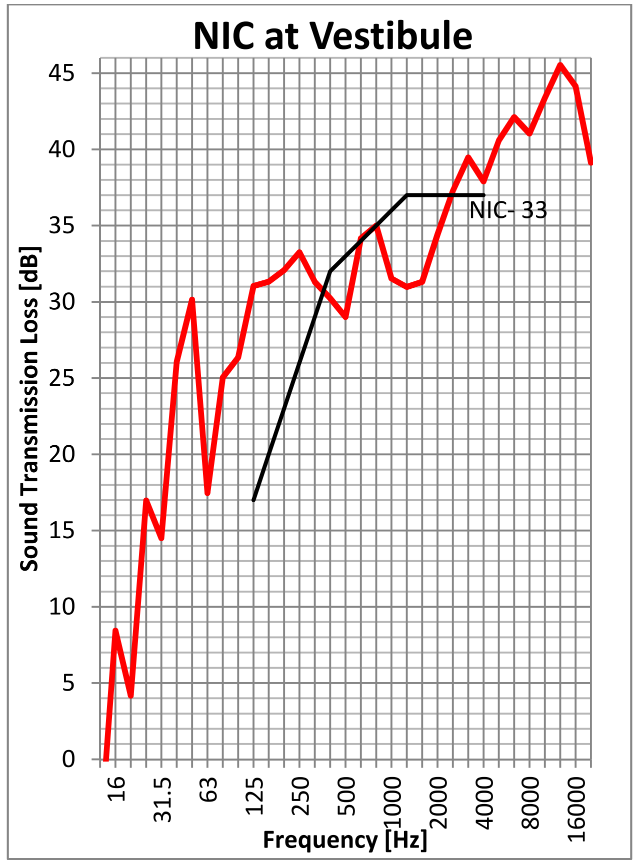

Figure 5.4- Results of sound isolation testing between Theater and Vestibule.

Figure 5.5- Junction of isolated and fixed slabs bridged by sheet metal.

development was a major design concern. A wall was constructed between the two buildings of two layers of 8" thick CMU, completely filled with grout. A design decision was later made to provide direct access between the two areas, and a door was added in the sound isolation wall, largely negating its effectiveness. Note that the theater representatives that we were in contact with were not aware of any noise complaints at the hotel.

The Audio Control Suite is separated from the Theater by a Corridor and Vestibule, with sound rated doors between the Theater & the Corridor, and the Corridor & the Vestibule, and with heavy, double-paned sliding doors in the vestibule at the Control and Machine Rooms. Note that the door at the Machine Room is left open most of the time to allow adequate airflow through the room for equipment ventilation. Our measurements were taken with the sliding door at the Machine Room open and all other doors in the Audio Control Suite closed – typical conditions during production.

Walls at the Audio Control Suite are double steel stud construction, reportedly with up to twelve layers gypboard at some areas. The window between the Control and Machine Rooms is constructed of two layers of laminated glass, one attached to each side of the wall. Penetrations were made to the Audio Control Suite shell for return air transfer boots, as shown in Figure 5.6; it is not clear if these are internally lined.

One isolation issue that has arisen is between the Audio Control Suite and the nearby service elevators. On occasion, the audio engineer can hear a rumble that he attributes to the

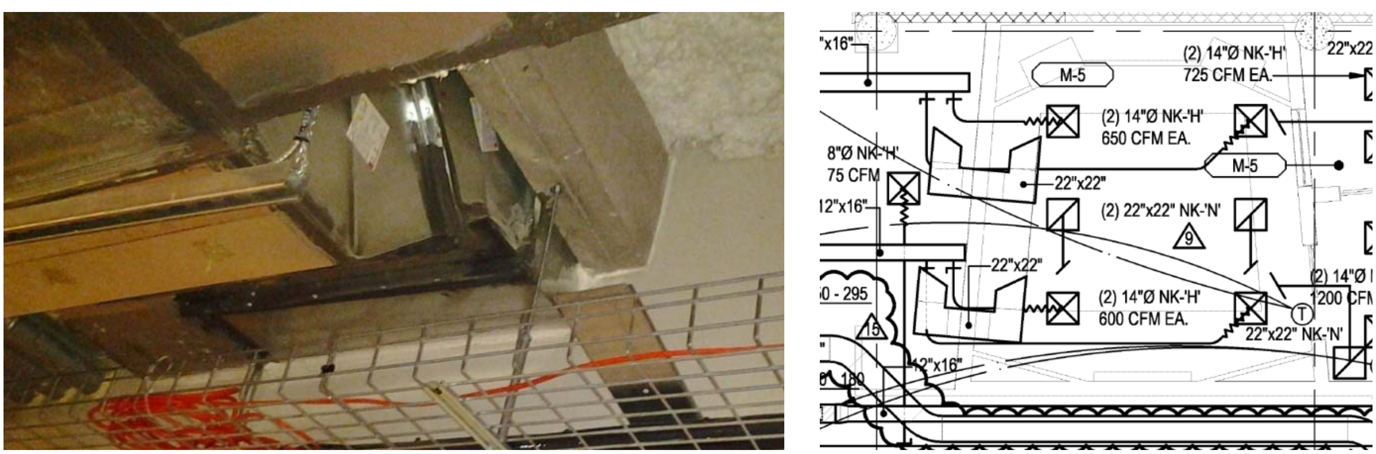

Figure 5.6. Penetrations at the Audio Control Suite isolation wall as photographed (left), and as shown on the HVAC design drawing (right)

operation of the elevators. Unfortunately, due to ongoing activity at the site during our visit, we were not able to test sound conditions in the Control Room with the elevator in operation.

NOISE CONTROL

The HVAC needs of the Theater are served by several air handler units through perforated fabric ductwork over the main floor area, shown in Figure 5.7, and through traditional sheet metal ductwork at the upper level seating areas.

Ambient sound levels throughout the Theater hovered generally around NC-40, as shown in Figure 5.8, significantly higher than the maximum recommended NC-30 for this type of venue. The elevated ambient noise levels in the Theater can be

Figure 5.7- Fabric ductwork serving main seating area

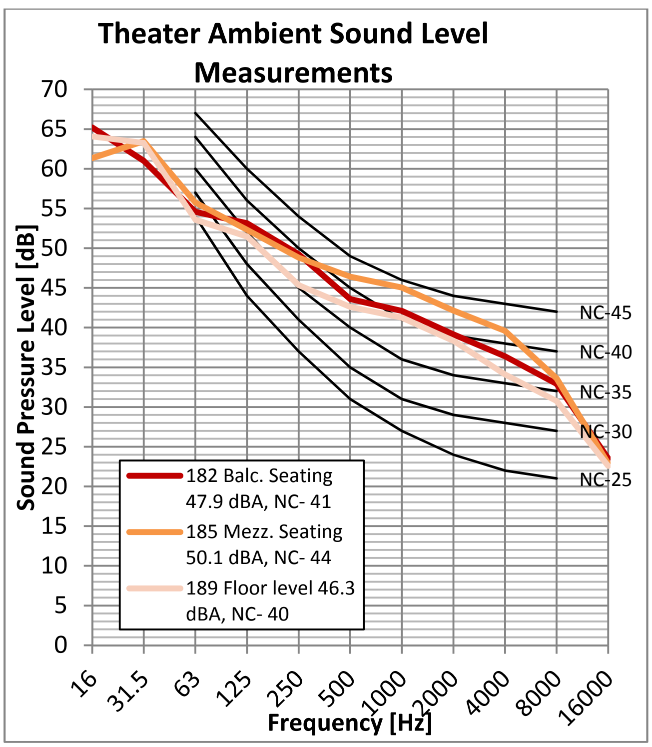

Figure 5.8- Ambient noise levels throughout the Theater

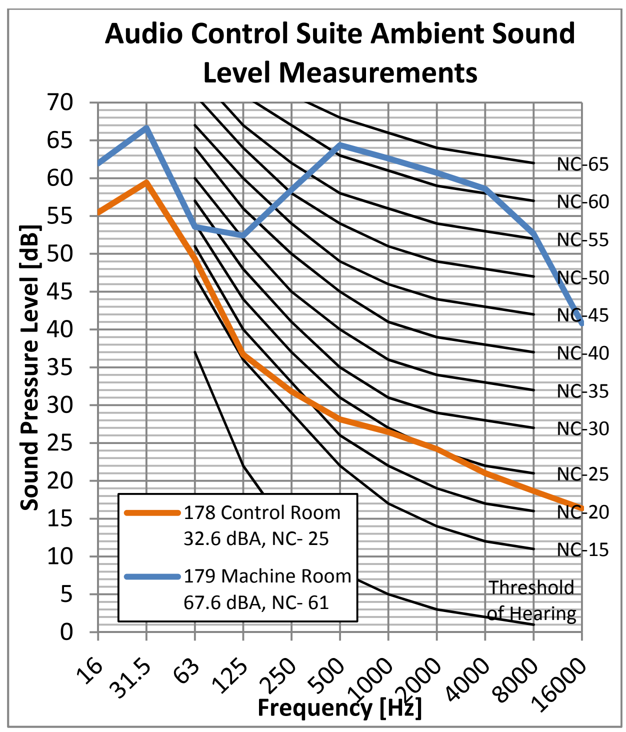

Figure 5.9- Ambient noise levels in the Audio Control Suite

attributed to different sources based on the listener's location; the dominant noise source at the Floor level is the equipment in the bars, at the upper levels HVAC noise is more apparent. Ambient sound levels were found to vary considerably over the seating area, with some seats experiencing levels as loud as 50.1dBA, NC-44. High ambient noise levels have been problematic during particularly quiet performances.

The fabric ductwork serving the Theater offers negligible amounts of sound attenuation and insertion loss. Therefore HVAC noise control for these portions of ductwork must be accomplished upstream of the transition from sheet metal to fabric ductwork. The details of how this was addressed were not immediately available.

Ambient sound levels in the Audio Control Suite are shown in Figure 5.9. Levels in the Control Room were found to be 32.6dBA, NC-25, within the recommended range for this type of room. Levels in the Machine Room were measured at 67.6dBA, NC-61.

CONCLUSION

The acoustical properties of the Theater vary somewhat based on how full the audience area is, and whether the Mezzanine and Balcony level seating areas are exposed or concealed behind the stage curtain. When the upper level seating areas are open, amplified sound reflects off of the hard rear walls, and causes the reverberation in the room to be more trebly, a condition that could be addressed by installing acoustically absorptive wall panels at the upper level rear walls, similar to the treatment at the Floor level.

Our contacts at the facility were not aware of any sound isolation issues between the Theater and adjacent areas, including a hotel, several retail establishments, offices, Audio and Video Control Suites, etc. Sound isolation is addressed with massive wall construction and sound rated doors. It is interesting that the gap around the floating slab in the Theater has been intentionally bridged by sheet metal. Further analysis would be necessary to completely investigate the efficacy of the floating slab in this condition.

Ambient sound levels in the Theater were somewhat higher than recommended for this type of facility, due primarily to noise generated by bar equipment at the Floor level, and to HVAC noise at the upper seating levels. Ambient sound levels were found to vary considerably over the seating area, but were generally higher than recommended for a music performance space. Ambient sound levels in the Audio Control Room were found to be within the recommended range for this type of room.

Thanks to Jeff Peterson, David Hough, and Zach Richards for their assistance in providing access to, answering questions about, and supplying construction drawings for the Moody Theater.

6. FUTURE WORK

Only a tiny fraction of the recording studios in the Austin area are covered in this report. A more complete study would include several additional venues of various specialties, and levels of sophistication.

This report focused mainly on the acoustical conditions in the Tracking Rooms at the various facilities visited, with only passing attention paid to conditions in the Control Rooms. Future work might include a more detailed study of the Control Rooms, including speaker placement, initial time delay gap, compliance with the BBC rule of thumb of 1500ft^3 minimum volume for critical listening spaces, phase alignment of monitor speakers, etc.

It is interesting that sound isolation between Tracking and Control Rooms was not generally a major design imperative. The reasoning for this is logical – that musical material in one room will be similar to that in the other room, and critical tasks (mixing in the Control Room and recording in the Tracking Room) are not undertaken concurrently. Sound isolation was considered more critical between the Tracking Room and the adjacent office areas at Studio 1A, and between the Tracking Room and the outdoors at all locations. Unfortunately, sound isolation measurements at these locations were not possible for various reasons, discussed in this report. It would be informative to measure these levels.

Reverberation time was measured at each of the venues with whatever furnishings happened to be in place at the time of our visit. At various locations this meant that the room was either set up for an upcoming event, was still set up from a recent event, or was relatively neat and orderly. Acoustical conditions at each of the venues visited are variable, either by adding or removing absorptive treatment (gobos at Austin Signal and EAR, and variable acoustical panels at Studio 1A), or by manipulating the effective volume of the room (closing off upper seating levels with a heavy stage curtain at the Moody Theater, which also significantly increases the percentage of acoustically absorptive surface area). Additionally, it is important to note that all measurements were made with the rooms nearly unoccupied; reverberation times will be somewhat lower with audiences in place at Studio 1A and the Moody Theater. It would be interesting to revisit these venues to do more extensive testing, including evaluating reverberation time under several typical conditions.

It would also be interesting to measure other metrics of the acoustical conditions at the various locations, such as early decay time and the initial time delay gap, and vibration transfer through building structural components.

7. REFERENCES

1. ASHRAE Handbook Ch. 45-Sound and Vibration Control. American Society of Heating, Refrigeration and Air-Conditioning Engineers, 2010. Print.
2. ASTM E336-11 Standard Test Method for Measurement of Airborne Sound Attenuation between Rooms in Buildings. American Society for Testing and Materials, 2011.
3. ASTM C634-11 Standard Terminology Relating to Building and Environmental Acoustics. American Society for Testing and Materials, 2011.
4. ASTM E2235-04 Standard Test Method for Determination of Decay Rates for Use in Sound Insulation Test Methods. American Society for Testing and Materials, 2004.
5. Adelman-Larson et al. Suitable reverberation times for halls for rock and pop music. JASA, Vol 127 pp.247-255 (2010).
6. Babb, Peter; Cheek, Casey; Hargrove, Phil; and Chulavatr, Pawn. Personal interview. 9 April 2013.
7. Beranek, Leo. Concert Halls and Opera Houses. Springer: New York, 2004. Print.
8. Egan, M. David. Architectural Acoustics. McGraw-Hill, New York, 1988. Print.
9. Everest, F. Alton. The Master Handbook of Acoustics. McGraw Hill, New York, 1989. Print.
10. Harris, Cyril M. Noise Control in Buildings. McGraw Hill, New York, 1994. Print.
11. Hough, David, Peterson, Jeff, and Richards, Zach. Personal interview, 23 April 2013.
12. Long, Marshall. Architectural Acoustics. Academic Press: New York, 2006. Print.
13. Niess, Jon and Klinginsmith, Greg. Personal interview. 19 April 2013 and 1 May 2013.
14. Educational Uses of Non-Coursepack Materials. *Copyright & Fair Use*. Stanford University. Web. 15 May 2013. http://fairuse.stanford.edu/Copyright_and_Fair_Use_Overview/chapter7/7-b.html
15. Stevens, James. Personal interview. 21 April 2013.