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CASE STUDY OF A HOSPITAL ATRIUM WITH OVERLOOKING PATIENT ROOMS

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Abstract

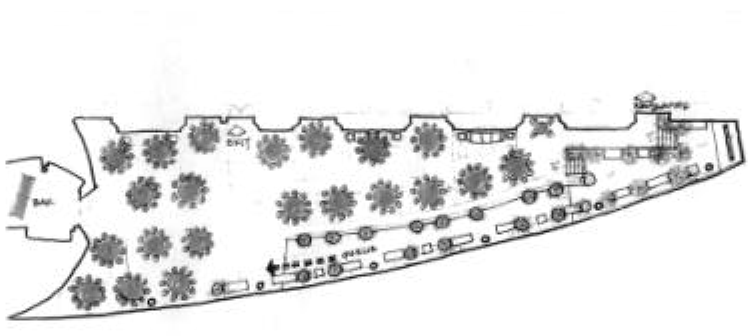
As environmental noise and other urban impacts become increasingly significant, atriums become ideal spaces for functions once reserved for outdoors. Although atriums can provide buffer noise reduction to sound sensitive spaces from environmental noise exposure, sound isolation between atriums and adjacent sound sensitive spaces becomes an issue.

An atrium was designed for a hospital recently constructed. The space is a slender, four story atrium with two walls constructed primarily of glass, housing a waterfall and artwork. Patient rooms overlook the atrium through fixed windows, which bring in natural light and scenic views. The atrium provided isolation to patient rooms from environmental noise (traffic, helicopter, sirens, etc…).

The hospital management desired to use the space for receptions and presentation meetings, potentially with amplified sound. Designers recognized that the meeting function of the atrium would require an acceptable acoustical environment and should not cause intrusion into adjacent patient rooms. For this reason the mechanical background noise in the atrium, reverberation decay time in the atrium, the transmission loss of the building envelope, and the transmission loss of the partitions between the atrium and the patient rooms were significant factors.

Design criteria for the project and success of the design implementation will be discussed based on validation measurements.

INTRODUCTION



An atrium was designed to serve as an intermediate area between the outdoor environment and indoor patient rooms at a Texas hospital. The hospital, located in the Houston Medical Center, has a helipad and frequent ambulance traffic with loud sirens, and is surrounded by other medical facilities with helipads and ambulance traffic. The atrium would provide a buffer for this environmental noise. Late in the design process the atrium was proposed to serve as a reception and meeting space with amplified sound and a general public lounge/waiting area. The space was envisioned as a narrow, four-story space with a glass exterior envelope, marble and plastic "wood" laminate accented, painted plaster walls, patient room windows, a waterfall, tables and seating for patrons, terrazzo floors, and suspended mobile artwork. Three stories of patient room windows, and one floor with a presentation conference room and several reading rooms line the interior wall of the atrium. Additional seating, a sound system, and a stage can be brought into the space and set up for meetings.

PRESENTATION OF THE PROBLEM

As acoustical consultants to Morris Architects, **JEAcoustics** was challenged with conceiving and developing means to provide adequate speech intelligibility in the atrium and sound isolation between the patient rooms and the atrium. The atrium will occasionally utilize a portable sound amplification system and it is imperative that the adjacent patient rooms have low, undisturbed, sound levels at all times. The atrium needs to have a short enough reverberation decay time (T_{60}) and a low background ambient continuous noise level (from the mechanical systems noise) to provide good (natural and amplified) speech intelligibility in the space. In addition, the proposed waterfall design feature should not be too loud. These design elements could also affect the quality of the acoustics in the adjacent spaces. If the reverberation decay times were too long, or the background levels were too high in the atrium, the sound system volume would likely be increased, resulting in noise intrusion into adjacent spaces. Another factor that must be considered is the intermittent noise level introduced by users of the space. The most significant of these noise levels is the occupant vocal output in the reverberant field, which can be predicted by the following formula[1] where "n" is the number of speakers and "A" is the amount of sound absorption:

$$L_{p,rev} = 65 + 10 \log (4n/A) \qquad (1)$$

The design was fairly progressed when **JEAcoustics** became involved in the project. Only after construction had begun did the atrium become programmed for use as a meeting space. All hard reflective building surface finishes had already been envisioned and scheduled for the space**.** **JEAcoustics** was challenged to select acoustically absorptive surface finishes that were in keeping with the architectural designers' aesthetic vision for the space.

Acoustical Design Criteria

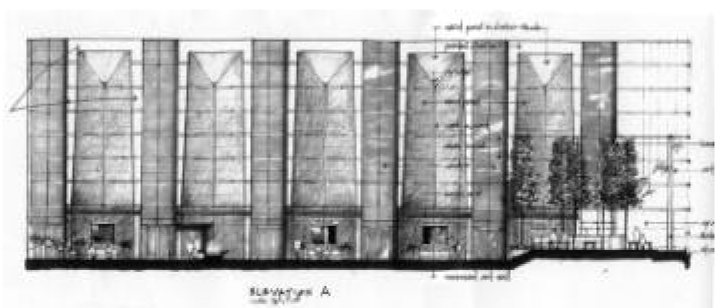
Acoustical design criteria were established for amplified and non-amplified speech presentation as the principal function of the Atrium, with tolerances to accommodate pre-recorded music tracks as a part of presentations. Design criteria were as follows:

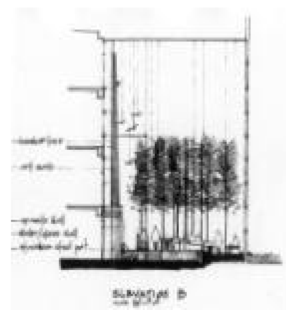
- Reverberation Decay Time (T_{60}): $\leq$ 1.75 seconds, in the 500- 2000 Hertz octave bands[5]
- Continuous Ambient Noise (HVAC): NC-30 to NC-40[2]
- Water Feature Design for little water turbulence: $\leq$ 75 dBA
- Sound Isolation between the Atrium and the Patient Rooms: Atrium noise in the patient rooms $\leq$ patient room + 5 dB, with short transient disturbance or possible annoyance $\leq$ 10 dB above ambient (serious reaction expected when intrusive noise is more than 10 dB above ambient). The patient room ambient noise design criterion is NC-25 to NC-35[2] (34 to 44 dB).

Acoustical Design Issues

Classic Sabine formula[3] analysis indicated a need for absorption. Ray diagram[4] analyses of the sound propagation patterns indicated potential for vertical flutter echoes, but did not indicate significant horizontal flutter echo or other undesirable reflection patterns. The acoustical absorption needed to integrate aesthetically into the already developed design. The large volume and very narrow and tall shape of the space had to be considered relative to good meeting room acoustics.

Based on the glass window design for the north, south, and east walls of the Atrium and the hard terrazzo floors, the only available space for surface absorption was on the ceilings and the non-glass portions of the west walls of the Atrium (the partition between the patient rooms and the Atrium). Ceiling absorption would control vertical flutter echo and reduce reverberation. Additional wall absorption would supplement reverberation control. Patient room windows covered ~25% of the west wall, curved plastic wood panels were scheduled for ~20%, and marble accent panels were scheduled for an additional ~6%. JEAcoustics recommended acoustical absorption that was in keeping with the design aesthetic of the space on the remaining available wall space, and for the ceiling in the atrium. Acoustically absorptive plaster, with an NRC greater than or equal to 0.60, was recommended in lieu of hard reflective plaster. In lieu of additional plastic paneling, **JEAcoustics** recommended perforated metal with absorptive wall panels (with an NRC greater than or equal to 0.90) behind. A fiberglass acoustical tile ceiling was recommended. The ceiling and the available wall space accounted for ~30% of the total surface area in the room.





The tall narrow room is to be used for informal receptions and presentations, not formal meetings. Any required speakers, seats, and podium are mobile and temporary. Therefore, **JEAcoustics** did not recommend installing permanent floor mounted acoustical surfaces, shells, screens, or panels.

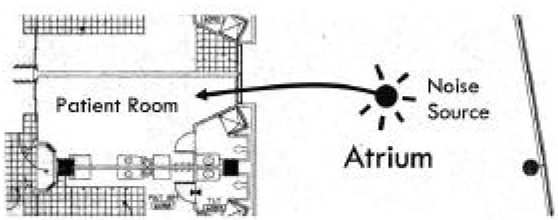
Mechanical Noise Control Concepts

The allowable continuous noise criteria for the Atrium required physical separation of external sound sources, attenuation of fan, duct and fitting noise, and vibration isolation of equipment, pipes and ducts[5]. Air handler and duct attenuation was designed to minimize fan noise. Duct and fitting velocities were specified to avoid turbulence noise. Diffusers, registers and volume dampers were specified for quiet operation. Flexible couplings and vibration isolators were sized to achieve > 90% transmission loss of force.

Water Feature Design Concepts

In order to limit the continuous background noise yet allow for some masking noise for speech privacy, the water feature design should prevent the water from entering free fall[6]. The glass should be at a small slope, so that the water clings to the surface of the glass, rather than falls. The glass surface should continue into the surface of the pool of water, to diminish, but not eliminate, splashing at the bottom of the feature.

Sound Isolation Design Concepts



The sound isolation between the patient rooms and the Atrium was controlled by the windows. The windows had been scheduled as 1” total thickness insulating glass with two 1/4” panels, and a 1/2” airspace. **JEAcoustics** recommended an upgrade to laminated insulating glass, however the 1” thick insulating windows were all ready specified and could not be changed. Therefore the sound level in the atrium would need to be limited to 75 dBA at a distance greater than 10’ from the loudspeaker. **JEAcoustics** recommended the loudspeakers be oriented to direct sound in the long direction of the room, pointing slightly downward, or toward a point 65% to 75% of the distance from the loudspeaker to the opposite wall. If the speakers must be aimed in the short direction, locate the speakers near the interior atrium wall, below the patient rooms and pointed toward the floor at a point near the exterior atrium glazing.

The sound isolation of the Atrium from outdoor noise was also controlled by the windows. The exterior glazing was also scheduled to be 1” total thickness insulating glass with two 1/4” panels of glass and a 1/2” airspace; **JEAcoustics** concurred.

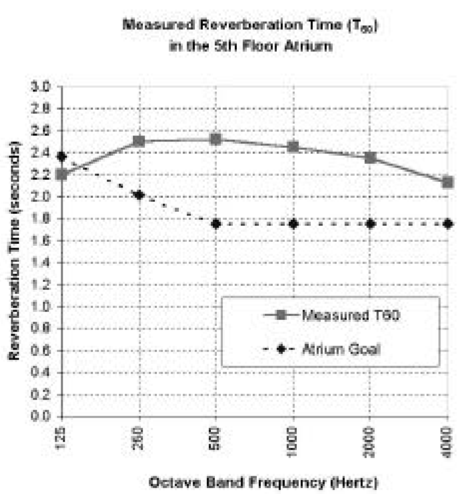
DESIGN IMPLEMENTATION

The majority of design concepts for acoustics, sound isolation and mechanical noise control were implemented by the architects and engineers, including absorptive materials on the north walls and the ceiling, high transmission loss window assemblies, water feature noise control measures, and mechanical noise control measures. **JEAcoustics** recommendations were severely limited by the progress of the project when the meeting room design function was added to the schedule for the Atrium space. Thus, some design concepts were not implemented:

- The quantity and absorption coefficients of the acoustical absorption in the space were limited by the architectural design. JEAcoustics informed the client that given the aesthetic limitations, the reverberation decay time design criteria could not be met.

- Sidewall supply registers were installed with opposed blade face dampers, contrary to JEAcoustics recommendation that dampers be up stream a minimum of three equivalent duct diameters from the registers. Long throw of the sidewall diffusers is also an acoustical issue. **JEAcoustics** would have preferred using more diffusers to achieve greater distribution of air in the space. This was not possible due to the advanced stage of the construction.
- As recommended, the water feature was installed sloped at an angle of 2 degrees to prevent the water from entering free fall. The glass terminated 1" above the water surface, contrary to recommendation, but generates a very moderate sound level.
- None of the windows were upgraded to laminated insulating glass. The architects, in concert with owner preferences, opted to limit the noise levels generated in the Atrium rather than upgrade the construction.

PERFORMANCE



Reverberation Decay Time (T_{60})

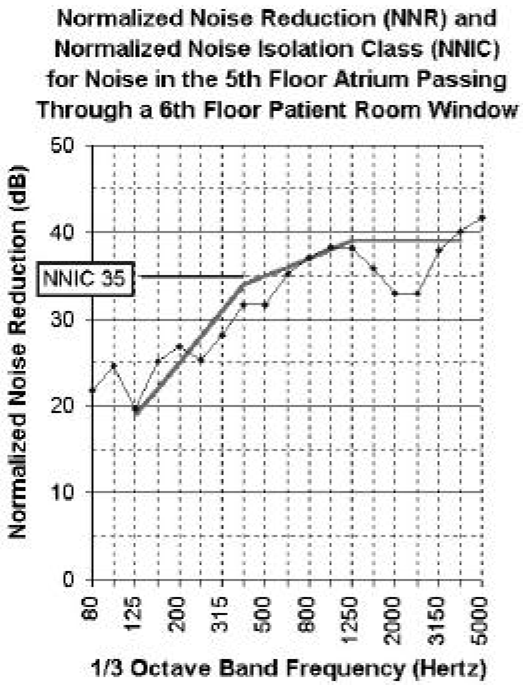
The tested reverberation decay time in the 500 to 2000 Hertz octave bands was between 2.3 and 2.5 seconds[7]. Reverberation decay time is expected to decrease slightly (~ 0.1 seconds) when groups of people occupy the floor.

Continuous Background Noise

At the time of validation measurements, the HVAC system was not yet tested and balanced. One of the four sidewall diffusers was missing a damper and was significantly over volume. The measured performance of the unbalanced system was in compliance with NC-50[7] conditions. Additional measurements will be made after the system is balanced.

Water Feature

The water feature was not operable at the time validation measurements were taken. Observation during construction walk through, however, indicated moderate sound levels.



Sound Isolation/ Transmission Loss (NIC)

The sound transmission through the patient room envelope, which was controlled by the window, is NNIC 35. Based on the measured noise reduction provided through the composite wall and window, sound levels in the center of the Atrium (about 5' AFF) may be amplified up to 80 dB during presentations. Based on a tolerance of 5 dB above patient room ambient levels, with transient disturbance 6 to 10 dB above ambient, the sound level could possibly be increased to 85 dBA[7], without causing significant disturbance in patient rooms.

Summary

The atrium acoustic design meets design intent, except for the background noise (which is not yet balanced). For presentations in the space, the cumulative effect of the reverberation decay time, the continuous background noise, and the typical user-introduced noise in the reverberant field provides a space where speech is expected to be intelligible over an approximate distance of 10 meters (39 feet). However during receptions and other conversation-based functions, the number of people speaking is expected to increase. As a result, the distance over which speech will be intelligible will decrease.

POTENTIAL IMPROVEMENTS

- Reverberation Decay Time: Given the limitations on available surface area for acoustical absorption, only slightly greater surface absorption might be provided with significant increase in material absorption coefficients.
- Movable screens with absorption, or reflective screens to focus sound in desired areas for presentations could be set up in the space. Additional acoustical absorption banners or baffles could be considered, although they might conflict with the architectural aesthetic.

- Water Feature: The water feature design meets the design objective, no improvements necessary.
- Continuous Background Noise: Volume dampers should be moved up stream of the diffusers. Greater distribution of air with more diffusers throughout the space would be recommended in lieu of the sidewall diffusers with long throw.
- Sound Isolation: The windows installed meet the design objective, no improvements necessary.

CONCLUSIONS

The Atrium is a success in that it will provide the desired environmental buffer between the outdoor environment and the patient rooms. Furthermore, the meeting room function of the Atrium space will not disturb the patients in their rooms when sound levels in the Atrium are limited to moderate levels. The Atrium will be more reverberant and have a slightly higher ambient background level than is typically desired for meeting rooms. However, the secondary meeting room function of the space is feasible within limited sound amplification use. Furthermore the aesthetics of the space, as well as expenses and scheduling of the project, were more important criteria to the architects and owners.

ACKNOWLEDGEMENTS

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