Canadian Acoustics / Acoustique Canadienne 20(4) 11-16 (1992) **Research article / Article de recherche**

THE BENEFITS OF FIELD TESTING THE ACOUSTIC PERFORMANCE OF SOUND ISOLATION ROOMS

Erwin Rebke
Alberta Public Works, Supply and Services
Acoustics Section
10th Floor, 8215 - 112 Street
Edmonton, Alberta, Canada T6G 5A9

ABSTRACT

Sound Isolation Rooms, typically used for auditory examination and research, are designed to provide a Noise Reduction in excess of ninety decibels and a background noise level approaching the auditory threshold. The Noise Reduction of these specialized rooms, as published by the various manufacturers, are usually laboratory tested in accordance with ANSI/ASTM E 596. Although methods of field testing these rooms have been proposed, there is no standardized procedure that allows the in-situ performance to be directly compared to the laboratory measurements. One main consideration is the physical environments surrounding a Sound Isolation Room placed in a building, which varies greatly from the uniform test conditions of a reverberation chamber. Numerous Sound Isolation Rooms were recently field-tested for their acoustic performance. Airborne sound isolation, background noise and structureborne sound isolation were investigated. For determining airborne sound isolation in the field, a simplified measure of Noise Reduction was used. Airborne sound leakage paths were clearly identified within the rooms. Consequently, these areas of deficiency were treated to optimise the on-site, airborne sound isolation. The measurements of background noise and structureborne sound isolation also revealed limitations in the acoustic performance that resulted in useful information for the examination and research personnel using these rooms.

SOMMAIRE

Les chambres d'isolation acoustique, dans lesquelles l'on fait l'examination auditive ou la recherce audiologique, sont déssinées afin d'insonoriser au delà de quatre-vingt dix (90) décibels tout en ayant un bruit de fond au seuil de l'audition. La réduction des niveaux publié par les manufacturiers pour ces chambres proviennent d'éssais en laboratoire conformément au standard ANSI/ASTM E-596. Plusieurs méthodes d'essais en place (après l'installation dans un batîment) ont été proposée mais aucune d'elles permetterait une comparaison directe aux résultats de laboratoires. Le variable principal c'est l'environment acoustique entourant la chambre dans un batîment qui varie nessairement d'une salle de réverberation.

Réçament, nous avons eu l'occasion de vérifier la performance acoustique de plusieurs de ces chambres dans des hôpitaux. Le niveau d'insonorisation fût déterminé par une mesure simplifiée de la réduction des niveaux, l'isolation structurelle avec une machine à impactes standardisé et le bruit de fond fût mesuré. Les lacunes acoustiques fûrent clairement identifiées et corrigées. Ceci améliora l'insonorisation subtantielment. Les mesures de briut de fond et de l'isolment structurel démontrèrent des limitaions importantes pour les usagers de ces chambres.

1. INTRODUCTION

One of the first successful applications of a lightweight, double-wall enclosure for sound isolation was at an industrial site in 1953. Since that time, the design of Sound Isolation Rooms (SIRs) has improved and their use has expanded to include many applications where acoustic isolation is critical. Along with their popular use as an audiometric testing facility, these modular units are utilized for industrial noise control, music practice rooms, broadcast studios, and test cells for various medical and life sciences.

A notable feature of these rooms is that their construction is modular. This gives them the ability to be easily fabricated within existing buildings at almost any location that provides the space. Also, these rooms can be disassembled and relocated, if the need arises.

The acoustic performance required from a SIR is highly dependent on its application. Perspective user groups typically base their purchase decision on the manufacturers published data of Noise Reduction and maximum Background Noise Levels. Once a SIR is installed on-site, they are usually not tested acoustically for their field performance. One reason may be the fact that there is no standardized procedure that allows the in-situ acoustic performance to be directly compared to the manufacturers data of Noise Reduction (ANSI/ASTM E596). It does seem, though, that many user groups rely on the expertise of the manufacturer and construction personnel to provide a SIR with optimum acoustic performance.

Eight Sound Isolation Rooms, used primarily for audiometric examination and research, were field tested for their acoustic performance. Airborne sound isolation, background noise and structureborne sound isolation were all investigated. Several acoustic deficiencies were disclosed that resulted in acoustic performance much less than optimum. In many cases, these deficiencies were easily corrected so that the on-site performance was optimized. The following describes the field test methods used to measure these rooms and summarizes the measurement results. The benefits of field testing these rooms are also outlined, based on the test results and site experiences.

2. LABORATORY TESTING VS. FIELD TESTING OF NOISE REDUCTION

For determining the airborne sound isolation of SIRs, manufacturers have them tested for Noise Reduction (NR) by a certified laboratory in accordance with ANSI/ASTM E596 Laboratory Measurement of the Noise Reduction of Sound-Isolating Enclosures. This standard test method requires that all four sides and the top of the SIR be exposed to the testing sound source. Also, the sound pressure level created by this source must be very uniform along all of these five surfaces. The laboratory requirements [free volume greater than 200 m^3, at least ½ wavelength clearance between chamber surfaces and isolation room walls, non-parallel alignment] give fairly uniform exposure of the top and all sides.

The physical environment surrounding a SIR placed in a building is different for each installation and varies greatly from uniform laboratory conditions. Field installations will often have the ceiling and one or more walls protected by the building surfaces and finishes. Therefore, one might expect better noise reduction for the field installations, given that the measured sound pressure level outside the exposed faces should be similar for field and laboratory.

To date, there is no standardized method for measuring sound isolation in the field so that the results can be directly compared to the laboratory NR. There has been considerable controversy in the past about how to measure a field NR and just how meaningful the results are. It is understood, though, that ASTM is currently working on a field NR standard.

3. FIELD TEST METHODS

3.1 Airborne Sound Isolation

A simplified measurement of NR was performed in the field to determine sound isolation of the rooms tested. A commercial sound reinforcement system was used to generate broad-band pink noise around the exposed surfaces of the SIRs. To produce a satisfactory sound pressure level within these double-walled enclosures, the sound systems used were capable of generating a reverberant level of 111 decibels, A-weighted when measured one metre from the test enclosure.

Typically, the loudspeakers were positioned with the speaker fronts directed away from the test room surfaces. The distance between the loudspeakers and the measuring microphone was as far as practical to create a reverberant sound field around the rooms and maintain the required sound pressure levels.

Two stationary microphone positions were chosen inside the SIRs. The microphones were placed at least 1000 mm away from each other and set 900 mm and 1200 mm from the floor.

Although two sampling positions inside the enclosure is far from ideal, this limited sampling was chosen mostly because of time constraints. Substantial spatial variation in the sound pressure is to be expected in these small and non-reverberant enclosures. Therefore, more extensive sampling within the "useful volume" of these rooms is recommended for greater accuracy. Two stationary microphones positions were also chosen outside and near to the exposed surface(s) of the tested rooms. Both of these 'source' microphones were at least 1000 mm from all vertical surfaces and 1200 mm from the floor. For each pair of source/receiving microphones, sound pressure levels were measured simultaneously. All sound levels were sampled for a duration of 30 seconds to obtain the Equivalent Continuous Sound Level (Leq). The one-third octave band results were stored on the floppy disk of a real-time analyzer for future reference.

The measured sound pressure levels within the SIRs were corrected for signal-to-noise in each one-third octave band. This involved logarithmic subtraction of the measured background noise levels in each room. When the signal-to-noise was less than four decibels, two decibels were added to the uncorrected level and the actual NR is assumed to be greater than this value. The reported results are an average value of the two microphone positions using the mean-square pressure method.

3.2 Background Noise

The background noise produced within the SIRs is predominantly due to the ventilation system. The sound pressure level, in the standard I.S.O. frequency bands, was measured at one position within each room. The measurement location was the first of the two positions that were used for the airborne sound isolation measurements. The Leq was taken over 30 seconds with the room ventilation system operating.

3.3 Structureborne Sound Isolation

There are both field (ASTM E 1007-84) and laboratory (ASTM E 492-86) standards for evaluating impact sound transmission. These standards specifically outline how to measure floor-ceiling assemblies of all kinds. Both of these methods are based on the use of a calibrated tapping machine that conforms to the specifications in ISO 140/IV - 1978(E).

The impact sound measurements that were done on the SIRs involve a different transmission path than the standard floor-to-ceiling. The greater concern was whether impacts (eg. high heels, dropped items) on the floor directly outside the rooms could be heard within the rooms. A standard tapping machine was used for this measurement and was placed on the floor 1200 mm from the door of each room under test. The Leq was measured for a duration of 30 seconds at one position in the room. It is important to note that the ISO tapping machine does not produce impacts that correlate well with the most usual type of impact; specifically footsteps. Therefore, it cannot be resolved that the noise level and characteristic measured within the rooms is the same as that produced by footsteps. The differences in the noise levels between similar rooms, however, can be directly compared and the effect of variables (eg. floor finish) can be determined.

Four of the rooms were tested in the manner described. The floor finish directly outside three of these rooms consisted of vinyl directly on concrete. The room finish outside of the fourth room was a commercial carpet on concrete. Since the structureborne test described was not formally part of the commissioning process, the other four enclosures were not investigated using the tapping machine. However, the results of the rooms tested show that this can be a useful method to identify structureborne sound flanking.

Another "impact" source that was used in another instance is the slam of a nearby office door. This particular office is located across the corridor from a SIR on the second floor of a building. The noise levels encountered in the test room were recorded while the office door was slammed shut.

4. MEASUREMENT RESULTS AND SITE OBSERVATIONS

4.1 Airborne Sound Isolation

There is an advantage to comparing the measured, in-situ performance of NR to the laboratory results of a similar enclosure. Regardless of the absolute value of NR, the one-third octave spectra performance should be typical of a double-leaf partition. That is, the field and laboratory values should both be increasing at a rate close to 18 dB per octave after the fundamental mass-air-mass resonance of the wall/ceiling system. The slope of the performance gradually decreases in the higher frequencies from secondary resonances. As well, the signal-to-noise limitations of the measuring equipment also affects the slope of the recorded performance at the higher frequencies. However, any large variance in the performance spectra does indicate that sound leakage is occurring.

These sound isolation deficiencies show up quite dramatically because of the high sound transmission loss rating of the construction. Examples of the airborne sound isolation measured for specific SIRs and the effect of sound leakages are shown in Figure 1, 2 and 3.

Field measurement results are compared to the laboratory NR values of a similar room and variances in the spectral shapes can be observed. Figure 1 shows the results of a SIR where sound leakage is occurring through the door bottom of one of the double doors and the light fixture located on the ceiling. Spectrum shape has certainly been

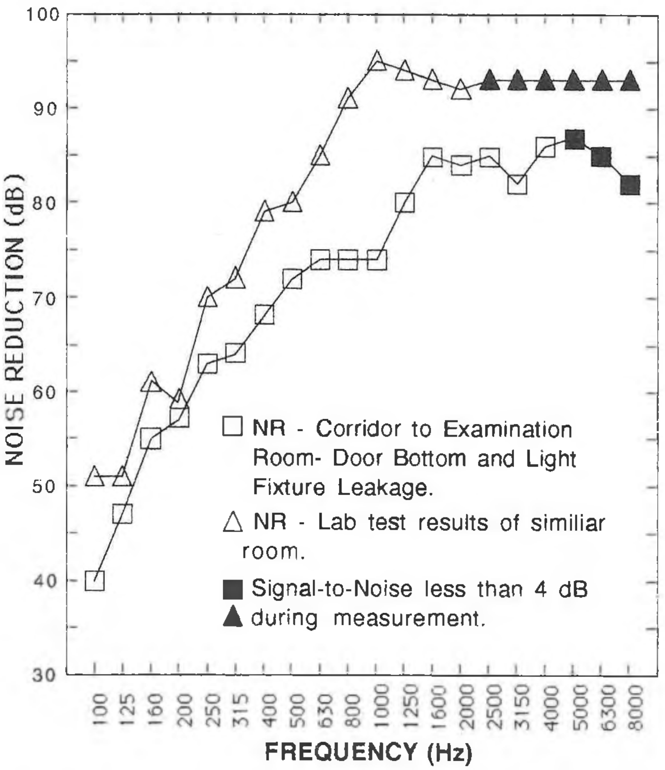

Figure 1. Field Noise Reduction Measurement Versus Laboratory Noise Reduction (ASTM E 596 - 78) of Sound Isolation Room - Effect of Sound Leakage.

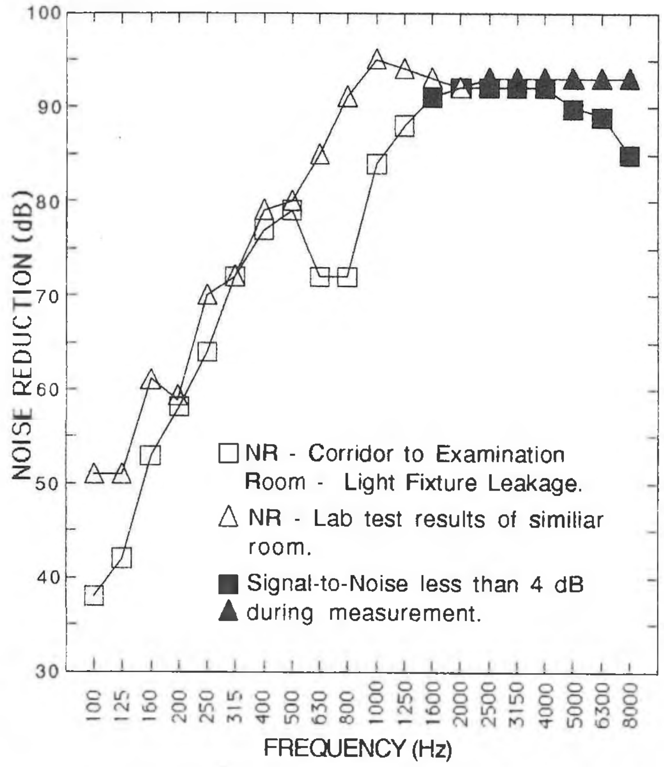

Figure 2. Field Noise Reduction Measurement Versus Laboratory Noise Reduction (ASTM E 596 - 78) of Sound Isolation Room - Effect of Sound Leakage.

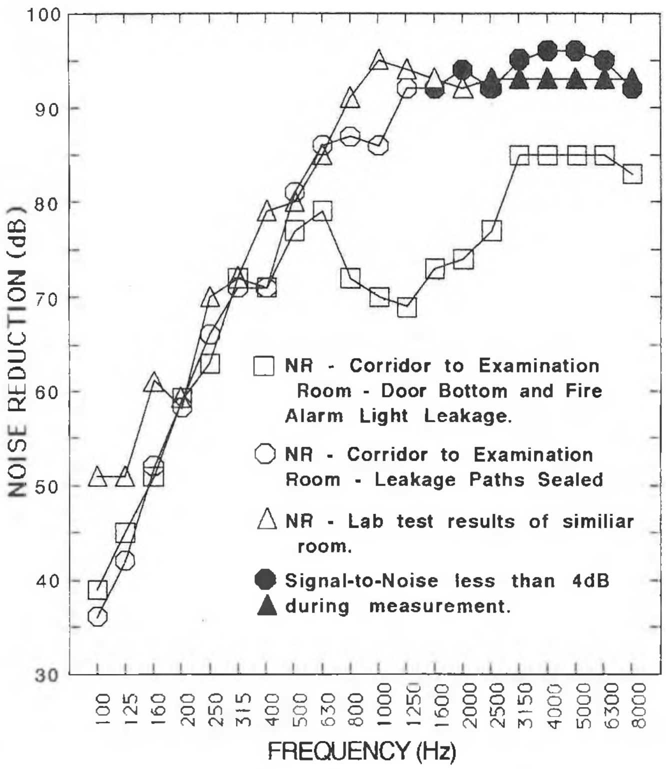

Figure 3. Field Noise Reduction Measurements - Effect of Sealing Sound Leakage Paths.

altered due to these acoustic deficiencies. Figure 2 shows another similar room where the only sound leakage occurring is through the ceiling light fixture. A dramatic 'dip' in performance is obvious at the 630 Hz and 800 Hz bands. In Figure 3, the result of sealing two construction deficiencies is shown. In this room, sound leakage was noticed along the door bottom and a site-installed fire alarm light. The airborne sound isolation of this room was greatly increased when these deficiencies were corrected. For this room, on-site NR values after the leakage paths were sealed are surprisingly close to the lab NR values.

4.2 Background Noise

The results of background noise levels measured within eight SIRs has been compiled. The range of sound pressure levels measured at specific one-third octave bands is shown in Figure 4.

As a comparison, the maximum allowable sound pressure levels for audiometric testing (ANSI S3.1 - 1977) are also illustrated. In addition to the standard ISO frequency bands shown, audiometric testing uses measurement frequencies of 750 Hz, 1500 Hz, 3000 Hz and 6000 Hz. The maximum allowable sound pressure levels are shown for these frequencies. However, no site measurement data is given at these one-third octave bands because filters with similar centre frequencies were unavailable during testing. While these peculiar frequency bands are not

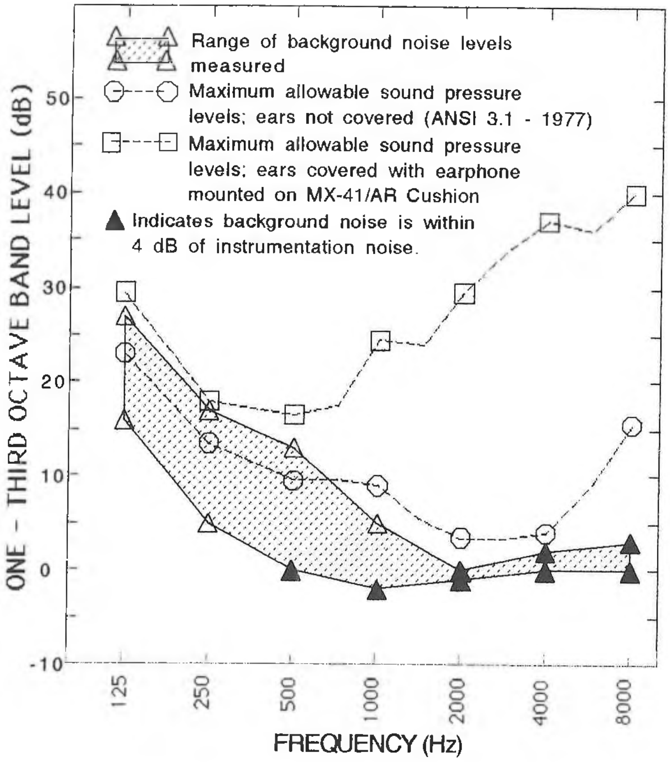

Figure 4. Range of Background Noise Levels Measured Within Eight Sound Isolation Rooms - Ventilation System On.

always measureable, most acoustic personnel can measure the standard frequency bands.

In all eight rooms, the sound pressure levels were within the maximum allowable when the ears are covered with the standard earphone mounted on an MX - 41 AR cushion. With the ears uncovered, three of the eight rooms did not comply with the maximum allowable levels at the low frequencies. If audiometric testing without earphones was done in these three rooms, the problem of excessive background noise levels would need to be analyzed and resolved.

4.3 Structureborne Sound Isolation

The measurement results for the structureborne sound tests are shown in Figure 5 and 6. Figure 5 is a plot of the sound pressure levels measured in three separate rooms with the Tapping Machine located on a vinyl-to-concrete floor just outside the room doors. All three SIRs were of the same make and located at the same facility. The sound pressure levels were reasonably similar in two of the rooms. However, one of the rooms recorded much greater levels, which is indicative of significant bridging between the building structure and the SIR.

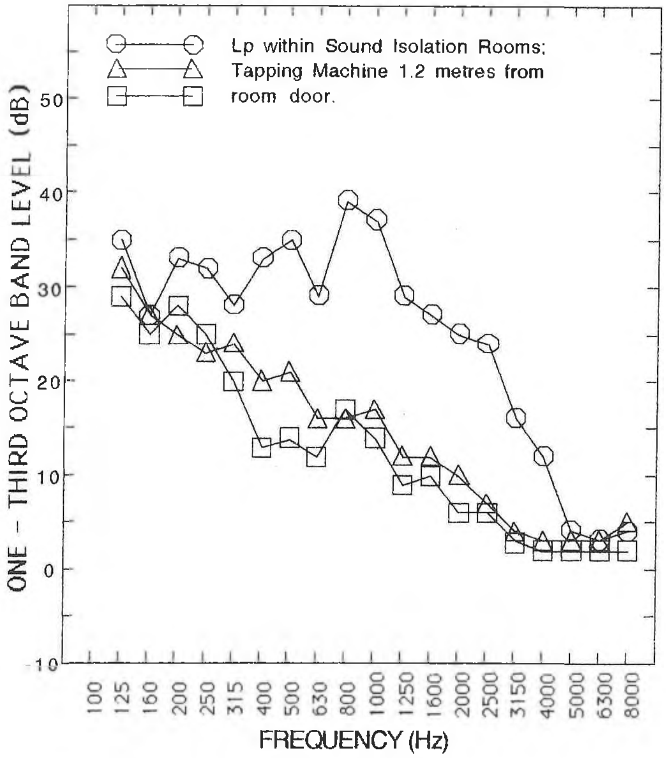

Figure 5. Assessment of Structureborne Sound Isolation Using ISO Tapping Machine; All rooms on main floor level of same building with vinyl on concrete floor finish.

The room that was tested with the tapping machine located on carpet were not measurable in the SIR. That is, the resultant sound levels were below the measured background noise levels in the room. Figure 6 illustrates the sound pressure levels created in another SIR when a nearby office door is slamming closed. The results are compared to ANSI S3.1 - 1977. These results clearly show that structureborne flanking exists and that audiometric tests may be affected by the occurrence of this noise.

Another case of structureborne flanking was observed during the measurement of background noise within a SIR located on the second floor of a building. The results of noise levels taken both during and after normal working hours is shown in Figure 7. During normal working hours, the background noise levels were significantly higher, with a peak level occurring at 125 Hz. After normal working hours, the levels were much lower. In both cases, the ventilation system supplying the test room was confirmed to be operating. The specific source of the noise during normal working hours is suspected to be equipment, related to the building mechanical system. This equipment is likely transmitting vibration to the building structure. As a result, structureborne noise is being transmitted to the room via mechanical bridging between the structural floor and the SIR.

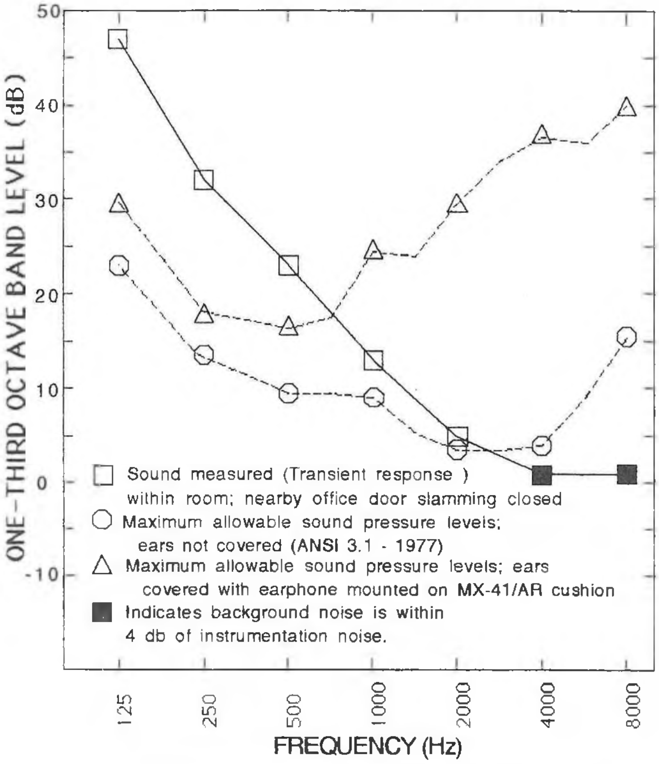

Figure 6. Structureborne Sound - Effect of Nearby Office Door Slam.

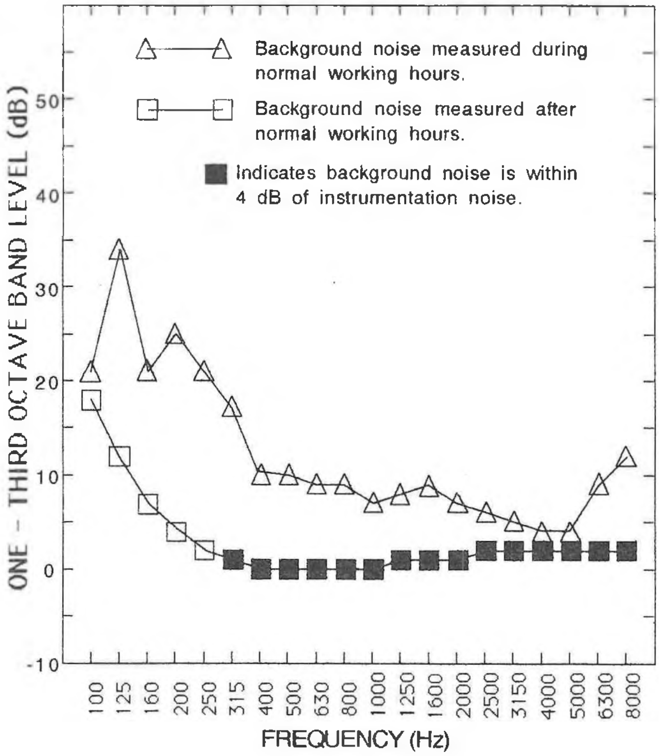

Figure 7. Background Noise Levels Measured in Sound Isolation Room - Influence of Extraneous Machinery Noise (Structureborne).

5. CONCLUSIONS

The acoustic performance of several Sound Isolation Rooms has been investigated in the field using simplified measurement methods. The test results are an indication of the types of acoustic deficiencies that occur when these specialized enclosures are installed on-site. The experience of doing acoustic commissioning on these rooms has resulted in a list of benefits that supports the field testing of these rooms. The most noteworthy ones are:

1. Identifies structureborne flanking and airborne sound leakage paths. Remedial measures for these optimize the on-site acoustic performance of the room.
2. Evaluates compliance with any construction specifications relating to the room (performance or otherwise).
3. Evaluates compliance with applicable regional, national or international standards (eg. ANSI S3.1), if this is important criteria.
4. Defines high and low on-site thresholds of acoustic performance criteria for the individual room. In certain sensitive research applications, this may be required to validate results.
5. Provides a resource of information that may be useful in the planning stages of future installations.
6. Provides manufacturers and authorized installers of these types of rooms with information that may prove useful in improving their existing design and/or installation details.

REFERENCES

1. Franks, J.R., and Lankford, J.E., "Noise Reduction Characteristics Of Prefabricated Sound-Isolating Enclosures: A Laboratory, Field Measurement, And Theoretical Analysis", Ear and Hearing, Vol. 5 No. 1, 2 - 12 (1984).
2. Acoustic Systems Acoustical Research Facility, Austin Texas, "Test Method For Measuring Noise Reduction Of Sound-Isolating Enclosures In The Field: (In-house, Feb. 1991).
3. American National Standard, ASTM E596-86 (90), "Laboratory Measurement Of The Noise Reduction Of Sound-Isolating Enclosures".
4. American National Standard, ASTM E336-77, "Measurement Of Airborne Sound Insulation In Buildings".
5. American National Standard, ANSI S3.1-1977 (R1986) "Criteria for Permissible Ambient Noise During Audiometric Testing".
6. Whitmarsh, P., "Acoustic Environments For Audiology", Noise & Vibration Worldwide, Oct. 20 - 22 (1990).