A NEW ACOUSTIC TEST FACILITY IN WESTERN CANADA PART B

TECHNICAL EVALUATION

M.G. Faulkner
Dept. of Mechanical Engineering
University of Alberta
Edmonton, Alberta

and

D. Olynyk
Acoustician
No. 22, 9740 - 62 Street
Edmonton, Alberta

1.0 Introduction

A new acoustic test facility has just been completed by Bolstad Engineering Associates Ltd. at 6720 - 30 St., Edmonton, Alberta. The facility, consisting essentially of a pair of reverberation rooms with associated electronic instrumentation, is the first full scale acoustical test facility in Western Canada.

The purpose of this article is to describe the evaluation of this facility for making laboratory measurements of sound absorption, sound transmission loss and sound power.

2.0 Description of Test Facility

The test facility which has been described in the preceeding article (see Figure 1) consists of two adjoining reverberation rooms, which can be linked through a common opening. The large reverberation room has interior floor dimensions of 28'4" x 22'4" with a height of 17'4" while the small rooms dimensions are 25'8" x 20'4" x 15'4". Suspended randomly throughout these rooms are diffusing devices consisting of slightly curved 4' x 8' x 3/8" thick plywood panels, the large room having eight while the smaller one has six. A 9'0" wide x 8'0" high test opening links the two rooms to accommodate walls for transmission loss measurements. When not in use the test opening is sealed with a filler plug wall.

Both reverberation rooms utilize a similar microphone system. By means of a rotating boom driven by the roof-mounted drive system the microphone is capable of traversing a circle 10 feet in diameter in a plane inclined at 5° with the horizontal.

The instrumentation used in conjunction with these rooms is shown schematically in Figure 1. Normally one loudspeaker assembly was used and it is placed on the floor near a trihedral corner.

3.0 Evaluation of Facility for Measurement of Sound Absorption

The most important standards for laboratory measurement of sound absorption have come from the International Organization for Standardization (ISO) and American Society for Testing and Materials (ASTM). Of interest are the following documents:

(1) ISO Recommendation R354 (1963) "Measurement of Absorption Coefficients in a Reverberation Room"

(2) ASTM C423-66 (Reapproved 1972) "Standard Method of Test for Sound Absorption of Acoustical Materials in Reverberation Rooms".

Measurement of sound absorption by this method is based on reverberation theory, the key hypothesis being that the sound field must be diffuse and the room surface be therefore exposed to an assembly of waves from all angles of incidence. To achieve good diffusion the standards agree quite closely that certain conditions must be met including liveness, size of rooms, shape, diffusing devices and precision of measurements.

To insure liveness, ISO recommends that the reverberation times of the empty room should exceed certain values, these values varying with room volume as given below:

125	250	500	1k	2k	4k	Hz
6.0	6.0	6.0	5.4	4.2	2.4	seconds for 310 cu.m. (10,963 ft^3)
5.4	5.4	5.4	4.9	3.8	2.2	seconds for 226 cu.m. (8,000 ft^3)

Measured reverberation times for the empty large and small reverberation rooms exceed ISO values at all frequencies. ASTM specifies this condition in another way by stating that the average absorption of the empty room surfaces shall be less than 0.06 at all measuring frequencies. In our case, the average absorption of empty room surfaces was found, after appropriate allowance for air absorption, to be 0.02 between 125 and 4000 Hz for both chambers.

For room size, ISO recommends a room volume larger than 180 m^3 (6357 ft^3) and further recommends, in the case of new construction, that the volume be as close to 200 m^3 (7,063 ft^3) as possible. (This criteria is met for both rooms). ASTM specifies that the smallest dimension of the room shall be more than one wavelength, λ, and preferably more than two wavelengths of the centre frequency of the lowest one third octave band at which measurements are to be made. The smallest dimension corresponds to one wavelength at 65 Hz and 73.5 Hz for the large and small reverberation rooms respectively. Corresponding frequencies where the smallest dimension is equivalent to two wavelengths are 130 and 147 Hz respectively.

Another factor that must be considered is room shape. ISO specifies that the shape of the room shall be such that $l_{max} < 1.9\ V^{1/3}$ where l_{max} is the length of the greatest straight line which can fit within the boundary of the room. Calculations show that this criterion is met for both chambers. ASTM specifies that the ratio of the largest to the smallest dimension shall be less than 2:1. The actual room dimension ratios in our case are within this range and are 1.63:1.29:1 for the large chamber and 1.67:1.32:1 for the small chamber. This is fairly close to the theoretical ratio of $1:\sqrt[3]{2}:\sqrt[3]{4}$ (1:1.26:1.59) commonly referred to in the literature.*

To insure a diffuse field ASTM recommends a number of sound-reflecting panels hung or distributed at random angles or kept moving presenting a room which continually changes in shape. ISO on the other hand mentions only static diffusing panels. ASTM essentially states that decay curves shall be independent of both microphone position, test specimen position and free of non-exponential irregularities. In general the decay curves became more exponential and smoother as the vanes and microphone were moving.

The number and precision of measurements is a factor worthy of consideration. ISO indicates that each evaluation of a decay rate for a given frequency band shall be based on at least 6 records, each under different variations in the sound field as far as loudspeaker position, microphone position, diffuser system configurations, etc.unless experience shows otherwise. ASTM recommends a group of measurements at each test frequency the size of the group chosen to yield an absorption coefficient to a precision of $\pm$ 0.04 at 125 and 4000 Hz and $\pm$ 0.02 at all intermediate frequencies with confidence limits of 90 percent. In addition, any decay curves with multiple slopes shall be excluded as both standards bring out. In tests made on an absorptive sample this precision was obtained by taking 8 to 10 decay curves for the empty room and a similar number with the sample in place.

4.0 Evaluation of Facility for Measurement of Sound Transmission Loss

The most important standard on this continent for laboratory measurement of sound transmission loss has come from ASTM and is entitled:

(1) ASTM E90-70, "Standard Recommended Practice for Laboratory Measurementsof Airborne Sound Transmission Loss of Building Partitions".

European practice is fairly similar to that of North American and is reflected in the following ISO standard:

(1) ISO Recommendation R-140-1960, "Field and Laboratory Measurements of Airborne and Impact Sound Transmission".

*Bolt (1947) "Normal Frequency Spacing Statistics", J. Acoust. Soc. Am. 19, 79.

The conditions for a diffuse field to be used for sound transmission testing are similar to those mentioned above for absorption measurements. The conditions for room size and shape as well as diffusing are met or exceeded by this facility. As well the absorption coefficient of the room walls are well below the specification of 0.06.

A further condition which must be met is that of flanking transmission. ASTM recommends that the sound power transmitted through the test structure be at least 10 dB greater than the power transmitted by all other paths. Flanking was investigated experimentally by a series of measurements on substantial walls in the test openings. Introduction of the available plug wall, normally used to seal the opening, yielded a value of the order of STC 56. A dip occurring in the vicinity of 2000 Hz is, presumably, the result of coincidence effects. A further test was carried out on a "better" wall consisting of a combination plug wall - batts - double leaf plasterboard wall; this resulted in the sound isolation being boosted up to STC 65. According to the measurements to date it is evident that the facility is capable of testing walls up to at least STC 55.

ASTM states that a sufficient number of measurements shall be taken to ensure that the mean value of the noise reduction is known to within ± 1 dB (90 percent confidence) except for the lowest band for which the limit shall be ± 2 dB. Similarly determination of the mean value of the receiving room absorption term (10 log A_2) must be made to the same precision. The data accumulated so far indicates that an averaging time or filter stepping time of at least 5 seconds should be used for one-third octave analysis. In this time interval the microphone completes one-half a revolution. The precision for the noise reduction was obtained by taking 9 to 10 sets of noise reduction measurements for one-third octaves from 125 Hz to 500 Hz. Above 500 Hz, 5 sets of measurements were sufficient to give the required precision. The precision of the receiving room absorption term was obtained with 4 to 5 decays for each one-third octave considered.

5.0 Evaluation of Facility for Measurement of Sound Power Level

A state-of-the-art standard for the measurement of sound power level is:

(1) American National Standard "Methods for the Determination of Sound Power Levels of Small Sources in Reverberation Rooms" S1.21-1972.

An attempt is made to achieve a uniform energy density within the room. Of the utmost importance is the volume of the room, its proportions and its absorption coefficient. Again the recommendations of ANSI are met or exceeded by these rooms.

A major factor affecting the qualification of a reverberation room for sound power determination is the uncertainty in the measurement of mean square sound pressure throughout the room. ANSI deals with these uncertainties by specifying the precision of measurements in terms of a maximum value for standard deviation for sound pressure. For broad band measurements these criteria are not difficult to meet.

In our case, a limited number of measurements were carried out for the purpose of assessing the test facility for sound power measurements. Room response to broad band excitation was determined by utilizing a loudspeaker as the sound source and exploring the sound field by stationary and rotating microphone. The maximum deviation was found to be of the order of 1 or 2 dB throughout most of the frequency range with somewhat higher scatter at the lower frequencies.

6.0 Conclusion

The new acoustic test facility by Bolstad Engineering Associates Ltd. has been designed with considerable thought. Introduction of novel moving diffusers and a rotating microphone system will contribute toward making efficient use of the facility for commercial sound laboratory testing and research purposes.

It is evident that the two reverberation rooms exceed minimum requirements for measurements of sound absorption according to ASTM and ISO standards. It would be desirable to make inter-laboratory comparisons on sound absorption coefficients of several materials. This would give a further opportunity to evaluate the effectiveness of the novel moving diffuser system.

In regard to measurement of sound transmission loss the pair of test chambers adequately meet minimum requirements given by ASTM. From the data obtained the facility is capable of measuring walls up to STC 55 and possibly higher.

Both reverberation rooms of the new test facility satisfy ANSI standards for measurement of sound power of broad band sources. Further testing is necessary to qualify the rooms for narrow band and discrete-frequency sources.

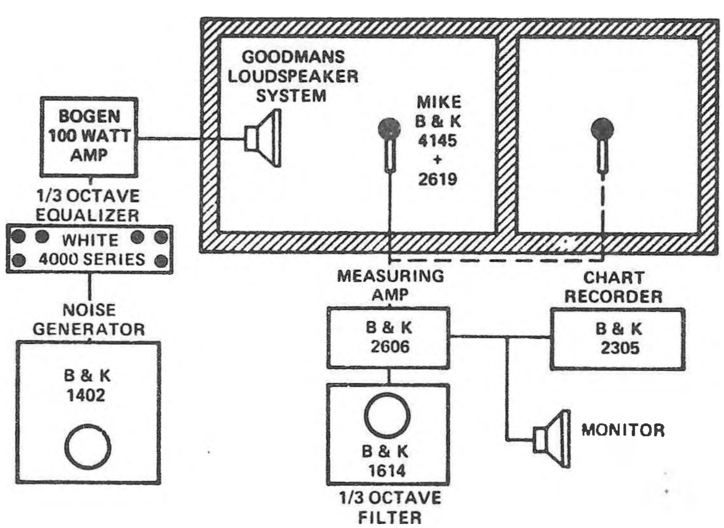

FIG. 1