EXPERIENCES WITH A NEW SINGLE NUMBER SOUND ISOLATION RATING METHOD

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Introduction

At the present time, the specification of party wall systems to provide air-borne sound isolation in multiparty dwellings is based on laboratory tests of the Sound Transmission Class of partitions. Designers and regulatory authorities use this rating in an attempt to provide a desired, or minimum, acoustic isolation. However, as sound is transmitted from room to room by several paths, installation of an adequately rated party wall is no guarantee of acceptable performance of the finished building.

The American Society for Testing and Materials (ASTM) has published a recommended practice (E 597-77T) which provides a method for "Determining a Single Number Rating of Air-borne Sound Isolation in Multi-Unit Building Specifications". This method states that "other sound paths are often of equal importance and must be included in any measurement of acoustic isolation" and "this isolation is readily measured in terms of the simple noise reduction between a pair of rooms". If for some non-evident reason the noise isolation of a room pair falls short of the anticipated value, then the path at fault may be identified by procedures of Recommended Practice E336, "Measurement of Air-borne Sound Insulation", or other valid method.

In this paper, we discuss the development of a noise source meeting the requirements of ASTM E597-77T and discuss our experiences in its calibration and field use.

It has been recommended that the resulting single number be referred to as "Privacy Index", and that term has been used in this paper.

Noise Source

The Recommended Practice requires an accurate, calibrated and stable sound source employing specially shaped source and absorption frequency spectra. After approximately two years of development, construction, and testing, Barron & Associates produced a noise source meeting these requirements. Originally, field transmission tests required packing, transporting, and unpacking (usually by hand and up 10 flights of stairs) many individual pieces of equipment. Out of desperation, a compact noise source was developed and used primarily for traditional air-borne field transmission loss testing. It was decided that it would be relatively simple to modify that box to meet the requirements of the new ASTM standard (or so we thought!).

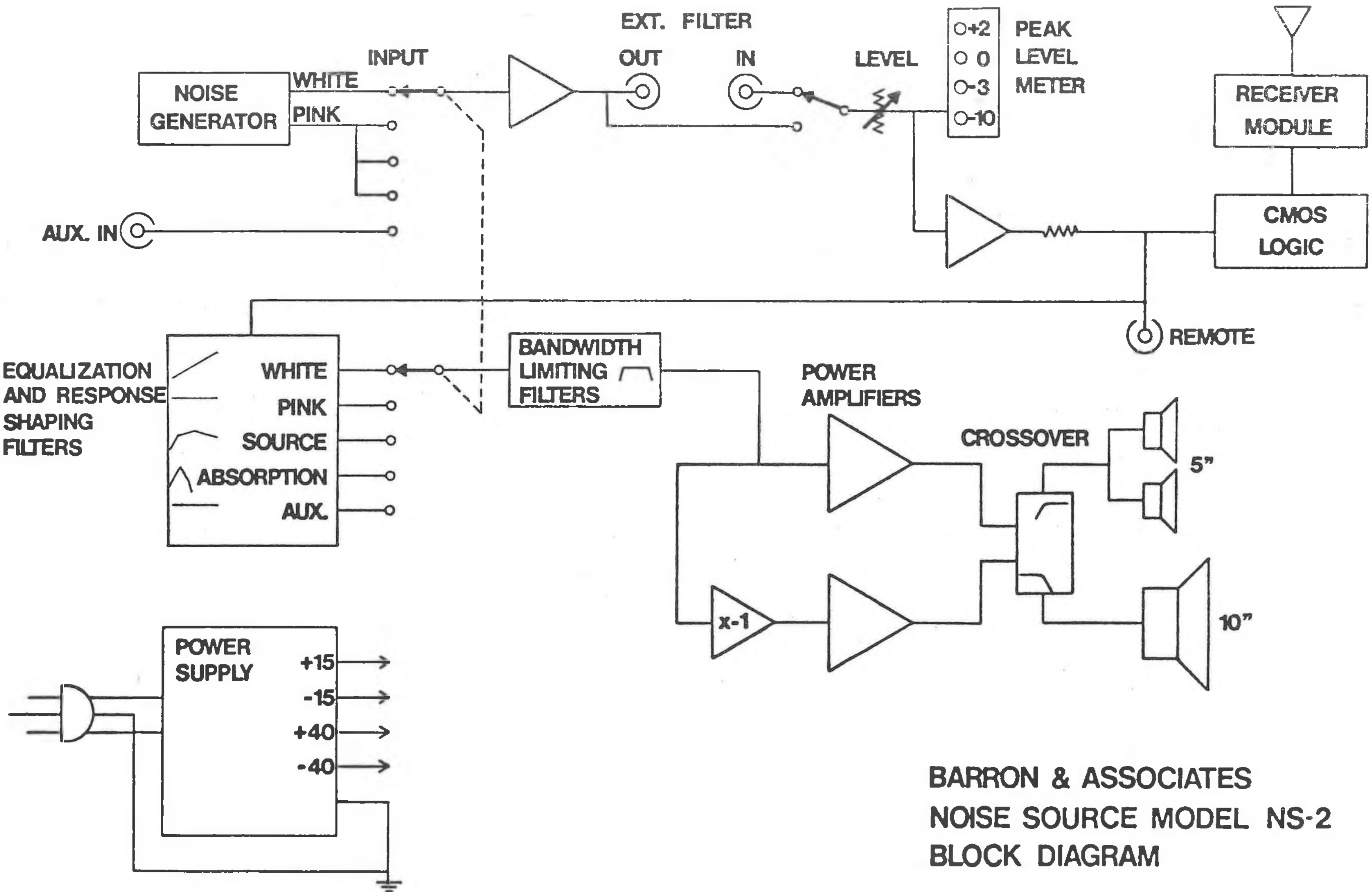
After approximately one year of "modifications", a box meeting the ASTM requirements evolved. The output signals available for testing are: pink noise, white noise and special source and absorption spectra. Also, inputs for auxiliary equipment and external filtering are provided. Total weight is approximately 45 pounds. The box contains a radio operated remote control which allows on/off operation from distances up to 300 ft. The output levels and the special spectra meet the requirements of ASTM E 597-77T, and are stable within $\pm$ 1 dB with line voltage variation from 90 V. to 125 V.

The block diagram shows the basic circuitry. All low level signal amplifiers and active filters utilize operational amplifiers with final power amplification by two 50 watt Hybrid IC power amplifiers connected for bridging operation to give a total output power of approximately 130 watts rms into an 8 ohm load. The remote control receiver is a prebuilt assembly connected to a digital logic circuit controlling the audio. The loudspeakers include a single 10" JBL full range unit, and two 5" JBL extended range loudspeakers. Originally only one 5" tweeter was used but it was discovered that although it could produce the acoustic power required on the "Pink" and the "Source" settings, the first time the box was operated in the "White" noise mode, it reverted to a low frequency generator permanently! Two 5" tweeters are now standard.

The result of all the construction, changes, testing, etc., is the TL Noise Source Model NS-100, being manufactured under license by TRACOUSTICS, Inc. of Austin, Texas. This is an ultra-stable device which can be used for privacy testing between dwelling spaces according to the new ASTM Recommended Practice as well as for standard transmission loss tests. The remote control permits tests of receiving room background noise level without leaving the receiving room to shut off the source, and permits one person to make reverberation decay measurements in large theatres, auditoria, or arenas. Finally, it can, with only the addition of a simple microphone and preamplifier, perform as a portable public address system.

Test and Analysis Procedures

Having constructed this unit it was now necessary to test it. The procedure which we have followed is to take every opportunity to carry out both a Privacy Index test and a Field Noise Isolation Class (NIC) test on the same party wall system. Our clients bear the cost of one of these tests and we absorb the other. To date, we have carried out 25 such tests, the results of which have been quite encouraging. As recommended in the Standard, tests have been confined to multi-family dwellings, hotels, and offices.



BARRON & ASSOCIATES
NOISE SOURCE MODEL NS-2
BLOCK DIAGRAM

Project: 100 971

May, 1977

The tests are performed using a calibrated ANSI Type 1 sound level meter and the special noise source. The procedure is to measure the space averaged sound level in the source room and the receiving room using the source spectrum. The difference between these levels is the Privacy Index. To normalize this value to a standard room finish, the source is moved to the receiving room and near and far field measurements are made of the absorption spectrum.

Noise reduction measurements and reverberation decays are made with a precision meter and recorded onto tape. The sound measurements were subsequently analysed by TOBADS which provides a video display and hard copy printout of one third octave band levels. Noise Isolation Class (NIC) is calculated by computer.

The resultant decay recordings are analyzed by computer and peripherals which sample and display the measured decays. The system, which allows considerable operator interaction in evaluation of decay sections, calculates and prints decay times by means of a least squares fit to a video displayed segment selected by operator controlled pointers.

Calculations and Results

The recommended practice describes the method of calculation which may be summarized on Figure No. 1.

The results of the 25 tests are available in the form of a Privacy Index Field Data Sheet and a graph showing the measured one third octave band noise reductions and reference NIC curve. These results have been summarized on Figure No. 2.

Graph A illustrates the relationship of D to NIC. The recommended practice suggests that D "will usually be 1 to 2 dB less than the measured value of the Noise Isolation Class (NIC)". The mean difference of NIC-D for the 25 tests performed is 1.37 dB $\pm$ 2.1 dB for 90% confidence limits.

An attempt to correlate the difference of NIC-D and the amount of absorption (furnishings) of a room or some other common test factor has not yielded any significant conclusions. There appears to be a slight trend for rooms containing no furnishings (bare) to exhibit smaller differences of NIC-D. However, this trend may be attributable to other factors. Tests in rooms that contain moderate amounts of absorption appear to provide values of D that are consistently 1 to 2 dB less than NIC.

Tests were performed in two executive offices (Tests No. 8 and 9) furnished with only a heavy carpet. One room (the boardroom) also contained a large conference table. The rooms appeared lightly furnished (i.e. no soft furniture). However, due to the heavy carpet, a suspended acoustical ceiling, and large areas of glass, the absorption was approximately equal to the floor area, as determined by decay measurements. The L_N - L_F measurements were approximately 2 dB larger than the values for other tests where the floor area was approximately equal to the ab-

SUMMARY OF TEST RESULTS

Test No.	D_n	D	NIC	NIC-D	B'	T_{60} (sec.)	Furn. Code
1	38.0	37.0	39	2.0	8.2	0.51	C
2	48.1	47.3	50	2.7	7.2	0.40	F
3	53.5	50.7	50	-0.7	8.5	1.00	B
4	52.5	49.4	50	0.6	8.5	1.00	B
5	44.2	43.9	47	3.1	8.2	0.43	F
6	37.9	38.1	38	-0.1	8.8	0.44	F
7	40.3	38.9	40	1.1	7.9	0.49	C
8	39.1	41.1	43	1.9	12.0	0.55	F
9	32.4	35.5	36	0.5	12.0	0.45	F
10	47.0	44.5	48	3.5	7.0	0.55	C
11	46.5	42.8	45	2.2	8.5	0.78	C
12	47.8	44.3	46	1.7	8.7	0.77	C
13	46.8	43.5	44	2.5	7.0	0.75	C
14	48.5	44.5	46	1.5	7.3	0.85	B
15	46.9	43.0	44	1.0	9.5	1.30	B
16	47.4	41.5	42	0.5	8.6	1.75	B
17	50.0	43.5	43	-0.5	8.2	1.60	B
18	50.8	47.5	48	0.5	8.5	0.85	C
19	49.8	42.5	43	0.5	8.2	2.20	B
20	43.0	38.0	42	4.0	7.7	1.20	B
21	41.1	36.5	38	1.5	7.5	1.80	B
22	46.1	47.8	51	3.2	8.8	.36	F
23	46.2	47.2	48	0.8	9.7	.49	C
24	43.1	41.1	41	-0.1	6.3	.92	B
25	45.0	43.7	44	0.3	10.5	.91	B

Note - Furnishing Code:

F - Furnished; normal room absorption, carpets, beds, etc.
C - Carpet, light room absorption
B - Bare; low room absorption

Figure No. 1 Calculation Formulae

1. Check Background Noise: If $L_R - L_B \leq 10$ apply correction

2. Determine D; A-weighted Sound Level Difference (Privacy Index):

$$D = L_S - L_R$$

3. Determine Ar; Receiving Room Sound Absorption in Metric Sabins:

$$Ar = \mathrm{Log}^{-1} \frac{L_N - L_F - B}{10}$$

4. Determine D_N = Normalized Sound Level Difference (Normalized Privacy Index):

$$D_N = D + 10 \log \frac{S_{fl}}{A_r}$$

Where S_{fl} = Floor area of the receiving room in m^2

Note: $D_N = D + 10 \log S_{fl} - (L_N - L_F - B)$

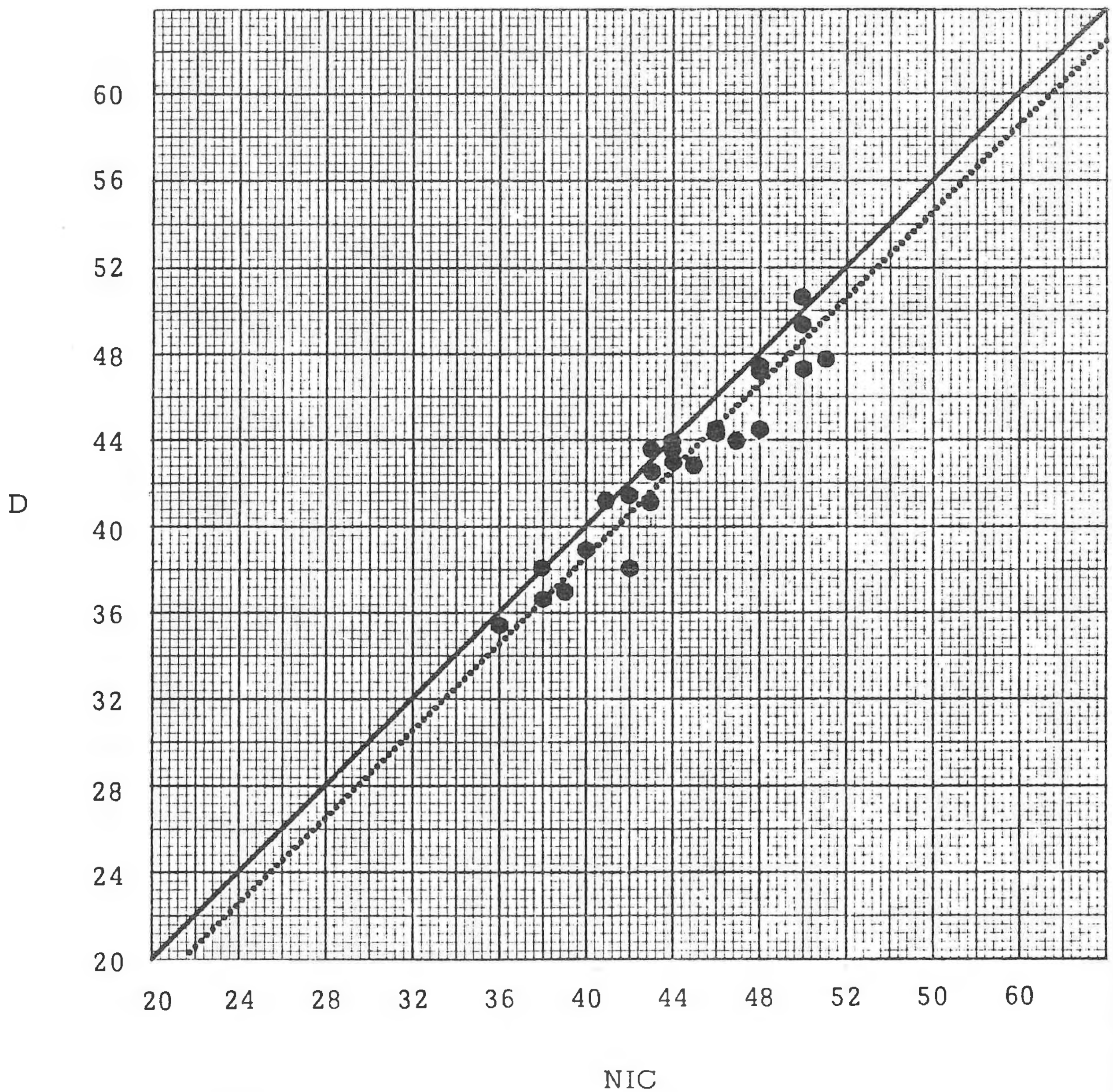
L_S = Source Room Level (Source Spectrum)

L_R = Receiving Room Level (Source Spectrum)

L_B = Receiving Room Background Level

L_N = Near Field Level (Absorption Spectrum)

L_F = Far Field Level (Absorption Spectrum)



LEGEND

Reference: D = NIC

D - NIC - 1.37

Measured Values

PROJECT DESCRIPTION

Privacy Index

GRAPH TITLE

Relationship of D to NIC

GRAPH NUMBER A

PROJECT NUMBER	DATE
100 971	October, 1977

sorption. The larger difference in L_N - L_F is supposed to indicate that room absorption exceeds the floor area and result in a D_N value less than D. Based on measured decay value, the larger value of L_N - L_F cannot be justified. The discrepancy may be due to an error discovered in the "Absorption Spectrum" shape of the prototype Noise Source and/or a function of the test room finish and shape.

Several tests in the series exhibited audible air-borne flanking of mid and high frequencies. Small amounts of high frequency flanking under particitions and at mullions were audible in several tests and showed on the noise reduction graphs for each, but did not affect the NIC rating or appear to affect the Privacy Index rating. Two of the rooms tested exhibited a flanking problem due to a resonance at Band 28 (630 Hz). Calculations were performed to estimate the effect of this flanking on D and NIC, and indicate that both values were reduced by approximately 3 to 4 dB due to the flanking. The audible effect of an unusual flanking problem of this nature may not be detected by untrained personnel and may lead to results which are not representative of final conditions. DNE test was severely flanked by cracks in a concrete block wall and gaps around joists. The NIC and D values for this test are both significantly reduced due to the flanking.

Tests 23 to 25 were carried out in rooms considerably larger than that recommended by the Standard. Although these do exhibit lower NIC-D differences they are within the 90% confidence limits. Further testing will be necessary to determine whether or not the restrictive room dimensions of the Standard (6m maximum dimension) are overly cautious.

Noise Source Calibration for Absorption

Calibration of the two prototype Noise Sources for determination of the "Standard Sound Source Calibration Constant B" was performed in a vacant carpeted room in the offices of Barron & Associates.

Measurements conforming to Section 9 of the standard were performed for each Noise Source at two locations in the room, providing the results tabulated in Figure No. 3.

The results of the measurements indicated a 1 dB lower L_{Nc} - L_{Fc} value for each Noise Source when directed toward the flat window wall rather than the hallway opening/closet end of the room. This effect, although small, is attributed to the open hallway entrance and should be considered when calibrating or testing in the field under similar circumstances. Decay times were consistent for all cases.

Calculation of "B" was based on the average values of L_{Nc} - L_{Fc} and the formulas shown on Figure No. 3.

A calculation of B values for other rooms was performed for comparison. The values are tabulated on the "Summary of Test Results",

CALIBRATION RESULTS AND FORMULAE

Noise Source	Location	$L_{Nc} - L_{Fc}$	Decay Time (T_{60})
1	1	19.3	0.50
1	2	18.2	0.49
2	1	19.8	0.52
2	2	18.6	0.51
Average		19.0	0.51

$$B = L_{Nc} - L_{Fc} - 10 \log \frac{Ac}{Ao} = 8.2 \text{ dB}$$

where, $Ac = \frac{0.9210\ Vd}{C}$

$V = 38\ m^3$
$C = 344$ m/sec
d = rate pf decay = $\frac{60 \text{ dB}}{0.51 \text{ sec}}$

and, Ao = 1 metric sabin

Figure No. 3

Project: 100 971 October, 1977

Figure No. 1 and are labelled B'. With the exclusion of Tests No. 8, 9, 23, 24 and 25, the average of B' provided 8.2 dB with a Standard Deviation of .67 and a Variance of .45.

Again, with the exception of Tests No. 8, 9, 23, 24 and 25, comparison of the B' values with the associated room dimensions and finish details (Tables and Graphs No. 1 to 25), does not indicate any significant correlation. The small variations in B' are attributed to inaccuracies in meter scale readings and variables associated with field test conditions. Tests 23 to 25 indicate that source calibration should not be undertaken in rooms which exceed the recommended dimensions.

The foregoing implies that there is reasonable latitude in selection of calibration rooms subject to previously mentioned constraints of room dimensions, geometry and apparent light furnishing.

Summary and Conclusions

A series of tests conforming to ASTM E 597-77T "determining a single number rating of air-borne sound isolation in multi-unit building specifications" performed in conjunction with one-third oactave band noise reduction measurements graded for NIC has allowed a preliminary evaluation of this method. The test results indicate the non-normalized air-borne noise reductions correlate with NIC ratings as NIC-D = 1.37 (± 2.1 dB for 90% confidence). This result is considered to be satisfactory, given the possible bias of test results due to noise source development factors and field test conditions. It will be necessary to review a much larger population of tests to provide results which may reduce the uncertainty or point to other factors that require consideration in practice.

Experience provided by this series of tests indicates that training of operators, correct calibration of Noise Sources and thorough reporting of test detail will be required to produce reliable, meaningful results. Any shortcomings of the procedure in terms of pinpointing deficiencies must be considered with the advantages of:

1. Relatively Low Equipment Cost

2. Portability of Equipment

3. Minimum Testing Time

4. Simplicity of Procedures

The above factors make the method prescribed by ASTM E597-77T ideally suited for screening the air-borne noise isolation or "Privacy Index" of multi-unit structures by persons with reasonable levels of skill and training.

Bibliography

1. ASTM E 597-77T - "Tentative Recommended Practise for Determing a Single Number Rating of Air-borne Sound Isolation in Multi-unit Building Specifications".

2. Barron, K.E. & Hall, G.D. - "Recent Field Testing Experience of Privacy Between Dwellings Using ASTM Recommended Practise E597-77T", Paper L2, 93rd Annual Meeting, ASA, June,1977.

3. Barron, K.E., & Rivard, M.T. - "Design, Development and Field Testing of a Stable Sound Source for Privacy Testing Between Dwelling Spaces According to ASTM Recommended Practice E 597-77T", Paper L1, 93rd Annual Meeting, ASA, June, 1977.

4. Schultz, T.J. - "A-Level Differences for Noise Control in Building Codes", Noise Control Engineering, NOCOA, Vol. 1, No. 2, Autumn, 1973, pp. 90-97.

5. Schultz, T.J. - "How Noise Creeps Past the Building Codes", Noise Control Engineering, NOCOA, Vol. 1, No. 1, Summer 1973. pp. 4-14.

Appendix

Note: Table No. 1 and Graph No. 1 have been included for explanation purposes. Requests for the full appendix containing graphs and tables No. 1 to 25 should be made to:

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PRIVACY INDEX - Testing to ASTM E 597-77T

Project: 100 971 Date: May 13/77 Engineer: GDH Page: 1

Title: Privacy Index - Barron & Associates

Location: Laundry Room (S) to Library (R)

Meter Calibration: + 4 dBA Source Calibration (B) = 8.2

Room Description	Source - (S)	Receiving - (R)
Length:	6.1 m	5.0 m
Width:	5.0 m	3.2 m
Height:	2.4 m	2.3 m
L x W:	30.5 m^2	16.4 $m^2 = S_{fl}$
Room Finish:	Cupboards, Concrete, Laundry	Carpet

(Note: Use other side for a sketch and additional notes)

Area of Common Partition: 9.9 m^2

Measurements (dBA) - Position -

		VU	1	2	3	Average
Source Spectrum	- Source Room	0	105.0	105.5	104.5	L_S = 105.0
	- Receiving Room	-	66.0	68.0	70.0	L_R = 68.0
Absorption Spectrum	- Near	0	91.0	-	-	L_N = 91.0
	- Far	-	71.0	72.0	72.0	L_F = 71.7
Background Noise	- Receiving Room	-	45.0	-	-	L_B = 45.0

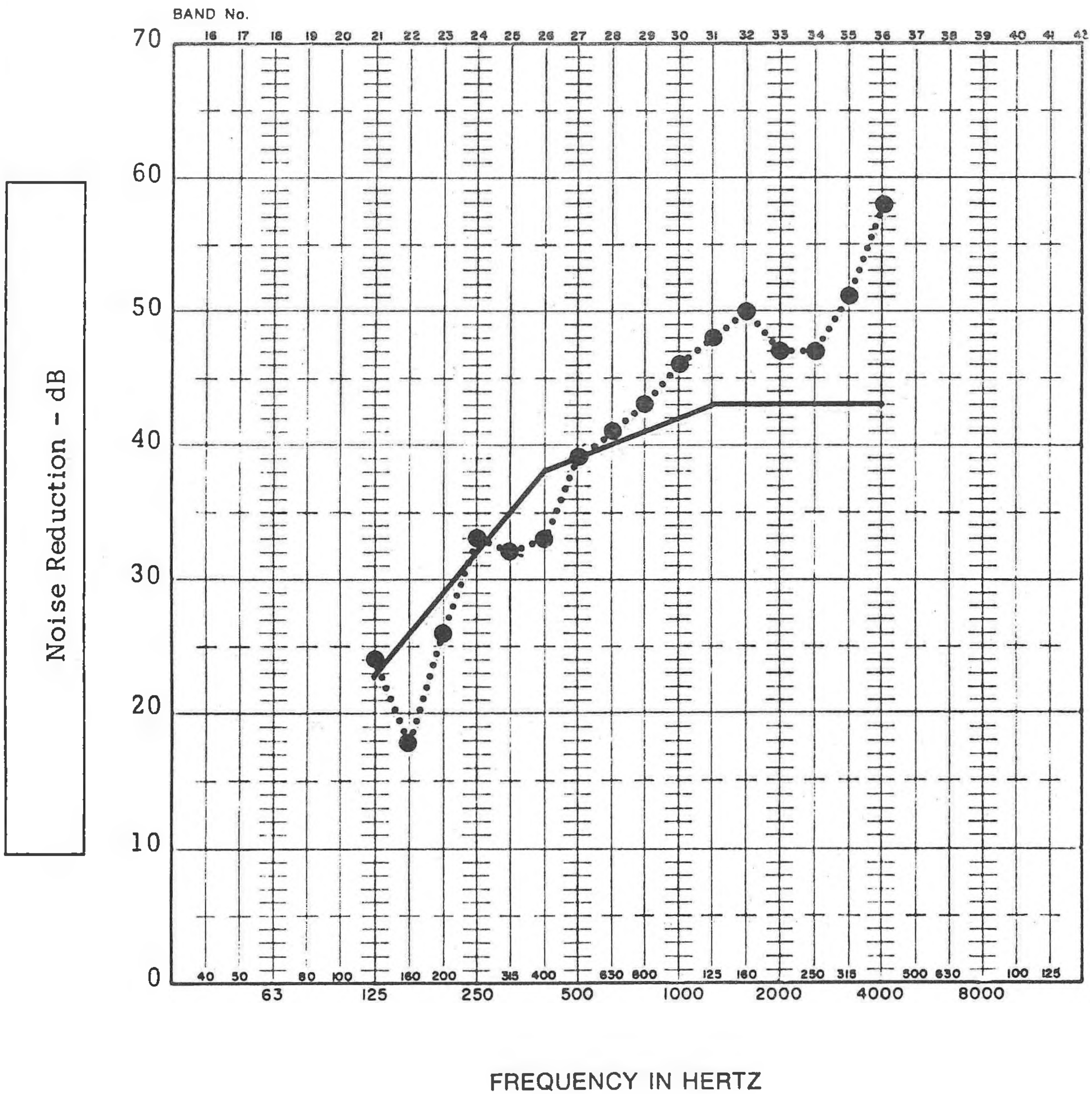
$$A_r = \text{Log}^{-1} \frac{(L_N - L_F - B)}{10} = 12.0$$

$$D = L_S - L_R = 37.0$$

$$D_N = D + 10 \text{ Log } \frac{S_{fl}}{A_r} = 38.0$$

Note: If $L_R - L_B \leq 10$ apply correction

Project: 100 971 Table No. 1 May, 1977.



LEGEND

Measured Noise Reduction

Standard NIC 39 Grading Curve

Note:

(1) (R) room - carpet

(2) Wood stud and G.W.B. construction

(3) Windows 1 m^2 approx.

PROJECT DESCRIPTION Privacy Index	
GRAPH TITLE Laundry Room (S) to Library (R)	
GRAPH NUMBER 1	
PROJECT NUMBER 100 971	DATE May, 1977.