MEASUREMENTS OF

APPARENT SOUND INSULATION

OF EXTERIOR AND INTERIOR WALLS

LEXINGTON, NC

Prepared for the

NAHB
Research
Center

Upper Marlboro, MD

by

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Stewart Acoustical Consultants has conducted tests of apparent sound insulation for exterior and interior walls of four duplex apartment buildings near Lexington, NC. The buildings had very similar floor plans but different details in the wall and floor designs. The various walls tested were of different designs. Details of the constructions, test methods, and results are provided in three individual reports. This report provides a summary in less detail.

Tests were conducted using ASTM E336 for the interior walls and ASTM E966 for the exterior walls. The first step in the E336 procedure is to measure the average noise reduction (NR) between the two interior rooms with a source in one. The standard test for exterior walls uses a sound source outdoors. Results for this test are valid only for the angle of incidence of the source unless tests are performed at several angles and averaged. Tests were conducted at only an angle of 45 degrees. All measurements are in third-octave bands. After establishing the difference in levels between two rooms or between outdoors and indoors, the absorptive properties of the receiving room are evaluated in each third-octave band by measuring the reverberation in the room. An apparent transmission loss (TL) may be calculated based on the differences in sound levels, the absorption in the room, and the area of the partition. Additional tests were performed on the exterior walls using a non-standard procedure with the sound source indoors. This test like the normal test between interior rooms should be valid for random angles of incidence.

The ASTM standards require stringent conditions to be met in the field before true transmission loss results can be reported. These include proof that the sound measured came through the partition, and requirements on the room sizes and absorption. The rooms did not meet the size or absorption requirements at some frequencies. Thus, the transmission loss results and ratings calculated from them must be labeled as "apparent." In most cases, these apparent results indicate much less sound insulation than the walls are actually capable of providing. This is because of various flanking paths around the walls that controlled the isolation. In some cases, flanking was clearly not significant and the results should be very close to the actual performance of the walls. In any case, the results are related to the performance as will be perceived by occupants. The actual performance of a partition itself is best measured in a laboratory.

Results are summarized in terms of single-number ratings based on the third-octave band results. All walls are rated using the methodology of ASTM E413 to determine an apparent Field Sound Transmission Class (FSTC) based on the transmission loss of the wall. This same method was applied to the noise reduction between interior rooms to determine a Noise Isolation Class (NIC). These ratings are most related to the ability of a wall to block speech or speech-like sounds. For the exterior walls, an additional rating, the Field Outdoor-Indoor Transmission Class (FOITC), was computed based on the methodology of ASTM E1332. This rating is most related to the ability of a wall to block typical transportation noises that have a stronger low-frequency content. The ratings based on transmission losses are designated FSTC and FOITC because they are based on field data.

Results for Exterior Walls

Each exterior wall had a brick surface on the outside and a gypsum surface on the inside. The four walls had different cores as listed in the tables of results. Construction details are in the individual test reports. The "End" walls were solid with no windows or doors. The "Front" walls each had a twinned window and a fiberglass door. The results for both the E966 tests and the non-standard inside-source test are as follows.

Results of E966 Tests	Apparent FSTC (45 degrees)		Apparent FOITC (45 degrees)	
Wall Core	End Wall	Front Wall	End Wall	Front Wall
Thermosteel Panels	39	30	32	25
Sheathing, Wood Studs, Batts	42	31	33	26
Autoclaved Aerated Concrete Block	45	32	36	27
Insulating Concrete Forms	46	32	37	27

Results of Inside-Source Tests	In-Out FSTC		In-Out FOITC	
Wall Core	End Wall	Front Wall	End Wall	Front Wall
Thermosteel Panels	43	27	34	23
Sheathing, Wood Studs, Batts	46	28	33	24
Autoclaved Aerated Concrete Block	47	27	38	23
Insulating Concrete Forms	48	29	39	24

Flanking of sound around the corner and in through the windows and doors was clearly evident during the testing of the end walls. The end wall performance in the absence of flanking should be significantly better than indicated. Differences among the end walls are still evident. Based on theoretical considerations, the end wall performance without windows or doors should rank in the same order as the tests indicate. If the walls did not contain the brick surface, differences among them would be larger but probably still in the same order. The reduced performance and very small difference among the front walls are related to the dominance of the similar doors and windows. The results for the front wall are close to what would be expected for the construction with the windows and doors. The FOITC emphasizes performance at lower frequencies more typical of outdoor sounds. The ratings are lower than the FSTC ratings because all walls are poorer blockers of low frequency sound.

The differences among the walls are logical. The heavier walls perform better at low frequencies. The Thermosteel wall is weakest since the core provides neither weight nor sound absorption. The AAC and Wood walls are stronger due to weight of the AAC block and absorption of the fiberglass in the Wood wall. The ICF wall is best because it is heaviest and because the polystyrene provides some separation of the gypsum from the concrete creating effectively three layers of mass for sound blockage. The front wall is weaker largely because of the light weight of the door and windows, and some likely leaks at seals.

The results of the non-standard test with the indoor source are a little different though still yielding essentially the same rankings of the walls. Recognize that results of the E966 test are valid only for the specific angle of incidence while room reflections give a random incidence for the inside-source test. The end-wall results with this method are mostly about 2 dB higher. Notable exceptions are the Wood wall with the same FOITC, and the Thermosteel and Wood walls with 4 dB higher FSTC values. Reduced opportunity for flanking may have contributed to these higher results. While the wood wall maintained a 3 dB higher FSTC than the Thermosteel wall in this test, the Thermosteel wall achieved a slightly better FOITC due to better performance below 125 Hz. The front-wall results are generally 2-5 dB lower with the source inside, but still with only a 1-2 dB difference between the best and worst performance. In addition to the flanking influence, the differences between the two methods for the end and front walls are likely related to two factors that interact. One is the difference in incidence of sound between a narrow range of angles for the standard test and random excitation due to reflections inside the room for the other test. The other is the difference between the thick heavy materials that dominate the end wall performance the thinner, lighter materials that dominate the front wall performance. These differences affect the way the walls react to sound at different angles of incidence.

<u>Results for Interior Living-Room Bedroom Partitions</u>
The interior walls between living room and bedroom differed only in the type of stud, with steel studs in one and wood studs in the other. Each was covered with half-inch gypsum on each side, but no batts were installed. The controlling factor for sound transmission was a hollow-core door with no seals. The living room was the source room. The measurement in one bedroom was repeated with the closets open and closed. The resulting NIC and Apparent FSTC were as follows.

Basic Construction	NIC	Apparent FSTC
Wood Stud (closets open)	26	28
Steel Stud (closets open)	26	28
Steel Stud (closets closed)	25	28

With the closets closed, the sound level in the bedroom increased slightly because of reduced room absorption. Thus, the NIC dropped one dB. When this was accounted for in the calculation of the apparent transmission loss, the results are the same for all tests. Note that the controlling frequency for the ratings is the 4000 Hz octave, probably related to the acoustical properties of the door. Normally, a steel-stud wall with a single set of studs would be expected to perform a little better than a similar wood-stud wall.

<u>Results for Interior Party Walls</u>
The tests evaluated the isolation and apparent insulation between bedrooms of adjacent apartments in four duplex buildings with different party wall designs. The rooms each had gypsum ceilings and carpeted wood floors. Gypsum was installed on each side of trusses to the roof above the ceilings. Each wall had 5/8-inch Type X gypsum on each side but different cores. Two were framed walls, one using wood framing and the other using steel framing. Each had two sets of studs on separate base plates and each contained batts. The floor was continuous under these two walls with joists parallel to the wall. Wood I-joists were used in the floor under

the steel-framed wall. A masonry wall divided the crawl space under this wall, leaving a two-inch gap under the floor. Standard wood joists were used under the wood-framed wall, and the crawl space under the wall was not divided. A third wall had a core of 5.5 inch Thermosteel panels and the final wall used insulating concrete form with a 4-inch normal-weight concrete core. These two walls were on a ground foundation that separated the floors of the two rooms. The bedroom walls had closets on each side that comprised about 40% of the wall area. Tests were conducted in all cases with the closets open and in three cases with the closets closed. The test results are as follows.

Party Walls	NIC		Apparent FSTC	
Basic Construction	Closets Open	Closets Closed	Closets Open	Closets Closed
Thermosteel	38	54	36	54
Wood Studs	53		52	
Steel Studs	50	53	49	53
Insulating Concrete Forms	53	61	51	62

The Thermosteel party wall is clearly the weakest of those tested. The performance is close to what would be expected based on its construction. The results with closets closed show that the weakness is in the wall itself and not due to flanking. The other party walls performed much better with closets open. The performance of the ICF wall was further improved by about 10 dB when the closets were closed. This again shows that flanking was not a major problem for this wall, though the results are not quite as good as would be theoretically expected in a laboratory test. Comparing the wood and steel stud performance with closets open, the wood stud construction appeared to perform better. The comparison of results with closets open and closed for the steel stud wall shows that flanking was significant but not the only cause of the difference between the two walls. Walls of this design with two sets of studs usually give comparable performance with either wood or steel studs.

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TESTS OF APPARENT 45 DEGREE INCIDENCE OUTDOOR-INDOOR TRANSMISSION LOSS FOR WALLS OF DUPLEX APARTMENTS, LEXINGTON, NC

TESTS CONDUCTED: August 20-21, 2001

FOR: NAHB Research Center
400 Prince George's Boulevard
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INTRODUCTION

The Apparent Outdoor-Indoor Transmission Loss at 45 degrees incidence, Apparent OITL(45), was measured for four different exterior wall designs, both with and without doors and windows. This requires first producing a sound outdoors and measuring the difference in sound levels near the wall outdoors and within an enclosed room. Then the reverberation must be measured within the room and the absorption in the room calculated. The required result is then computed from this data.

The Transmission Loss, TL, is a property of a partition that indicates its ability to block the passage of sound at a particular frequency. The transmission loss varies with frequency. A solid heavy wall is typically better at blocking low-frequency sound, while a wall in layers can be better at higher frequencies even if lighter.

"Outdoor-indoor" indicates that the test was conducted in the field with the sound source outdoors. In this case, the transmission loss will also vary with the angle of incidence of the sound on the wall. This result is valid only for the specific angle of incidence and is not directly comparable to results measured in a laboratory even if ideal conditions are achieved in the field. The tests were conducted at only one angle, 45 degrees. A better approximation of laboratory results can be obtained by measuring at several angles and combining results. In the actual application, sound blockage of outdoor sounds will depend on the angle of incidence of the sound that may be varying with time.

The word "apparent" indicates that minimum required test conditions for reporting measurement were not ideal. The test rooms were too small and too absorptive. Separate tests were conducted of wall sections with and without doors and windows. However, during the test of the walls without doors or windows, no special steps were taken to prevent sound bending around the corner from entering the room through the door and windows. Thus, the tests of the walls without windows or doors were strongly influenced by this flanking. The actual transmission loss of the base wall should be much higher than indicated by the testing.

A single-number rating can be applied to the data to compare constructions. The most appropriate single-number rating for exterior walls is the Outdoor-Indoor Transmission Class, OITC. This emphasizes the ability to block transportation noise and is the rating recommended in E 966. The most commonly used single-number is the Sound Transmission Class, STC. It is most appropriate for speech and speech-like sounds. When based on results tested in the field, these ratings are properly labeled FOITC and FSTC. Further, when test conditions do not meet minimum requirements, and when flanking is present, the results must be labeled as Apparent FSTC and Apparent FOITC.

DESCRIPTION OF TEST ENVIRONMENT AND PARTITIONS
The tested walls are the two exterior walls of four apartment living rooms in four duplex buildings constructed with different wall materials. For each building, the "end" wall contained no doors or windows. The "front" wall contained a 36-inch by 80-inch fiberglass front door (1.75 inches thick) and a 64-inch by 62-inch twinned window. The windows have a vinyl frame and 13/16 inch insulating glass typical of residential construction. A planned storm door had not been installed. Compression fitted weather stripping was installed around sides and top of the door and the bottoms were tightly fitted to a composite threshold.

Each wall had a nominal four-inch brick exterior and differed in the core construction. Each wall had a gap of about a half-inch to an inch between the brick and core wall. Connections between the brick and core wall were on approximately 24-inch centers. The four constructions were as follows:

1. Standard Wood Construction (Wood)- This wall about 9.5 to 10 inches thick used nominal 2 by 4 studs, ½-inch gypsum inside, R13 Kraft faced batts in the cavity, and 5/8 inch asphalt impregnated sheathing (with 7/16 inch OSB sheathed corners) covered with Tyvec. The interior surfaces of the walls measured about 16 by 8 feet for the end wall, and about 16 feet 10 inches by 8 feet for the front wall.
2. Autoclaved Aerated Concrete Block (AAC)- This wall about 11.5 to 12 inches thick used the special concrete block with 1/2-inch gypsum adhered and screwed directly to the surface inside. The interior surfaces of the walls measured 15 feet 11 inches by 8 feet 3 inches for the end wall, and 16 feet 8 inches by 8 feet 3 inches for the front wall.
3. Thermosteel Panels (TS)- This wall about 9 inches thick used 3.5 inch panels of polystyrene with imbedded steel studs and 1/2-inch gypsum applied directly to the inside surface fastened with screws. The interior surfaces of the walls measured 15 feet 11 inches by 8 feet for the end wall, and 16 feet 10 inches by 8 feet for the front wall.
4. Insulating Concrete Forms (ICF)- This wall about 16 to 16.5 inches thick used polystyrene forms to hold a solid, normal weight, 6-inch concrete core wall. The polystyrene was 2 3/8 inch thick on each side of the concrete, and ½-inch gypsum was attached directly to the inside surface. The interior surfaces of the walls measured 15 feet 9 inches by 8 feet for the end wall, and 16 feet 9 inches by 8 feet for the front wall.

In addition to the volume defined by the above dimensions, the corner of each room directly opposite the exterior corner was open to an extra volume of about 260-270 cubic feet. This was a common connecting area for all the rooms of the apartment. No door was provided for the kitchen that opened to this area with an opening of 2 feet 8 inches by approximately 7 feet. Doors to the other three rooms were closed except during testing of the ICF end wall. Reverberation was measured with the doors in the same condition as during the level reduction measurements. Note that the room does not meet minimum volume requirements for measurements below 100 Hz. All room surfaces were hard except carpet on the floor. Reverberation measurements indicated the rooms had excessive absorption for measurement of transmission loss at low to low-mid frequencies.

Each building had a plywood roof covered with shingles, a ½-inch gypsum ceiling, and the equivalent of R-30 blown fiberglass attic insulation. Vents were included along the roof edge at the front wall and at the roof ridge. Each building except the ICF building had an eight by sixteen-inch foundation vent in the lower end wall that was thermostatically controlled and partially open. This provided some sound exposure to the crawl space that was separated from the measurement room by a plywood floor. The floor was 5/8 inch thick in the wood building and ¾ inch thick in the others.

CONFORMANCE TO STANDARDS

Tests were conducted following the ASTM Guide E 966-99 Field Measurements of Airborne Sound Insulation of Building Facades and Facade Elements. ASTM E 966-99 is a guide providing several options for outdoor-indoor measurements of sound isolation. Various options provided in the guide were selected, and one exception to the guide was taken in the measurements.

Specific options in the guide that define the tests conducted are as follows:

1. The sound source was placed at a 45-degree angle horizontally from the center of the test wall, and vertically at approximately the height of the wall center. It was approximately 20 feet from the wall perpendicularly, and 28 feet from the center of the wall along the line at 45 degrees. The loudspeaker in each case was aimed at the test-wall center in the general direction toward the corner between the front and end walls. Measurements were made only with the sound source at 45 degrees as preferred (section 8.2.3.1 of E 966) for comparison of different constructions at a single angle.
2. The outdoor measurements were made in the area 4 to 8 feet from the wall in the method called "near the facade."
3. No attempt was made to eliminate flanking, and the test rooms did not meet size and absorption requirements necessary to report actual transmission loss. Thus, all results are labeled "apparent."

The only clear exception to the guide E 966-99 is that measurements both outside and inside (except reverberation measurements) were made with a manually moved microphone, recording only one result for each measurement. Thus, confidence intervals also were not computed.

Reverberation measurements to evaluate the absorption in the test rooms were made following an ASTM draft standard that provides more detailed guidance than is available in E 966. The Apparent FSTC values were computed according to ASTM E 413-87, Classification for Rating Sound Insulation. The Apparent FOITC values were computed according to ASTM E 1332-90, Classification for Determination of Outdoor-Indoor Transmission Class.

MEASUREMENT EQUIPMENT AND METHODS

The sound source was a custom speaker system provided by Electroacoustic Development Company of Lexington. The lower frequencies were produced by a 15-inch woofer in a compound loaded enclosure. The higher frequencies were produced by 500 Hz constant directivity horns (two used for outdoor source and one for reverberation measurements). The system was bi amplified using a two-channel two-kilowatt amplifier with an electronic crossover. The signal for the outdoor sound was a tape of broadband pink noise on a Sony TC-D5M cassette player. The signal for the reverberation measurements was provided by the measurement instrument. An equalizer was used to concentrate the sound in the frequency range of interest and to boost the high-frequency output to adequate levels during the blockage measurements. A flatter spectrum concentrated in the range of interest was used for the reverberation measurements. The loudspeakers were faced into a corner of the room for the reverberation measurements.

The sound levels were measured simultaneously in third-octaves with a Larson-Davis 2800 Precision Real-Time Sound Analyzer equipped with a Larson-Davis 2541 microphone. Each measurement of steady sound was averaged over a period of at least 30 seconds as the microphone was moved about the measurement space. The instrument stored the levels to the nearest tenth of a decibel. Reverberation decays were recorded in increments of .025 seconds over a one-second period after the signal was stopped. Sensitivity stability of the instrument was checked before and after each measurement using a Bruel & Kjaer 4231 Acoustical Calibrator.

Room background sound was measured using the same range settings used for sound measurements. Third-octave sound levels in the receiving room with the loudspeaker outside were always at least 10 dB greater than the background levels. Background levels during the reverberation measurements were always at least 40 dB and usually more than 50 dB below the source level in each third octave.

RESULTS OF MEASUREMENTS

Tabulated below is a summary of the results based on the one-number ratings. The following pages show the results of each specific test for each frequency band in a table and graph. Results are shown from 80 to 4000 Hz, as all these frequencies are required in the computation of the FOITC. The FOITC is computed based on the difference in overall A-weighted sound level between a reference spectrum of sound and that spectrum reduced by the measured data. The FSTC is based only on the sound data from 125 to 4000 Hz. It is computed by lowering the reference curve shown on the graphs until the difference between the data and reference curve does not exceed 8 at any frequency, and the sum of the differences at all frequencies (called deficiencies) does not exceed 32. The deficiencies from the contour curve used to establish the Apparent FSTC rating are shown.

Basic Construction	Apparent FSTC (45 degrees)		Apparent FOITC (45 degrees)	
	End Wall	Front Wall	End Wall	Front Wall
Thermosteel	39	30	32	25
Wood	42	31	33	26
AAC	45	32	36	27
ICF	46	32	37	27

DISCUSSION OF RESULTS

Flanking of sound around the corner and in through the windows and doors was clearly evident during the testing of the end walls. The end wall performance in the absence of flanking should be significantly better than indicated. Differences among the end walls are still evident. Based on theoretical considerations, the end wall performance without windows or doors should rank in the same order as the tests indicate. If the walls did not contain the brick surface, and flanking was not so strong, differences among them would be larger but probably still in the same order. The reduced performance and very small difference among the front walls are related to the dominance of the similar doors and windows. The results for the front wall are close to what would be expected for the construction with the windows and doors. The FOITC emphasizes performance at lower frequencies more typical of outdoor sounds. The ratings are lower than the FSTC ratings because all walls are poorer blockers of low frequency sound.

The differences among the walls are logical. The weaknesses in particular frequency ranges are often explained by resonance or coincidence frequency effects. The common resonance for cavity walls and thermal windows is based on the air in the cavity acting as a spring between two layers of mass. The coincidence frequency is where the speed of sound equals the propagation speed of the bending wave in the material. The weakness around 160-200 Hz can be related to the coincidence frequency of the brick and the concrete where present. Flanking through the windows that have a resonant frequency in this region also could contribute to this. The heavier walls perform better at low frequencies. The Thermosteel is weakest in the 500-2000 Hz region. The AAC and Wood walls are stronger in this region due to weight of the AAC block and absorption of the fiberglass in the Wood wall. The ICF wall is best because it is heaviest and because the polystyrene provides some separation of the gypsum from the concrete creating effectively three layers of mass for sound blockage. The apparent weaknesses around 1600-2000 Hz are not explainable by the wall structures and are likely related to flanking. The front wall is weaker largely because of the light door and windows, and some likely leaks at seals. The weakness around 1600-2000 Hz in the front wall is most likely related to the fiberglass door though no specific data is available to verify this. The windows would be particularly weak in the 160-312 Hz region due to resonance, and above 4000 Hz due to coincidence frequency.

The precision of this test method has not been established but is estimated according to E 966 to be of the order of 2 to 4 dB depending on frequency. Non-linearity of reverberation decays below 800 Hz in the small rooms introduces a potential variation of one dB in results at a specific frequency due to different interpretations of decay slope. All such cases that could have potentially changed an apparent FSTC rating were checked carefully and no possible variations in rating were found. Recognize also that results are valid only for the specific angle of incidence.

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Thermasteel Core - End Wall

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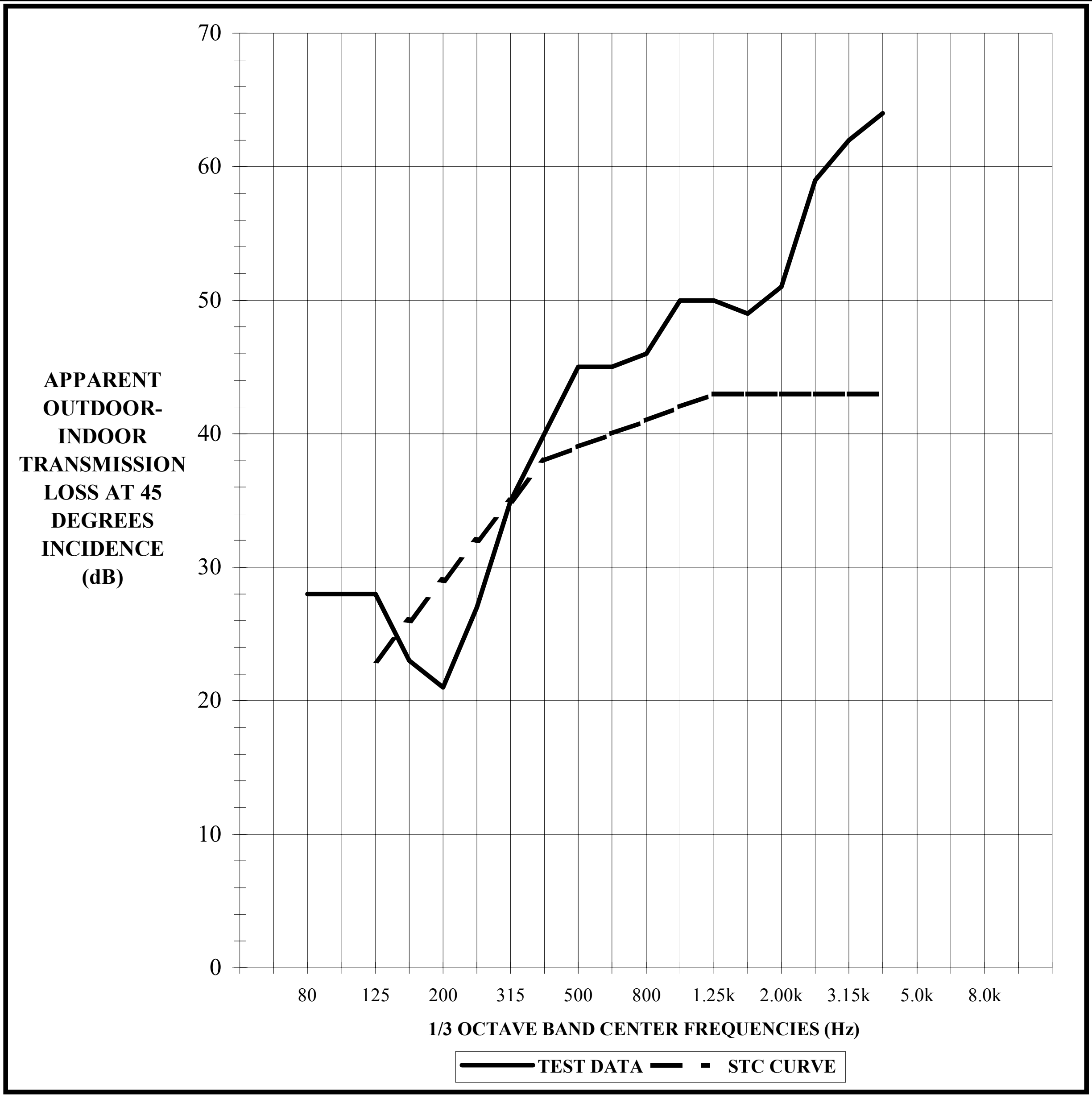
Frequency	80	100	125	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
Ap OITL (45)	28	28	28	23	21	27	35	40	45	45	46	50	50	49	51	59	62	64
Deficiencies				3	8	5												

Apparent FSTC = 39	Apparent FOITC = 32	Total Deficiencies = 16	Maximum Deficiency = 8



Wood Core - End Wall

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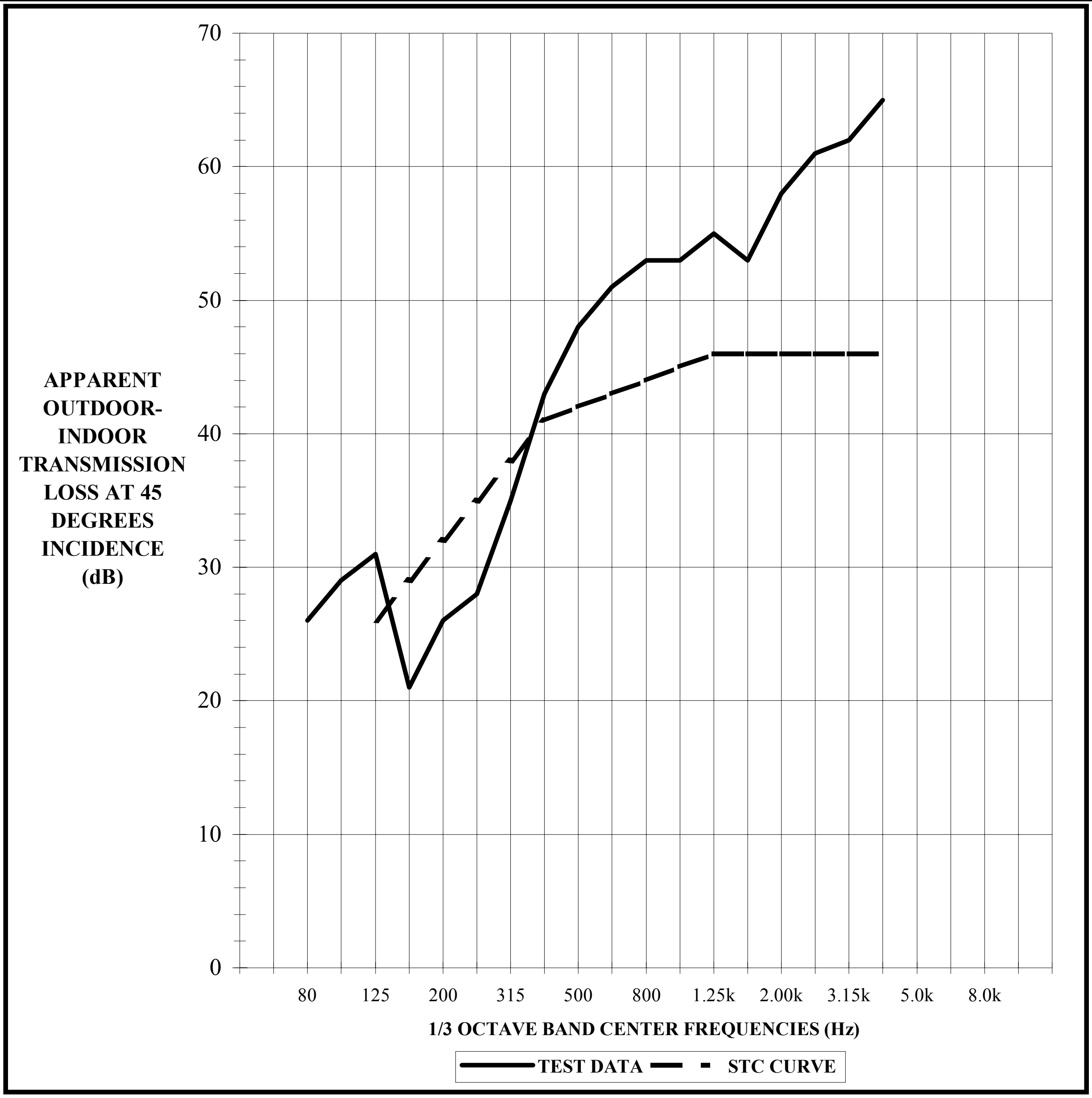
Frequency	80	100	125	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
Ap OITL (45)	26	29	31	21	26	28	35	43	48	51	53	53	55	53	58	61	62	65
Deficiencies				8	6	7	3											

Apparent FSTC = 42	Apparent FOITC = 33	Total Deficiencies = 24	Maximum Deficiency = 8



Autoclaved Aerated Concrete Core - End Wall

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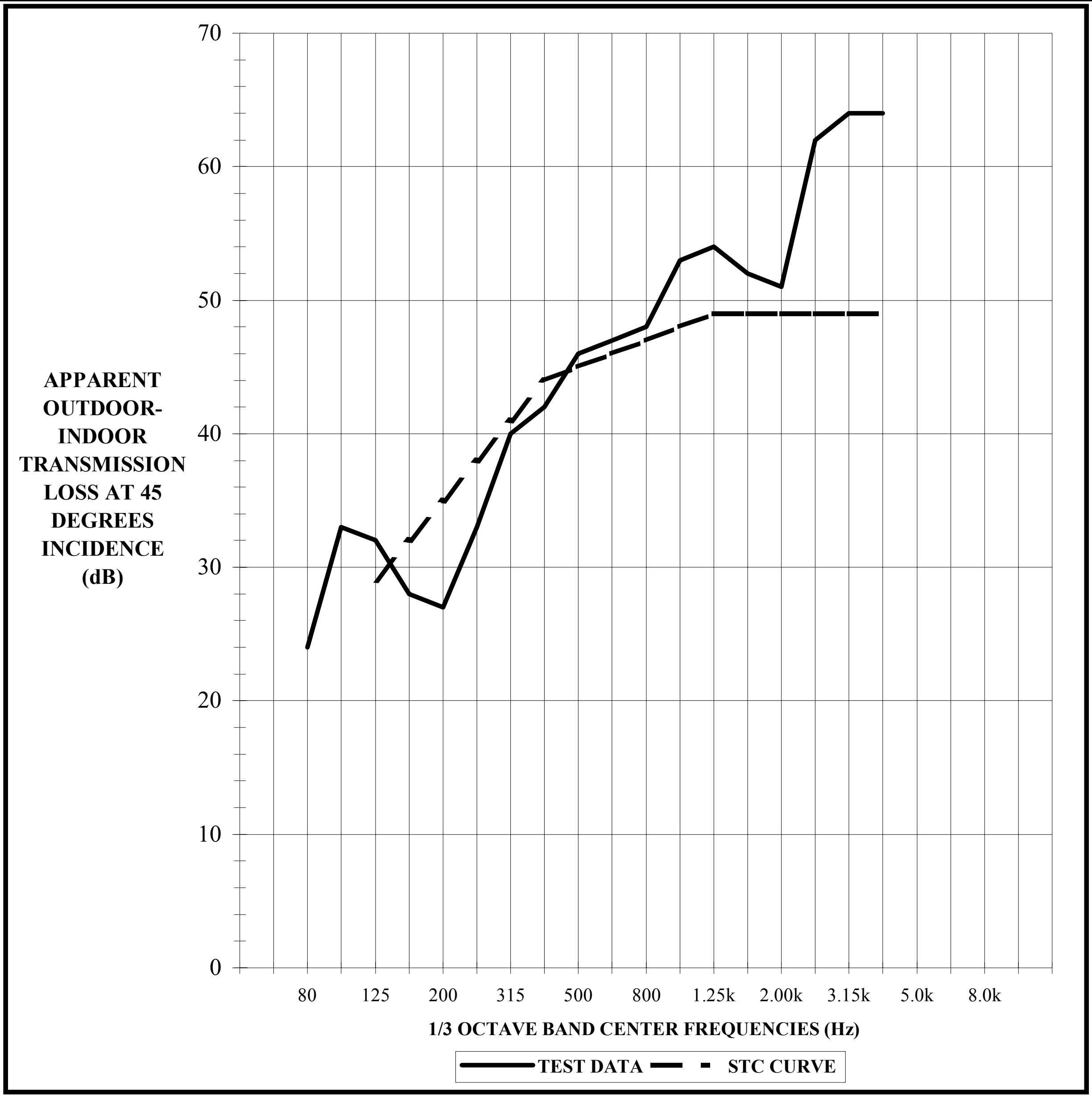
Frequency	80	100	125	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
Ap OITL (45)	24	33	32	28	27	33	40	42	46	47	48	53	54	52	51	62	64	64
Deficiencies				4	8	5	1	2										

Apparent FSTC = 45	Apparent FOITC = 36	Total Deficiencies = 20	Maximum Deficiency = 8



Insulating Concrete Form Core - End Wall

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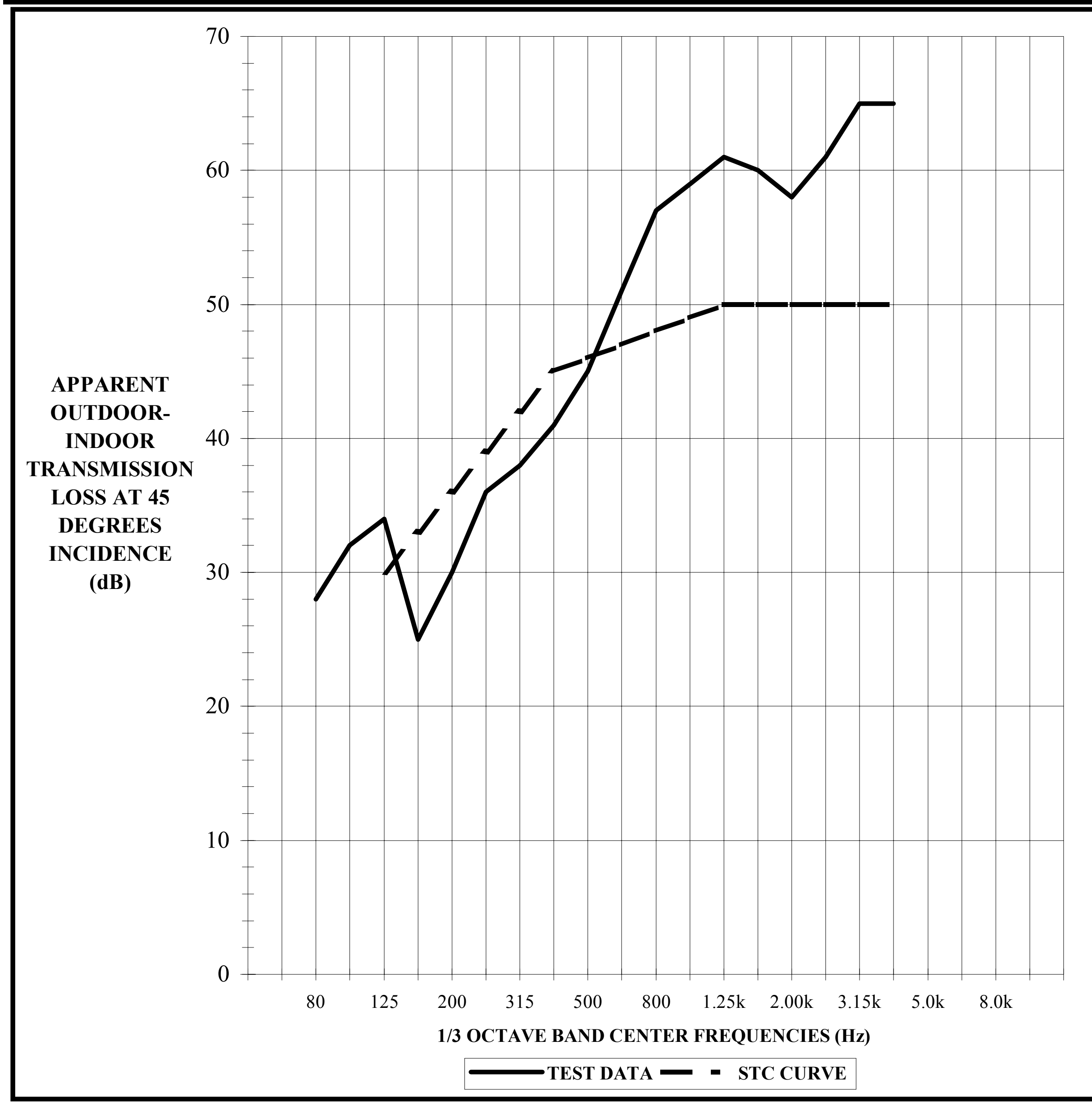
Frequency	80	100	125	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
Ap OITL (45)	28	32	34	25	30	36	38	41	45	51	57	59	61	60	58	61	65	65
Deficiencies				8	6	3	4	4	1									

Apparent FSTC = 46	Apparent FOITC = 37	Total Deficiencies = 26	Maximum Deficiency = 8



Thermasteel Core - Front Wall

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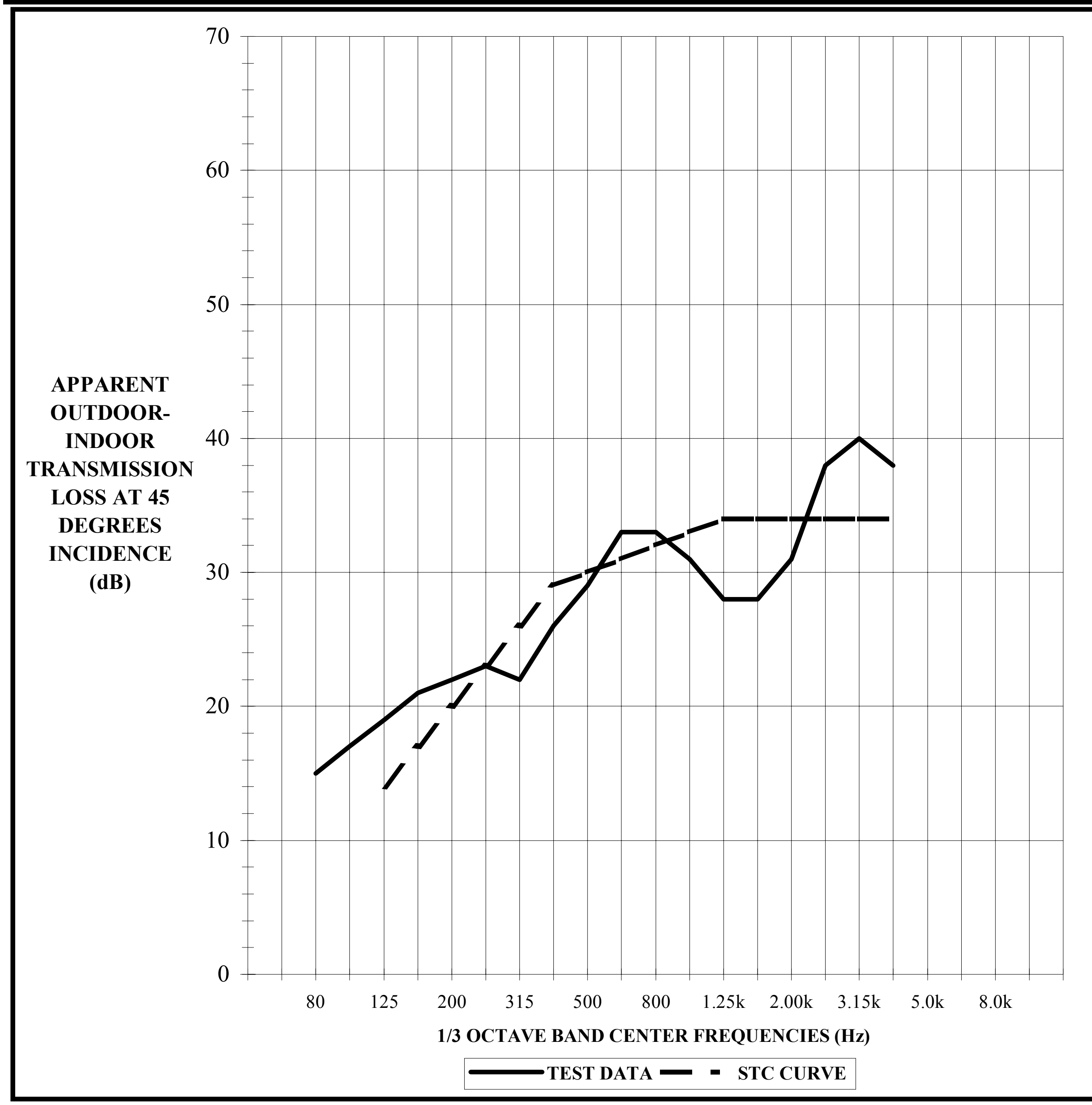
Frequency	80	100	125	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
Ap OITL (45)	15	17	19	21	22	23	22	26	29	33	33	31	28	28	31	38	40	38
Deficiencies							4	3	1			2	6	6	3			

Apparent FSTC = 30	Apparent FOITC = 25	Total Deficiencies = 25	Maximum Deficiency = 6



Wood Core - Front Wall

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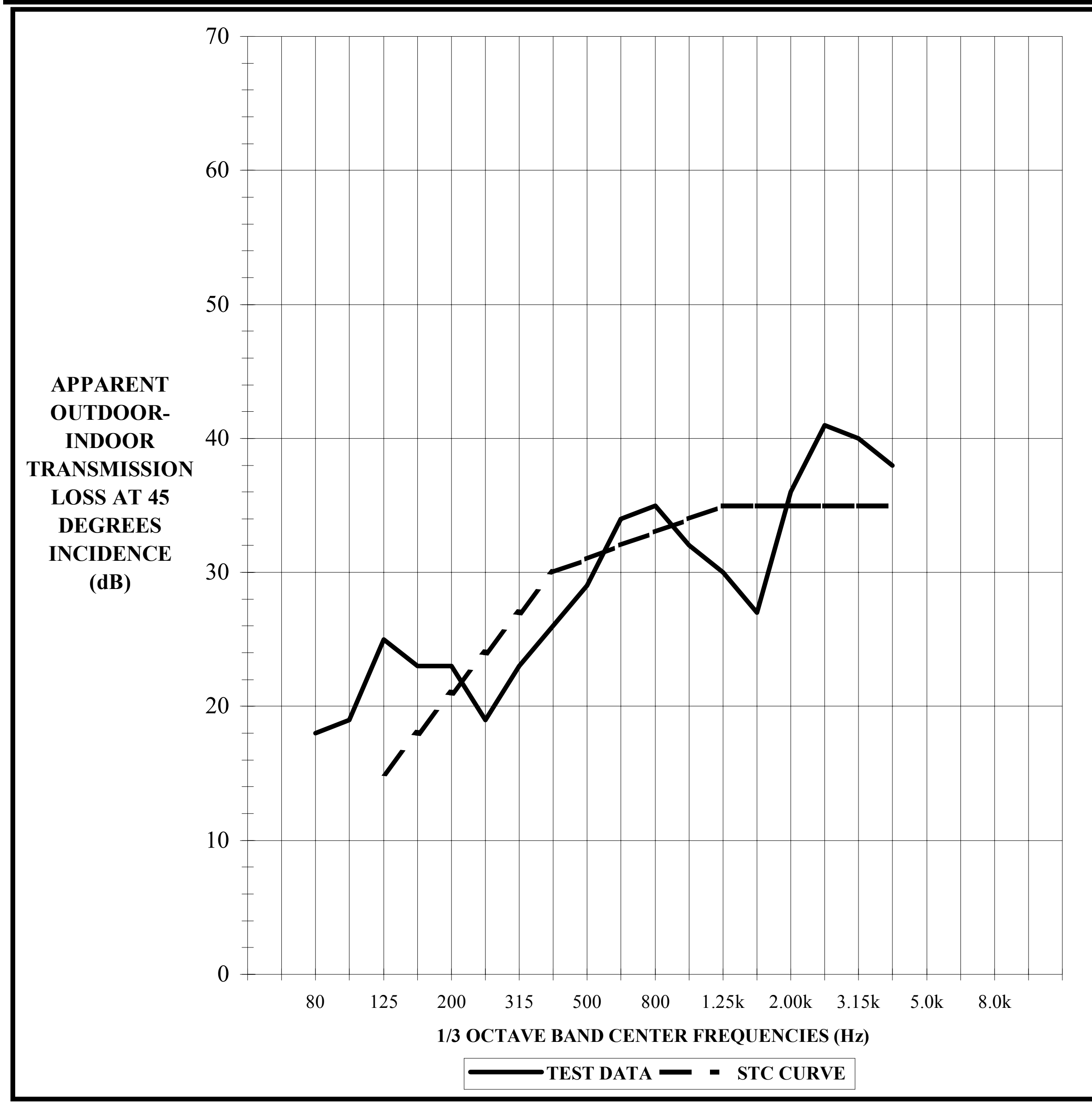
Frequency	80	100	125	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
Ap OITL (45)	18	19	25	23	23	19	23	26	29	34	35	32	30	27	36	41	40	38
Deficiencies						5	4	4	2			2	5	8				

Apparent FSTC = 31	Apparent FOITC = 26	Total Deficiencies = 30	Maximum Deficiency = 8



Autoclaved Aerated Concrete Core - Front Wall

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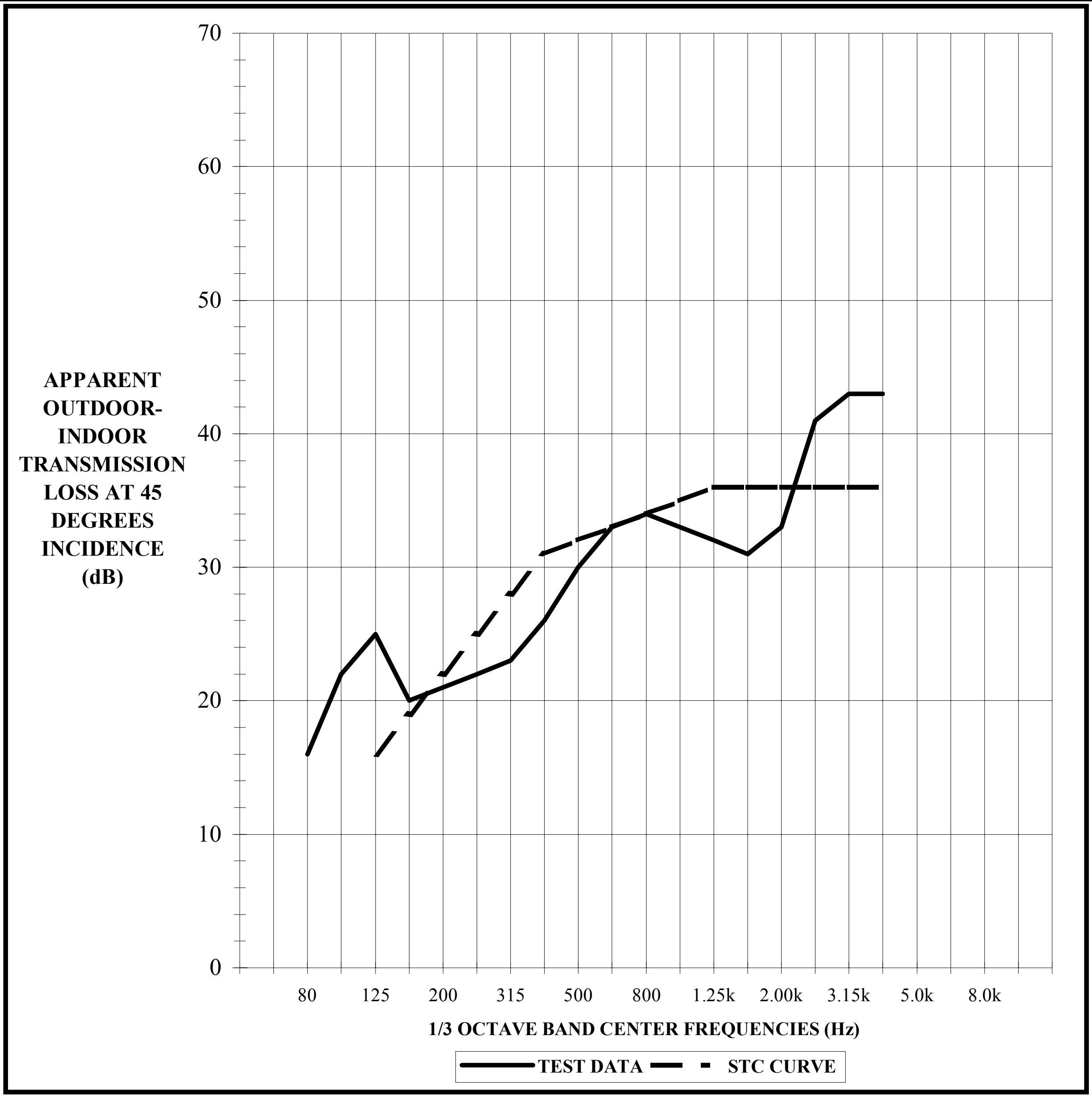
Frequency	80	100	125	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
Ap OITL (45)	16	22	25	20	21	22	23	26	30	33	34	33	32	31	33	41	43	43
Deficiencies					1	3	5	5	2			2	4	5	3			

Apparent FSTC = 32	Apparent FOITC = 27	Total Deficiencies = 30	Maximum Deficiency = 5



Insulating Concrete Form Core - Front Wall

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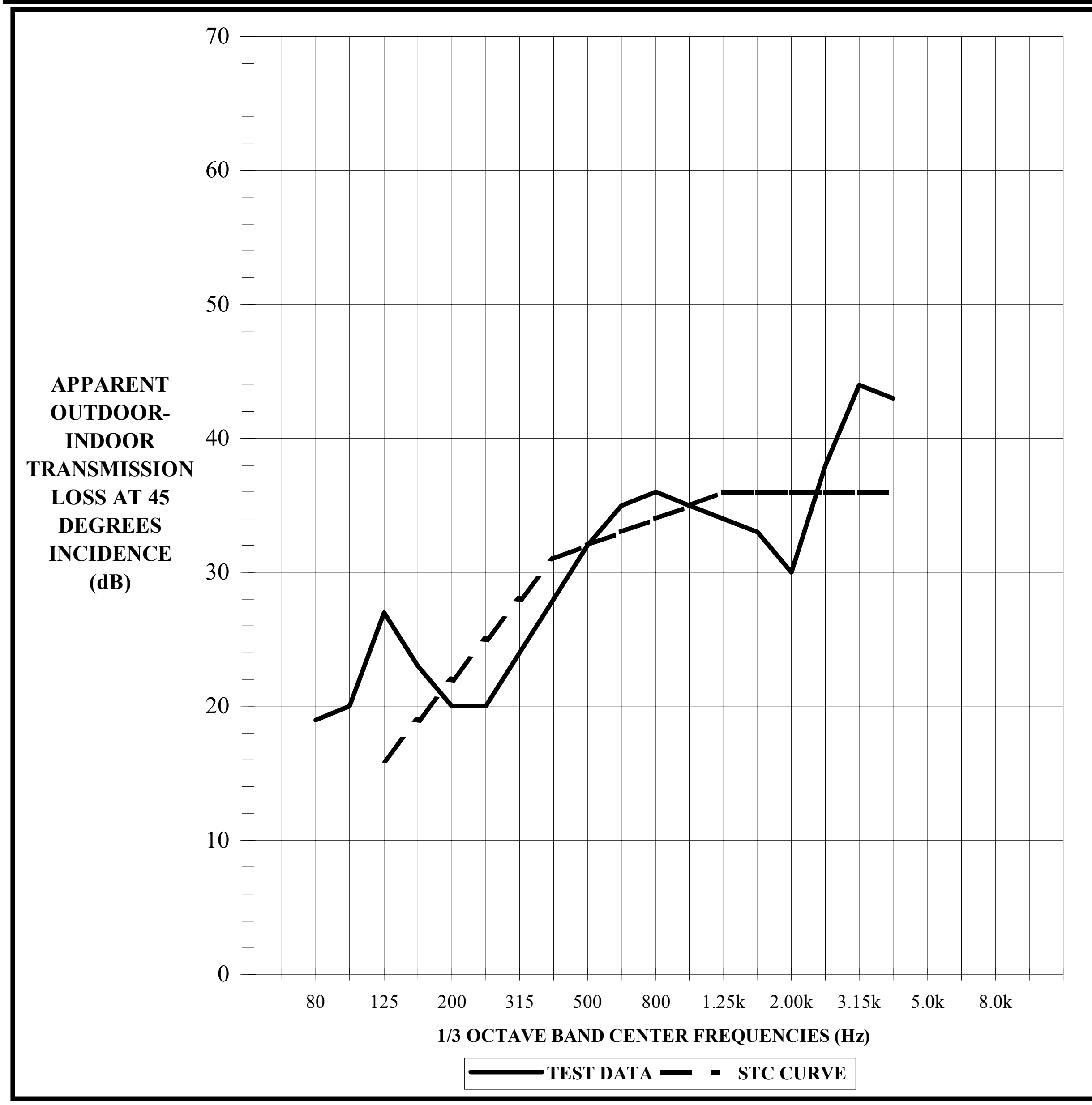
Frequency	80	100	125	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
Ap OITL (45)	19	20	27	23	20	20	24	28	32	35	36	35	34	33	30	38	44	43
Deficiencies					2	5	4	3					2	3	6			

Apparent FSTC = 32	Apparent FOITC = 27	Total Deficiencies = 25	Maximum Deficiency = 6



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September 21, 2001

NON-STANDARD TESTS OF INDOOR-OUTDOOR TRANSMISSION LOSS FOR WALLS OF DUPLEX APARTMENTS, LEXINGTON, NC

TESTS CONDUCTED: August 21, 2001

FOR: NAHB Research Center
400 Prince George's Boulevard
Upper Marlboro, Maryland 20774

INTRODUCTION

The traditional field test of facade sound blockage according to ASTM E 966 is performed with the sound source outside. It is valid only for a particular angle of incidence, while most tests of sound blockage are based on random incidence. To approximate random incidence results, measurements must be made with the loudspeaker at several angles. Sharp and Martin of Wyle Laboratories have proposed a test using a sound source indoors, with measurements indoors and near the facade outdoors. The results should represent random incidence properties comparable to other tests with a single measurement. The measurement and analysis are also is much simpler than the methods of E 966. Problems related to loudspeaker positioning and obtaining an even distribution of sound on the outdoor surface are avoided. Also, reverberation and sound absorption do not have to be measured and evaluated. The only obvious drawback is the greater reduction of sound from indoors to outdoors, and the greater potential for background interference outdoors. The build-up of sound inside helps make up for the greater reduction experienced from indoor to outdoors.

The method is based on the concept that the difference between the average level in the room and the level very near (but not on the surface of) the facade outdoors should equal the transmission loss plus 6 dB. This theory is as sound as the theory for the E 966 outdoor-indoor test. The reason it has not been incorporated into a standard is unknown.

MEASUREMENT EQUIPMENT AND METHODS

The sound source was a custom speaker system provided by Electroacoustic Development Company of Lexington. The lower frequencies were produced by a 15-inch woofer in a compound loaded enclosure. The higher frequencies were produced by 500 Hz constant directivity horns. The system was bi amplified using a two-channel two-kilowatt amplifier with an electronic crossover. The signal for the sound was a tape of broadband pink noise on a Sony TC-D5M cassette player. An equalizer was used to concentrate the sound in the frequency range of interest and to boost the high-frequency output to adequate levels. The loudspeakers were faced into the corner of the source room away from the facades.

Sound levels were measured simultaneously in third-octaves with a Larson-Davis 2800 Precision Analyzer equipped with a Larson-Davis 2541 microphone. Each measurement was averaged over a period of at least 30 seconds as the microphone was moved about the measurement space. The instrument stored the levels to the nearest tenth of a decibel. Sensitivity stability of the instrument was checked before and after each measurement using a Bruel & Kjaer 4231 Acoustical Calibrator.

Background sound was measured outdoors using the same range settings as used for sound measurements. Data were corrected for background when background sound was between 5 and 10 dB below the signal. In one case at 4000 Hz, insect sound dominated so an accurate result could not be measured. However, it was clear that this did not influence the overall single-number results.

DESCRIPTION OF TEST ENVIRONMENT AND PARTITIONS
The tested walls are the two exterior walls of four apartment living rooms in four duplex buildings constructed with different wall materials. For each building, the "end" wall contained no doors or windows. The "front" wall contained a 36-inch by 80-inch fiberglass front door (1.75 inches thick) and a 64-inch by 62-inch twinned window. The windows have a vinyl frame and 13/16 inch insulating glass typical of residential construction. A planned storm door had not been installed. Compression fitted weather stripping was installed around sides and top of the door and the bottoms were tightly fitted to a composite threshold.

Each wall had a nominal four-inch brick exterior and differed in the core construction. Each wall had a gap of about a half-inch to an inch between the brick and core wall. Connections between the brick and core wall were on approximately 24-inch centers. The four constructions were as follows:

1. Standard Wood Construction (Wood)- This wall about 9.5 to 10 inches thick used nominal 2 by 4 studs, ½-inch gypsum inside, R13 Kraft faced batts in the cavity, and 5/8 inch asphalt impregnated sheathing (with 7/16 inch OSB sheathed corners) covered with Tyvec. The interior surfaces of the walls measured about 16 by 8 feet for the end wall, and about 16 feet 10 inches by 8 feet for the front wall.
2. Autoclaved Aerated Concrete Block (AAC)- This wall about 11.5 to 12 inches thick used the special concrete block with 1/2-inch gypsum adhered and screwed directly to the surface inside. The interior surfaces of the walls measured 15 feet 11 inches by 8 feet 3 inches for the end wall, and 16 feet 8 inches by 8 feet 3 inches for the front wall.
3. Thermosteel Panels (TS)- This wall about 9 inches thick used 3.5 inch panels of polystyrene with imbedded steel studs and 1/2-inch gypsum applied directly to the inside surface fastened with screws. The interior surfaces of the walls measured 15 feet 11 inches by 8 feet for the end wall, and 16 feet 10 inches by 8 feet for the front wall.
4. Insulating Concrete Forms (ICF)- This wall about 16 to 16.5 inches thick used polystyrene forms to hold a solid, normal weight, 6-inch concrete core wall. The polystyrene was 2 3/8 inch thick on each side of the concrete, and ½-inch gypsum was attached directly to the inside surface. The interior surfaces of the walls measured 15 feet 9 inches by 8 feet for the end wall, and 16 feet 9 inches by 8 feet for the front wall.

Each building had a plywood roof covered with shingles, a ½-inch gypsum ceiling, and the equivalent of R-30 blown fiberglass attic insulation. Vents were included along the roof edge at the front wall and at the roof ridge. Each building except the ICF building had an eight by sixteen-inch foundation vent in the lower end wall that was thermostatically controlled and partially open. This provided some sound exposure to the crawl space that was separated from the measurement room by a plywood floor. The floor was 5/8 inch thick in the wood building and ¾ inch thick in the others.

RESULTS OF MEASUREMENTS

Tabulated below is a summary of the results based on the one-number ratings FSTC and FOITC. The following pages show the results of each specific test for each frequency band in a table and graph. Results are shown from 80 to 4000 Hz, as all these frequencies are required in the computation of the FOITC. The FOITC is computed based on the difference in overall A-weighted sound level between a reference spectrum of sound and that spectrum reduced by the measured data. The FSTC is based only on the sound data from 125 to 4000 Hz. It is computed by lowering the reference curve shown on the graphs until the difference between the data and reference curve does not exceed 8 at any frequency, and the sum of the differences at all frequencies (called deficiencies) does not exceed 32. The deficiencies from the contour curve used to compute the FSTC rating are shown.

Basic Construction	In-Out FSTC		In-Out FOITC	
	End Wall	Front Wall	End Wall	Front Wall
Thermosteel	43	27	34	23
Wood	46	28	33	24
AAC	47	27	38	23
ICF	48	29	39	24

DISCUSSION OF RESULTS

These results were compared to tests on the same walls using the ASTM E 966 procedure at 45 degrees incidence. The end-wall results with this method are mostly about 2 dB higher possibly influenced by less flanking opportunity. Notable exceptions are the Wood wall with the same FOITC, and the Thermosteel and Wood walls with 4 dB higher FSTC values. The larger FSTC changes with less or no change in FOITC are due to differences in results at the low frequencies. With the outdoor source, both walls showed better performance at 80-125 Hz, but a weakness at 160-200 Hz reduced their FSTC rating. With the indoor source, the Thermasteel wall performed better than wood in the 80-125 Hz range giving the slightly higher FOITC. The front-wall results are generally 2-5 dB lower with the source inside, but still with only a 1-2 dB difference between the best and worst performance. The differences between the two methods for the end and front walls are likely related to the difference between excitation in a narrow range of angles and random excitation. This is related to the coincidence frequency that is very low for the dominant materials in the end walls but very high for those of the front wall.

STEWART ACOUSTICAL CONSULTANTS

Noral D. Stewart, Ph.D.

Thermasteel Core - End Wall

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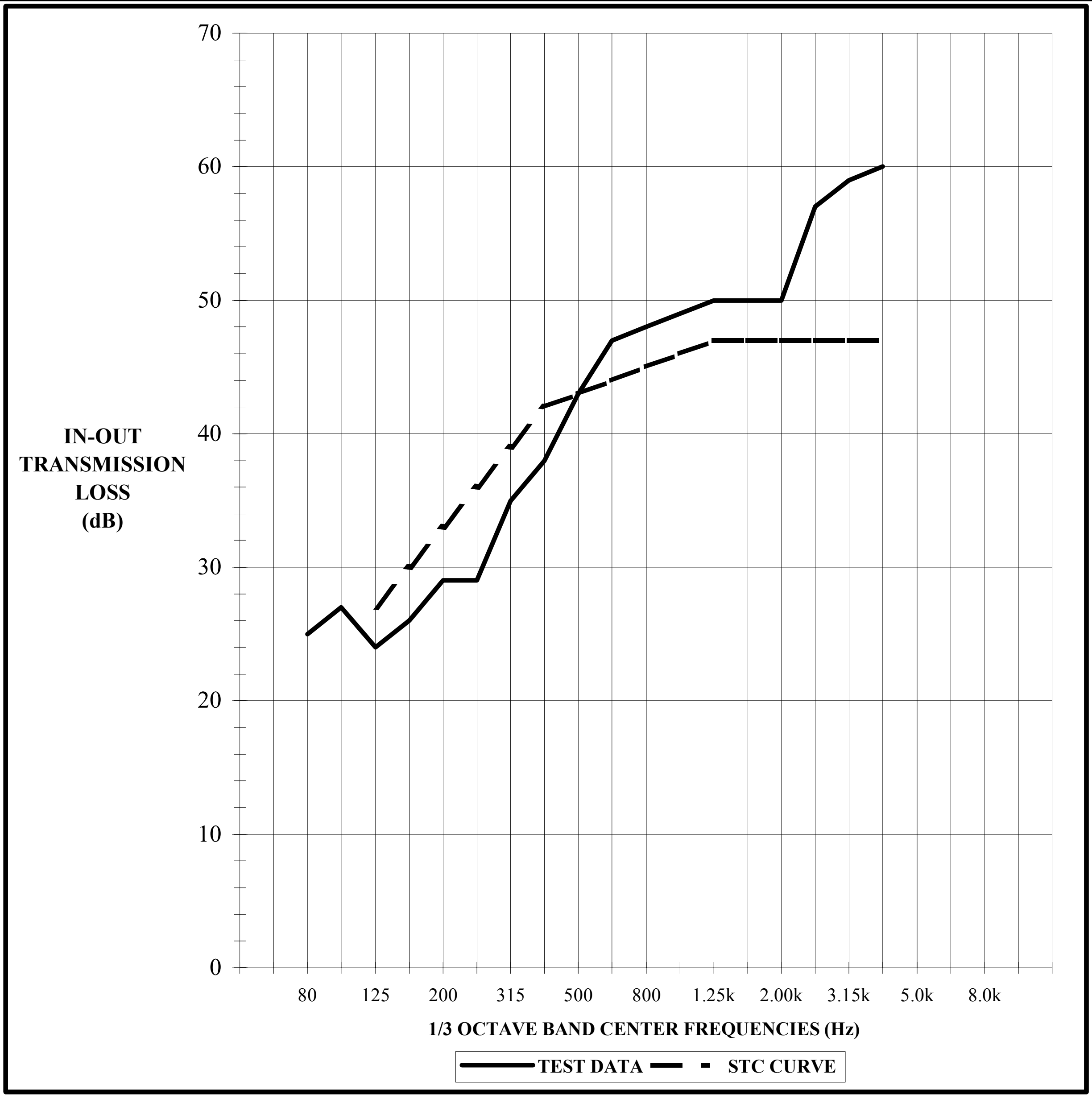
Frequency	80	100	125	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
In-Out TL	25	27	24	26	29	29	35	38	43	47	48	49	50	50	50	57	59	60
Deficiencies			3	4	4	7	4	4										

In-Out FSTC = 43	In-Out FOITC = 34	Total Deficiencies = 26	Maximum Deficiency = 7



Wood Core - End Wall

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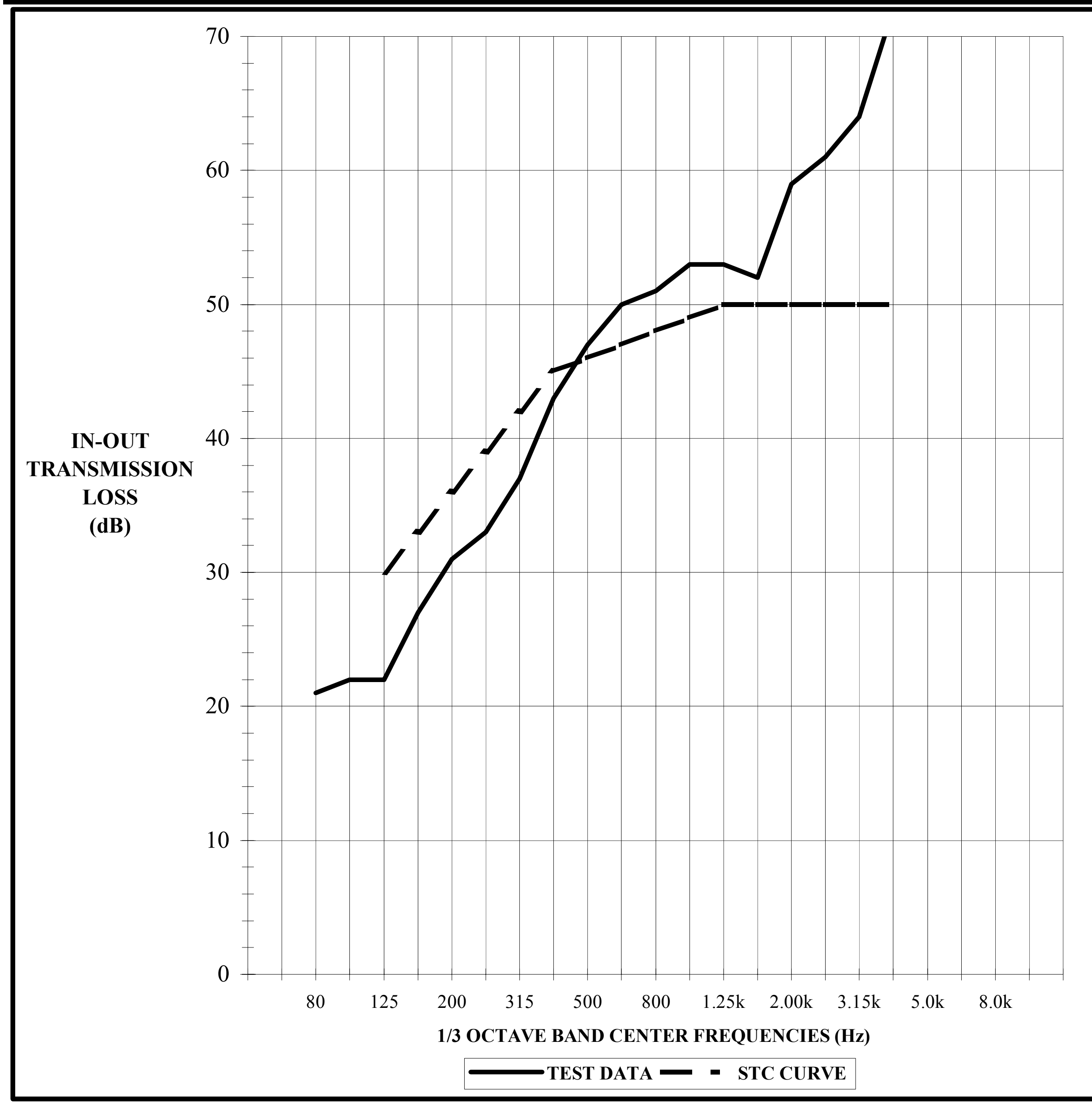
Frequency	80	100	125	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
In-Out TL	21	22	22	27	31	33	37	43	47	50	51	53	53	52	59	61	64	72
Deficiencies			8	6	5	6	5	2										

In-Out FSTC = 46	In-Out FOITC = 33	Total Deficiencies = 32	Maximum Deficiency = 8



Autoclaved Aerated Concrete Core - End Wall

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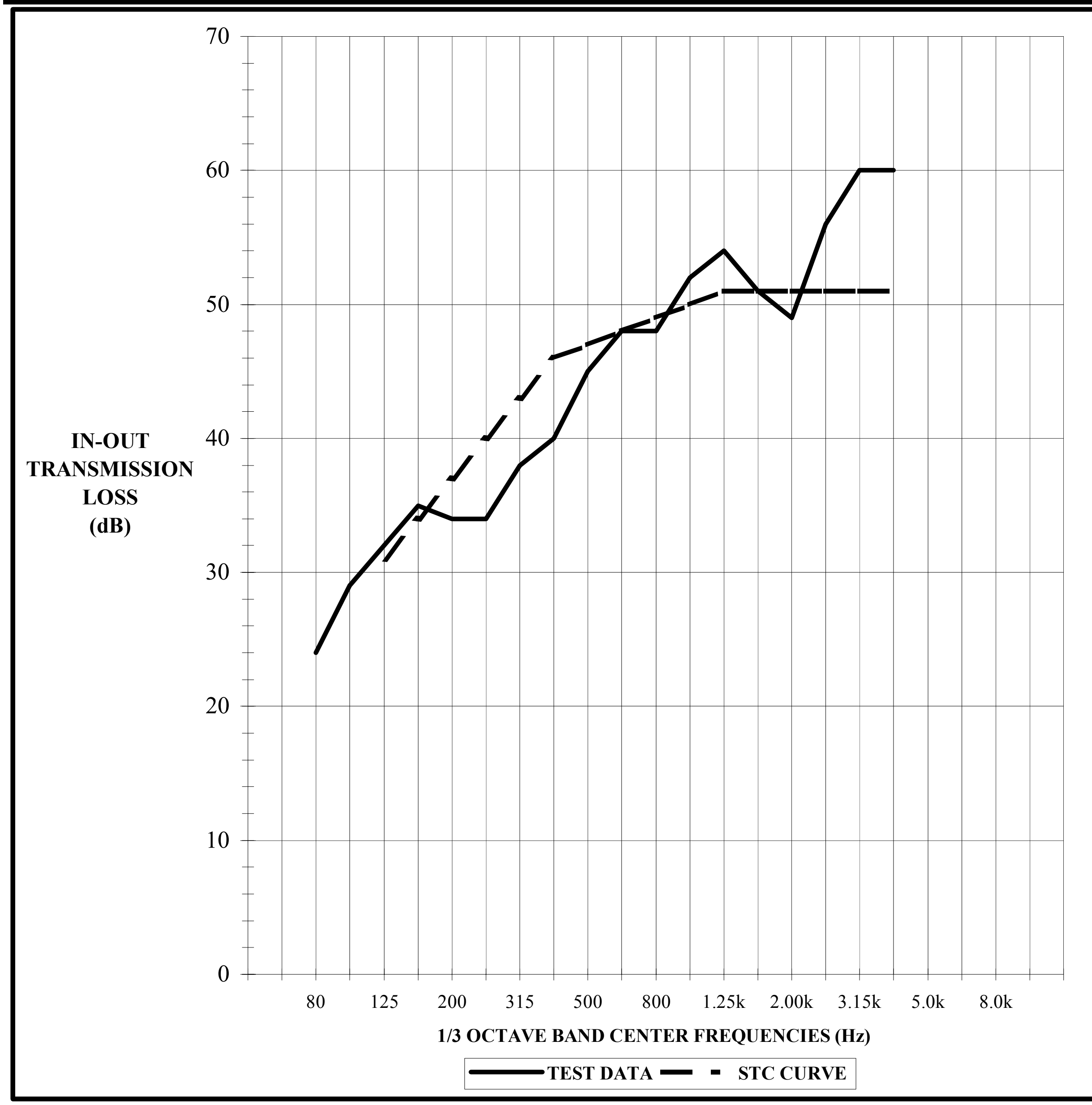
Frequency	80	100	125	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
In-Out TL	24	29	32	35	34	34	38	40	45	48	48	52	54	51	49	56	60	60
Deficiencies					3	6	5	6	2		1				2			

In-Out FSTC = 47	In-Out FOITC = 38	Total Deficiencies = 25	Maximum Deficiency = 6



Insulating Concrete Form Core - End Wall

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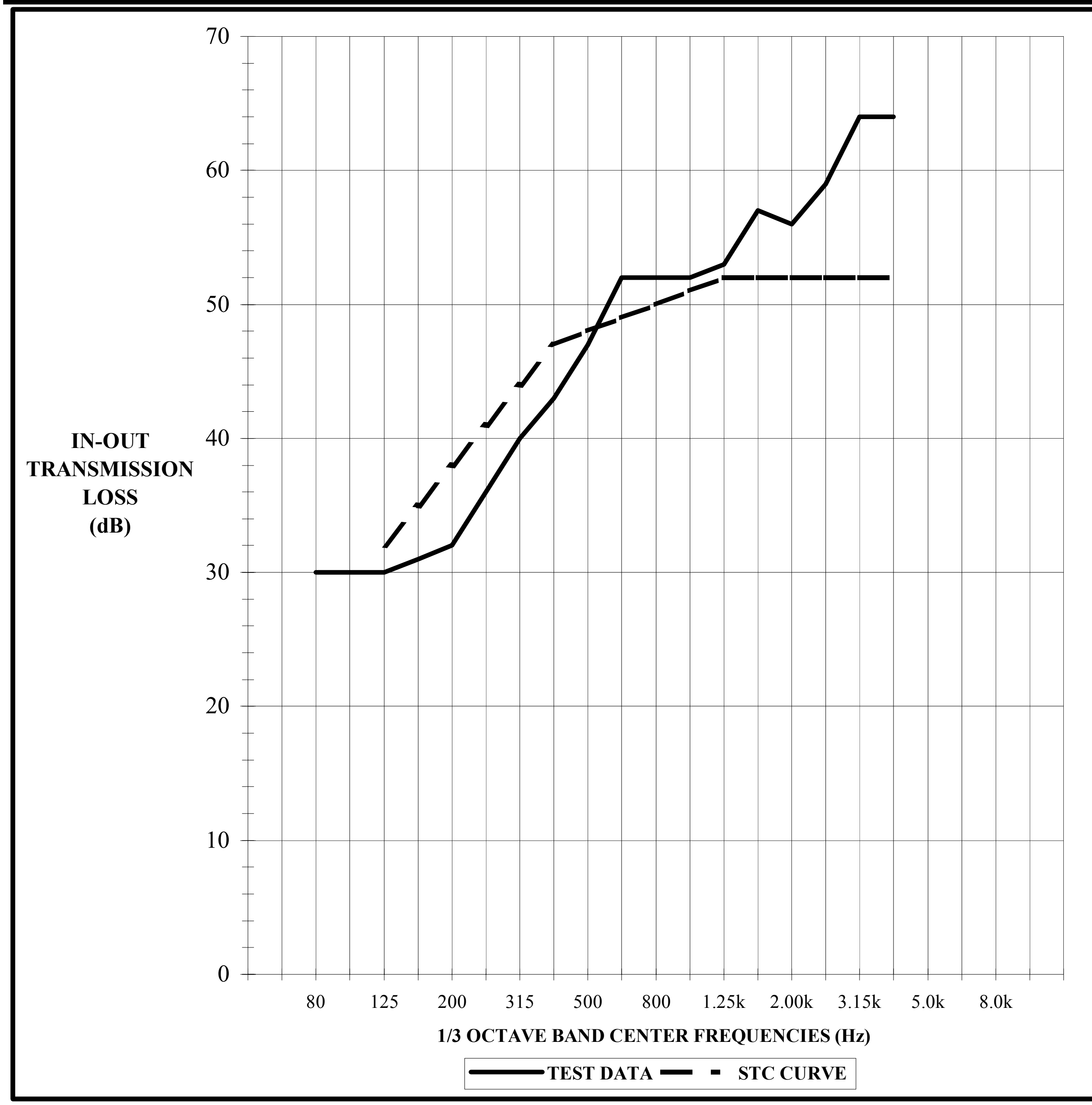
Frequency	80	100	125	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
In-Out TL	30	30	30	31	32	36	40	43	47	52	52	52	53	57	56	59	64	64
Deficiencies			2	4	6	5	4	4	1									

In-Out FSTC = 48	In-Out FOITC = 39	Total Deficiencies = 26	Maximum Deficiency = 6



Thermasteel Core - Front Wall

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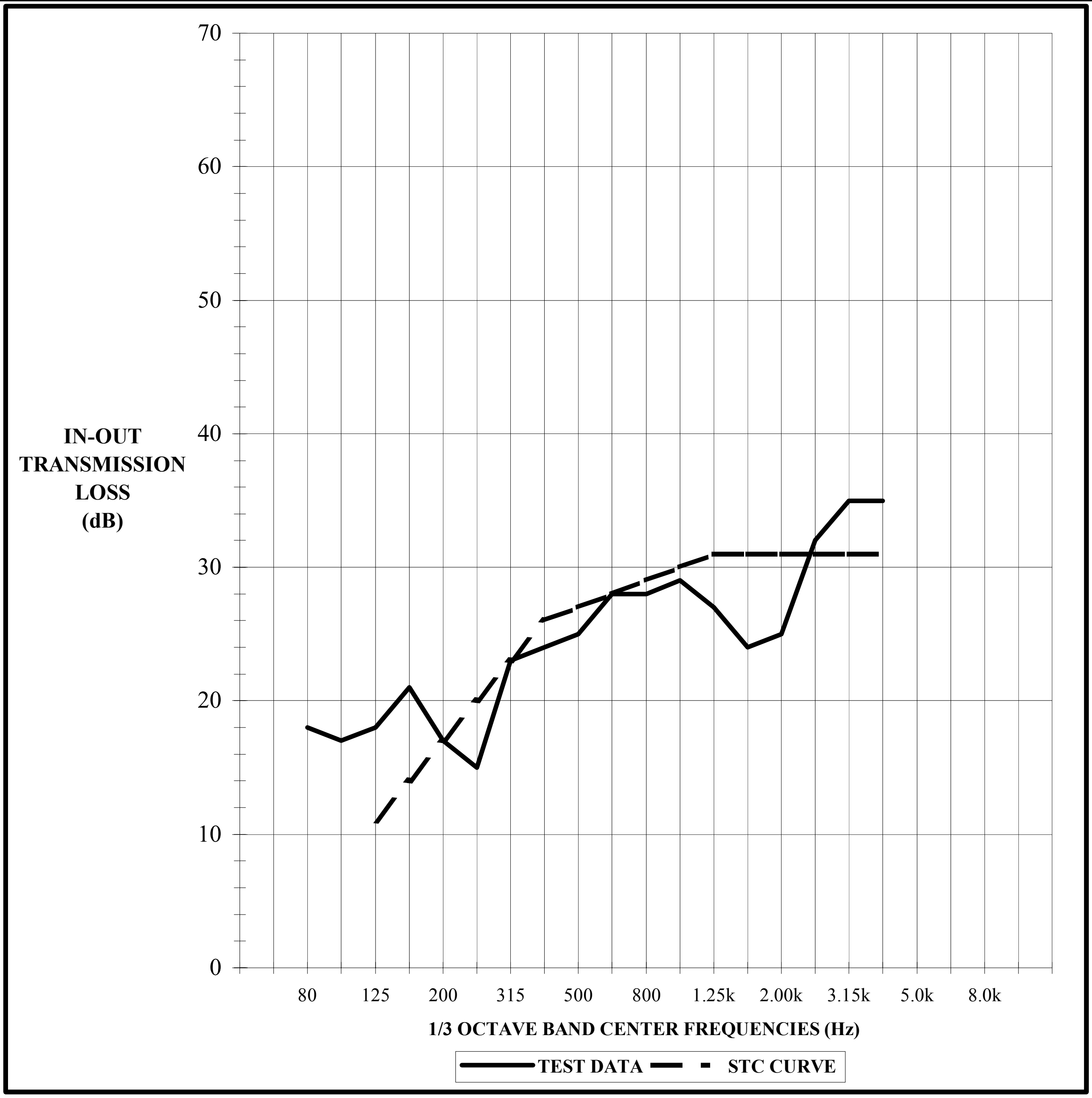
Frequency	80	100	125	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
In-Out TL	18	17	18	21	17	15	23	24	25	28	28	29	27	24	25	32	35	35
Deficiencies						5		2	2		1	1	4	7	6			

In-Out FSTC = 27	In-Out FOITC = 23	Total Deficiencies = 28	Maximum Deficiency = 7



Wood Core - Front Wall

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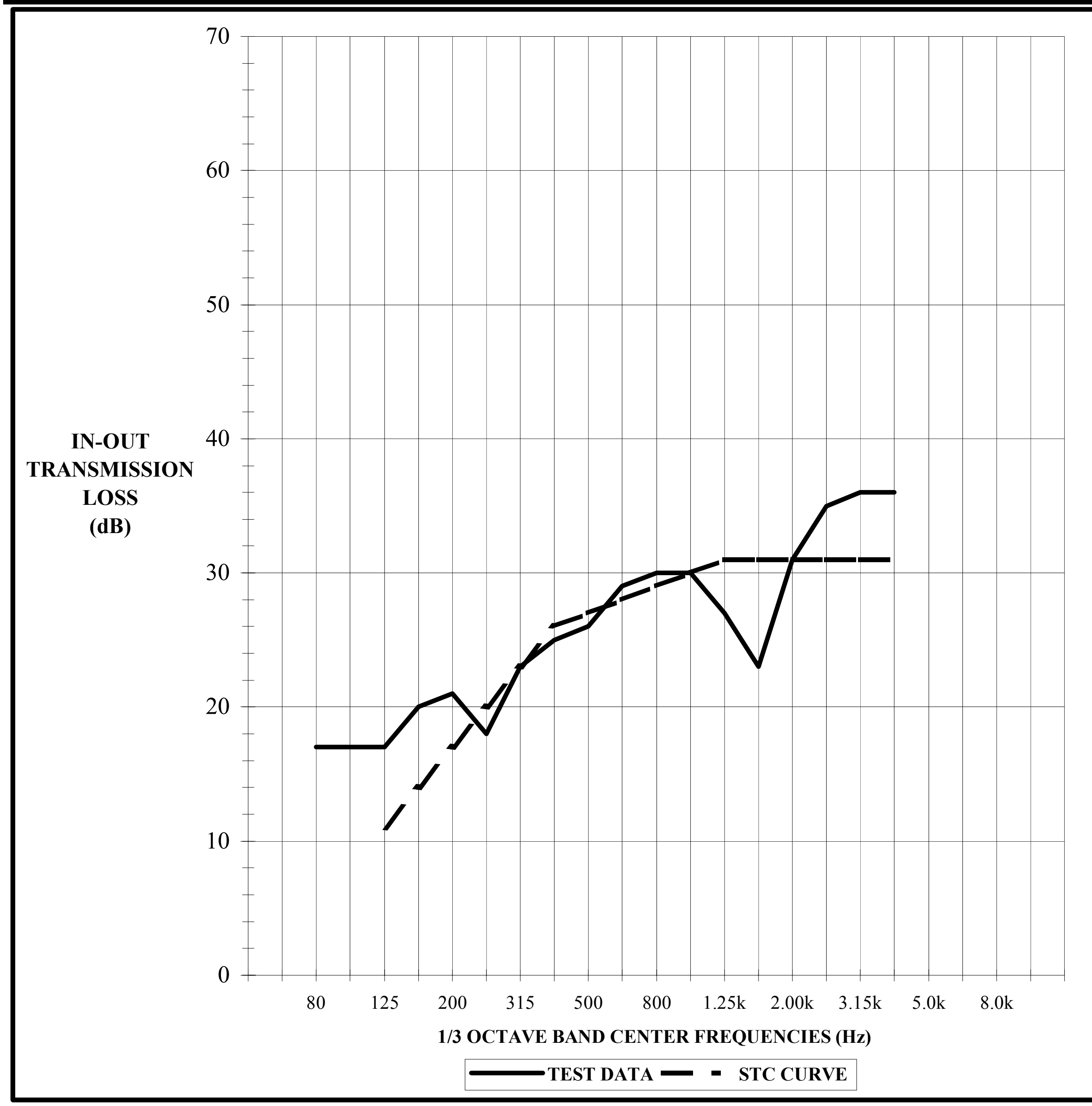
Frequency	80	100	125	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
In-Out TL	17	17	17	20	21	18	23	25	26	29	30	30	27	23	31	35	36	36
Deficiencies						2		1	1				4	8				

In-Out FSTC = 27	In-Out FOITC = 24	Total Deficiencies = 16	Maximum Deficiency = 8



Autoclaved Aerated Concrete Core - Front Wall

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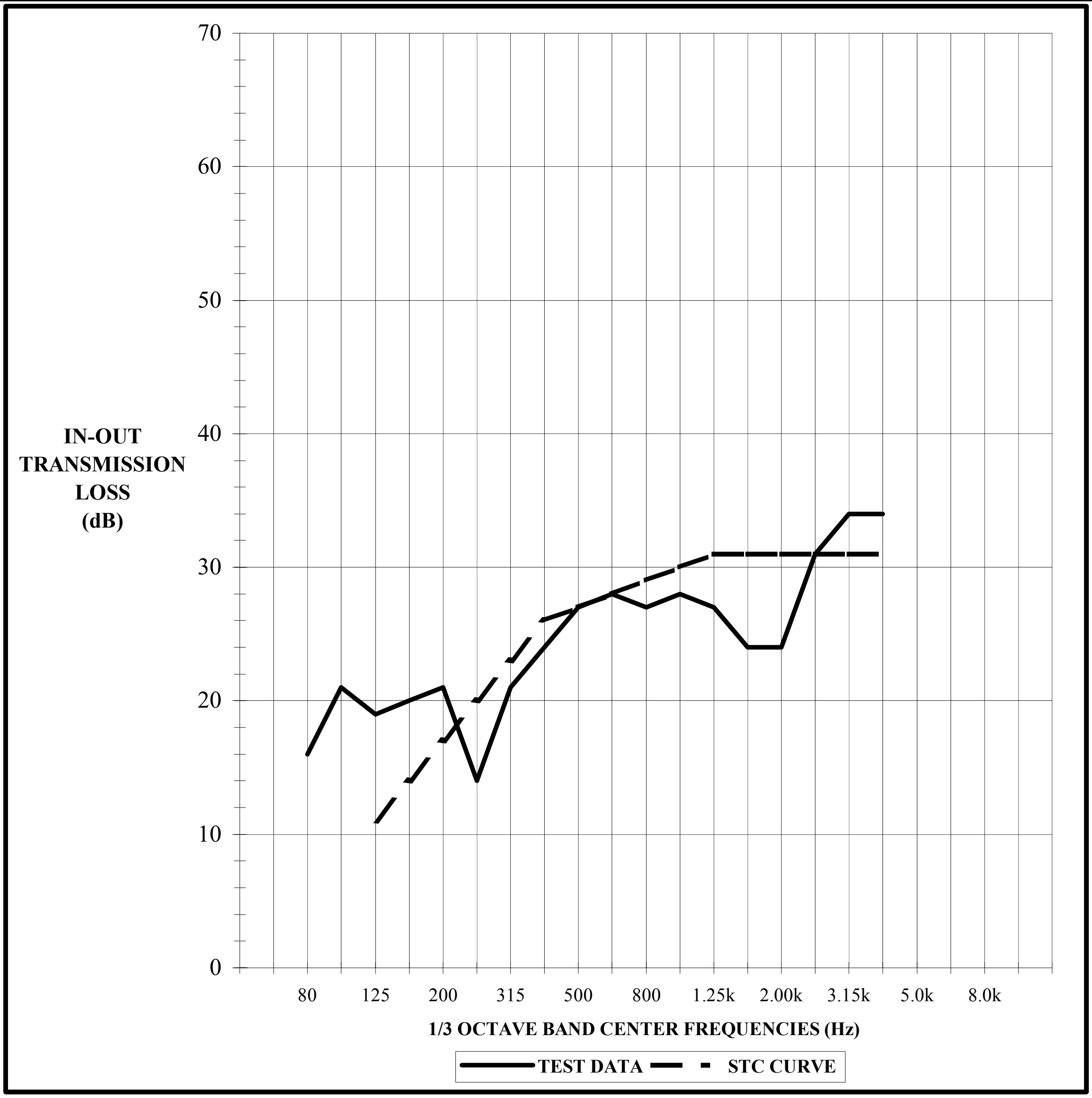
Frequency	80	100	125	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
In-Out TL	16	21	19	20	21	14	21	24	27	28	27	28	27	24	24	31	34	34
Deficiencies						6	2	2			2	2	4	7	7			

In-Out FSTC = 27	In-Out FOITC = 23	Total Deficiencies = 32	Maximum Deficiency = 7



Insulating Concrete Form Core - Front Wall

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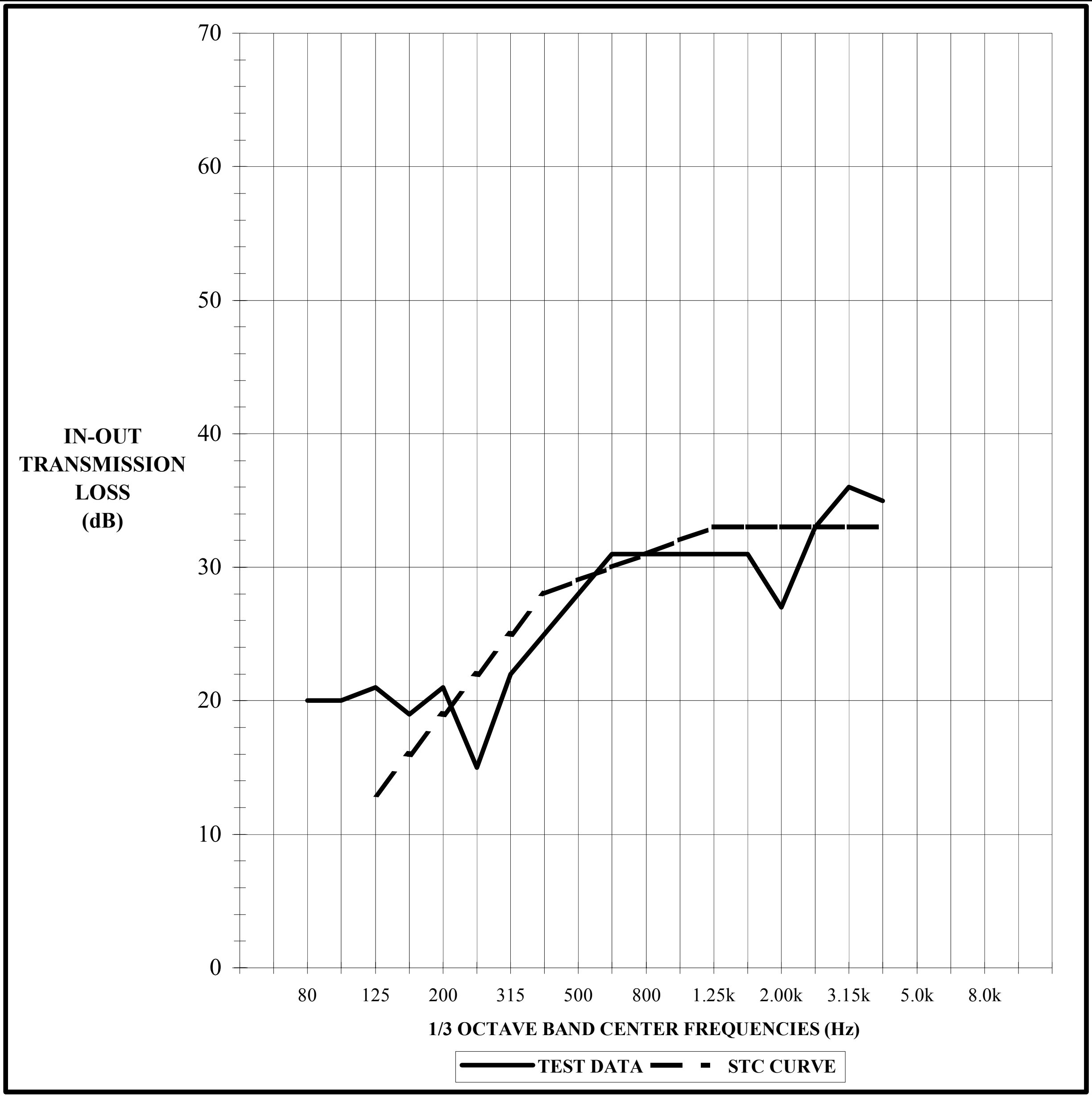
Frequency	80	100	125	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
In-Out TL	20	20	21	19	21	15	22	25	28	31	31	31	31	31	27	33	36	35
Deficiencies						7	3	3	1			1	2	2	6			

In-Out FSTC = 29	In-Out FOITC = 24	Total Deficiencies = 25	Maximum Deficiency = 7



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August 31, 2001

TESTS OF APPARENT TRANSMISSION LOSS OF PARTY WALLS AND INTERIOR WALLS OF DUPLEX APARTMENTS, LEXINGTON, NC

TESTS CONDUCTED: August 21, 2001

FOR: NAHB Research Center
400 Prince George's Boulevard
Upper Marlboro, Maryland 20774

INTRODUCTION

These tests measured the Apparent Transmission Loss, ATL, of four party walls and of two interior walls that contained doors. The test involves first producing sound in one room and measuring the difference in the average levels in both rooms separated by the partition. This is the Noise Reduction, NR. Reverberation is then measured in the receiver room and absorption in this room calculated. The Apparent Transmission Loss is then computed from the Noise Reduction, the absorption in the receiver room, and the dimensions of the partition.

The Transmission Loss, TL, is a property of a partition that indicates its ability to block the passage of sound at a particular frequency. The transmission loss varies with frequency. A solid heavy wall is typically better at blocking low-frequency sound, while a wall in layers can be better at higher frequencies even if lighter.

When measurements are made in the field rather than in a laboratory, the results are labeled Field Transmission Loss, FTL. To report results as field transmission loss, minimum test conditions related to the test room size and absorption must be met, and it must be proved that flanking by paths other than through the partition did not influence the results. When minimum test conditions are achieved but flanking is not evaluated or is clearly present, results can be reported as Minimum Field Transmission Loss. When minimum room requirements are not met, results must be reported as Apparent Transmission Loss even if flanking is shown not to be a problem. The test rooms were too small and too absorptive. No special steps were taken to prevent flanking that was clearly evident in some cases. Thus, the actual field transmission loss of the walls cannot be reported. The influence of flanking obviously varied and this will be discussed to the extent possible.

A single-number rating can be applied to the data to compare overall isolation between room and partition performance. The most appropriate single-number ratings are the Noise Isolation Class, NIC, for the overall noise reduction between rooms, and the Sound Transmission Class, STC, for partition transmission loss. These are based on the ability to block speech and speech-like sounds. When based on results tested in the field, the STC is properly labeled FSTC. Further, when test conditions do not meet minimum requirements, the results must be labeled as Apparent FSTC.

CONFORMANCE TO STANDARDS

Tests were conducted according to the ASTM Standard Test Method E 336-97 Measurement of Airborne Sound Insulation in Buildings with two exceptions. First, the sound absorption for the tests of party walls was measured in the source room rather than the receiving room. This is believed valid and justifiable since the two rooms were nominally identical. Second, only the NR is reported rather than the levels measured in each room. Reverberation measurements to evaluate the absorption in the test rooms were made according to an ASTM draft standard that provides more detailed guidance than is available in E 966. The NIC and Apparent FSTC values were computed according to ASTM E 413-87, Classification for Rating Sound Insulation.

DESCRIPTION OF TEST ENVIRONMENT AND PARTITIONS

The tests evaluated the isolation and apparent insulation between bedrooms of adjacent apartments in four duplexes and between bedrooms and living rooms within two apartments. Each wall was a different design. The bedroom walls had closets on each side that when closed could improve the isolation. Tests were conducted in all cases with the closets open and in three cases with the closets closed to evaluate this. (It was later realized that this also provided an evaluation of flanking.) The closets had two doors in each room comprising approximately 40% of the wall area. Thus, opening the doors essentially exposed the party wall to the rooms and added the closet volume to the room volume. For two of the apartment pairs, the floor was continuous under the party wall contributing to flanking between the rooms. The source and receiver room pairs were nominally identical for the individual party walls. However, each pair had slightly different dimensions and potentially different absorption characteristics due to differences in wall and floor construction. All rooms were carpeted.

The four party-wall constructions were as follows:

1. Double Wood Studs (Wood)- This wall about 9 inches thick used two sets of nominal 2 by 4 wood studs on separate base plates, fiberglass batts in each cavity space, and 5/8-inch Type X gypsum on each exterior surface. The 5/8-inch plywood floor was continuous under this wall, supported on wood joists parallel to the wall. The area under the wall within the crawl space was open. Above the gypsum ceiling that was broken at the partition, gypsum was applied to both sides of trusses up to the roof. The partition measured 12 feet 7 inches by 8 feet high. The third dimension of the room including the closet was 13 feet 9 inches.

2. Double Steel Stud Wall (Steel)- This wall about 9 inches thick used two sets of nominal 3.5 inch steel studs on separate base plates, fiberglass batts in each cavity space, and a layer of 5/8-inch Type X gypsum on each exterior surface. The ¾-inch plywood floor was continuous under this wall, supported on wood I-joists parallel to the wall. There was an approximate two-inch gap between the floor and a continuous eight-inch masonry wall in the crawl space between the two units. Above the gypsum ceiling that was broken at the partition, gypsum was applied to both sides of trusses up to the roof. The partition measured 12 feet 7 inches by 8 feet 3 inches high. The third dimension of the room was 13 feet 4 inches including the closet and 11 feet without it.

3. Thermosteel Panels (TS)- This wall about 6.75 inches thick used a 5.5 inch panel of polystyrene with embedded steel studs clad with 5/8-inch Type X gypsum on each side. The wall rested on a masonry foundation that divided the floor between the two rooms and closed the gap below the floor. Above the gypsum ceiling that was broken at the partition, gypsum was applied to both sides of trusses up to the roof. The partition measured 12 feet 7 inches by 8 feet high. The third dimension of the room was 13 feet 9 inches including the closet and 11 feet 4 inches without it.

4. Insulating Concrete Forms (ICF)- This wall about 10 inches thick used polystyrene forms to hold a solid 4-inch normal-weight concrete core. The polystyrene was 2 3/8 inch thick on each side of the concrete, and 5/8-inch Type X gypsum was attached directly to each side. The wall polystyrene and concrete extended from the ground to the ceiling, dividing the floor between the two rooms and closing the gap below the floor. Above the gypsum ceiling that was broken at the partition, gypsum was applied to both sides of trusses up to the roof. The partition measured 12 feet 2 inches by 8 feet high. The third dimension of the room was 13 feet 6 inches including the closet and 11 feet 1 inches without it.

The walls between the living rooms and bedrooms differed only in the studs with wood in one case and light gauge steel in the other. Each had 1/2-inch Type X gypsum on each side and no batts in the cavity. The exposed wall between the two rooms was about 18 feet by 8 feet. The major section was about 13 feet without any openings. A five-foot section containing a 32-inch by 7-foot door was perpendicular to that. This section was exposed to a central area of the apartment at the interior corner of the living room. This central area connecting rooms was fully exposed to the living room. The floor was continuous under the walls. The doors were hollow, six-panel pressed medium density fiberboard with no seals. The living room used as the source room had a volume of approximately 2400 cubic feet including the central area connecting rooms.

Note that the living room does not meet minimum volume requirements for measurements below 100 Hz and the bedroom does not meet those requirements for measurements below 160 Hz. All room surfaces were hard except carpet on the floor. Reverberation measurements indicated the rooms had excessive absorption for measurement of transmission loss at low to low-mid frequencies up to about 630 Hz.

MEASUREMENT EQUIPMENT AND METHODS

The sound source was a custom speaker system provided by Electroacoustic Development Company of Lexington. The lower frequencies were produced by a 15-inch woofer in a compound loaded enclosure. The higher frequencies were produced by 500 Hz constant directivity horns (one used for reverberation measurements and two used for some tests of walls with higher performance). The system was bi amplified using a two-channel two-kilowatt amplifier with an electronic crossover. The signal for the outdoor sound was a tape of broadband pink noise on a Sony TC-D5M cassette player. The signal for the reverberation measurements was provided by the measurement instrument. An equalizer was used to concentrate the sound in the frequency range of interest and to boost the high-frequency output to adequate levels during the blockage measurements. A flatter spectrum concentrated in the range of interest was used for the reverberation measurements. The loudspeakers were faced into a corner of the room opposite the walls being evaluated.

The sound levels were measured simultaneously in third-octaves with a Larson-Davis 2800 Precision Real-Time Sound Analyzer equipped with a Larson-Davis 2541 microphone. Each measurement of steady sound was averaged over a period of at least 30 seconds as the microphone was moved about the measurement space. The instrument stored the levels to the nearest tenth of a decibel. Reverberation decays were recorded in increments of .025 seconds over a one-second period after the signal was stopped. Sensitivity stability of the instrument was checked before and after each measurement using a Bruel & Kjaer 4231 Acoustical Calibrator.

Background sound was measured in the rooms using the same range settings as used for sound measurements. Third-octave sound levels in the receiving room with the loudspeaker operating in the source rooms were always at least 10 dB greater than the background levels. Background levels during the reverberation measurements were always at least 40 dB and usually more than 50 dB below the source level in each third octave.

RESULTS OF MEASUREMENTS

Tabulated below is a summary of the results based on the single-number ratings NIC and Apparent FSTC. The NIC is based on the Noise Reduction or simple measurement of difference in sound level between rooms and is influenced by the absorption in the receiving room. The Apparent FSTC is based on the Apparent Transmission Loss computed using absorption measurements to provide a result not influenced by room absorption. The following pages show the NR, ATL, and reverberation time results of each specific test for each frequency band in a table, and provide a graph of the ATL results. The NIC and Apparent FSTC are computed by plotting the NR or ATL lowering the reference curve shown on the graphs until the difference between the data and reference curve does not exceed 8 at any frequency, and the sum of the differences at all frequencies (called deficiencies) does not exceed 32. The deficiencies from the contour curve used to establish the Apparent FSTC rating are shown.

Basic Construction	NIC	Apparent FSTC
Living Room-Bedroom		
Wood Stud (closets open)	26	28
Steel Stud (closets open)	26	28
Steel Stud (closets closed)	25	28

Party Walls	Closets Open	Closets Closed	Closets Open	Closets Closed
Thermosteel	38	54	36	54
Wood Stud	53		52	
Steel Stud (AAC Bldg)	50	53	49	53
ICF	53	61	51	62

Wood Stud LR-BR Wall With Closets Open

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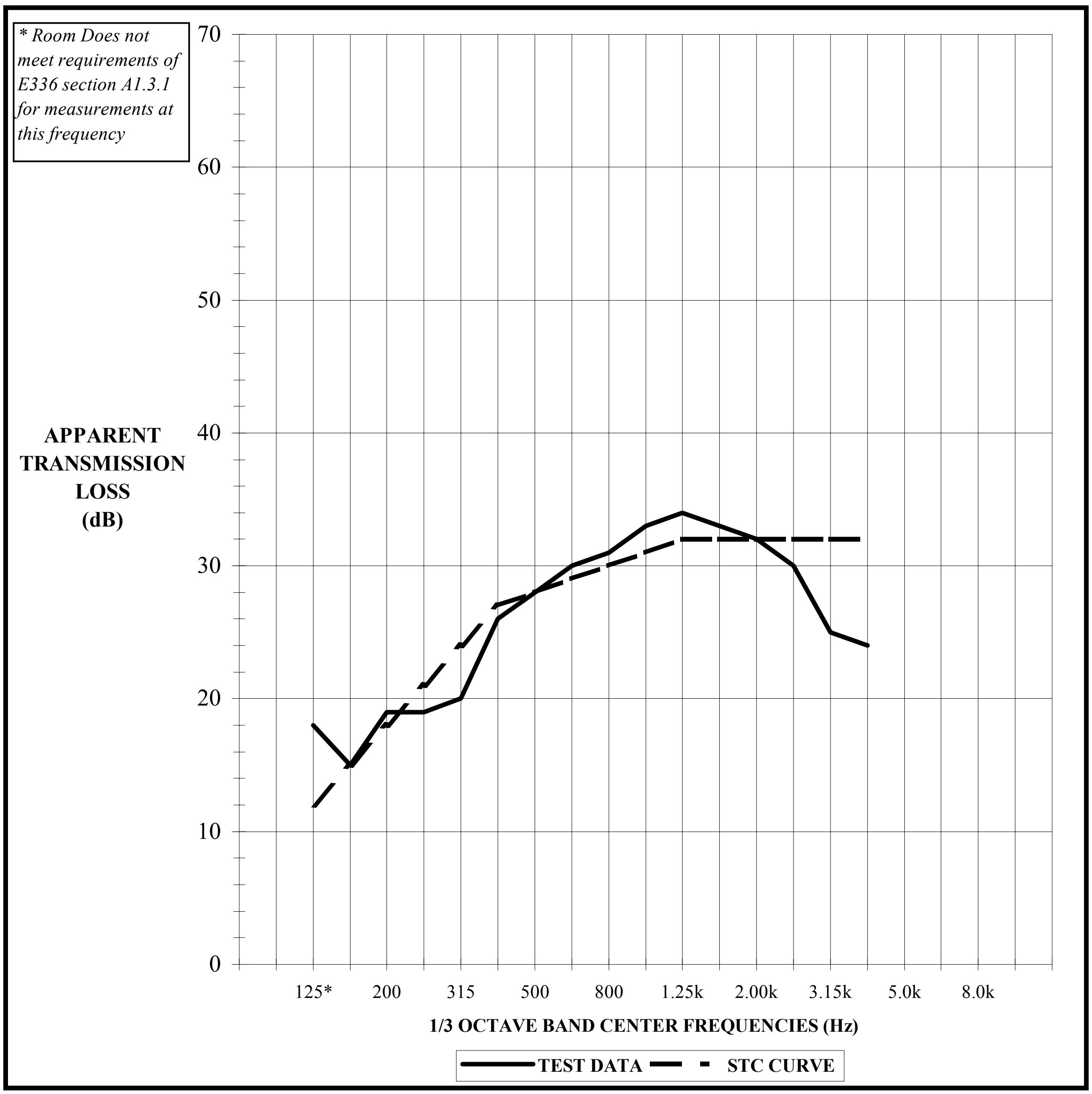
Frequency	125*	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
NR	19	14	19	20	21	26	28	31	31	32	32	31	30	29	24	22
RT	0.45	0.53	0.50	0.45	0.42	0.42	0.53	0.55	0.53	0.58	0.70	0.73	0.75	0.70	0.69	0.75
ATL	18	15	19	19	20	26	28	30	31	33	34	33	32	30	25	24
Deficiencies				2	4	1								2	7	8

Apparent FSTC = 28	NIC = 26	Total Deficiencies = 24	Maximum Deficiency = 8



Steel Stud LR-BR Wall With Closets Open

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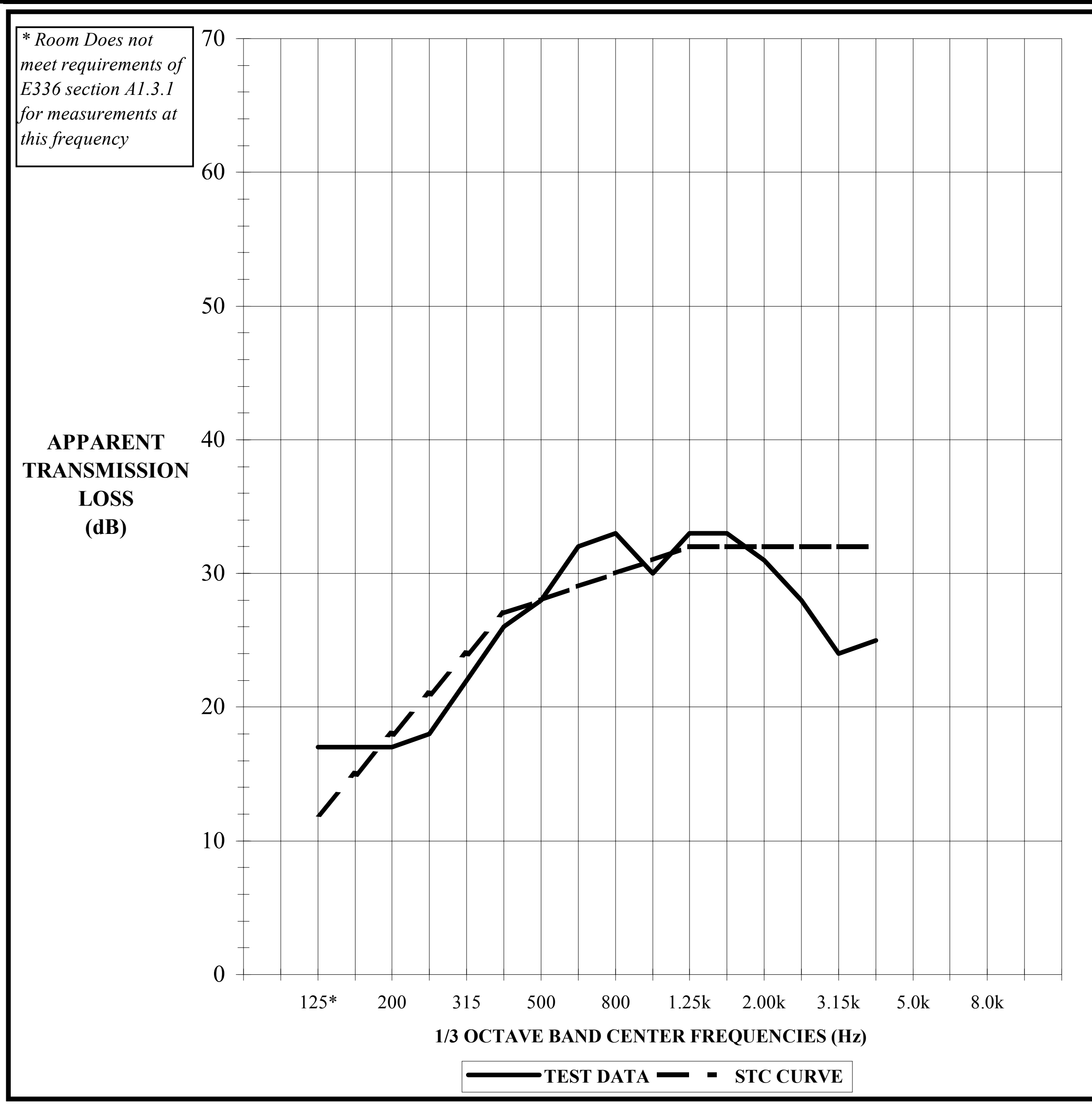
Frequency	125*	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
NR	17	17	16	17	22	27	28	32	32	29	32	31	29	25	22	22
RT	0.73	0.53	0.58	0.50	0.49	0.43	0.40	0.53	0.53	0.65	0.68	0.73	0.74	0.66	0.70	0.74
ATL	17	17	17	18	22	26	28	32	33	30	33	33	31	28	24	25
Deficiencies			1	3	2	1				1			1	4	8	7

Apparent FSTC = 28	NIC = 26	Total Deficiencies = 28	Maximum Deficiency = 8



Steel Stud LR-BR Wall With Closets Closed

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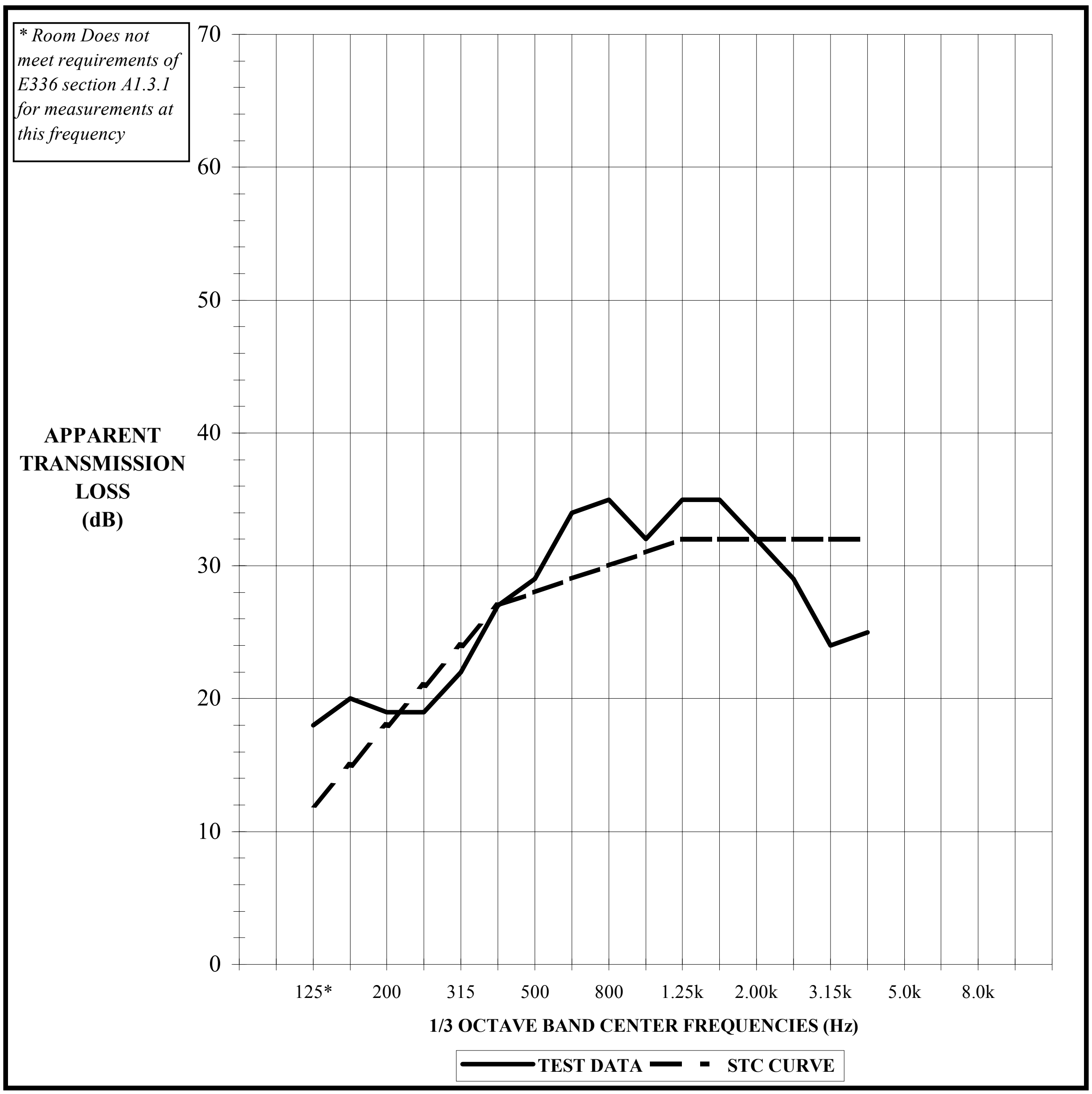
Frequency	125*	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
NR	16	18	17	18	21	26	28	31	32	28	31	31	28	25	21	22
RT	0.65	0.63	0.60	0.53	0.52	0.45	0.46	0.85	0.90	0.85	0.93	0.98	0.92	0.73	0.74	0.80
ATL	18	20	19	19	22	27	29	34	35	32	35	35	32	29	24	25
Deficiencies				2	2									3	8	7

Apparent FSTC = 28	NIC = 25	Total Deficiencies = 22	Maximum Deficiency = 8



Thermasteel Party Wall With Closets Open

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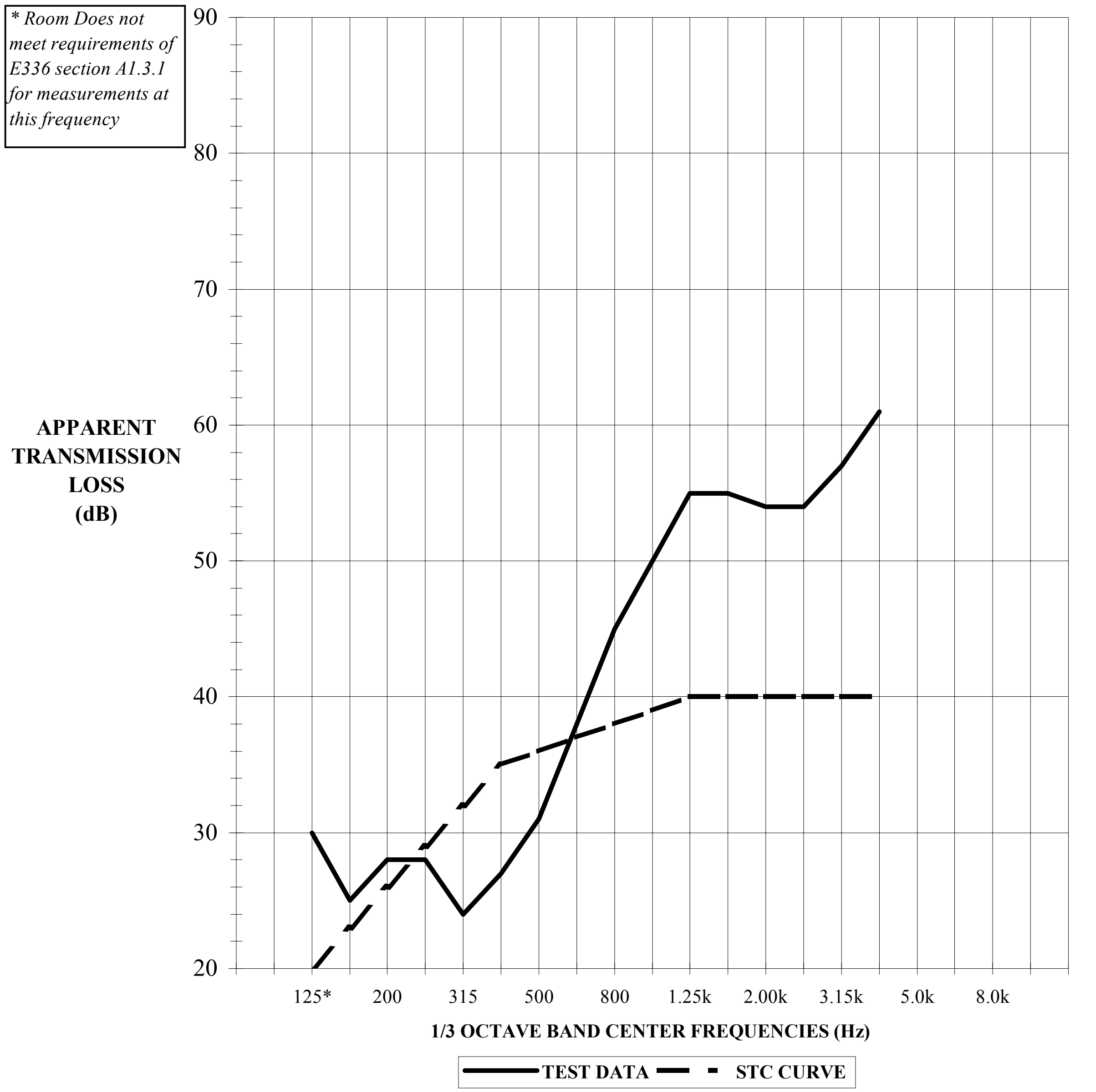
Frequency	125*	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
NR	31	26	28	29	26	30	34	39	46	50	55	55	53	53	56	60
RT	0.50	0.53	0.63	0.53	0.48	0.38	0.40	0.52	0.55	0.64	0.68	0.78	0.80	0.78	0.75	0.78
ATL	30	25	28	28	24	27	31	38	45	50	55	55	54	54	57	61
Deficiencies				1	8	8	5									

Apparent FSTC = 36	NIC = 38	Total Deficiencies = 22	Maximum Deficiency = 8

** Room Does not meet requirements of E336 section A1.3.1 for measurements at this frequency*



Thermasteel Party Wall With Closets Closed
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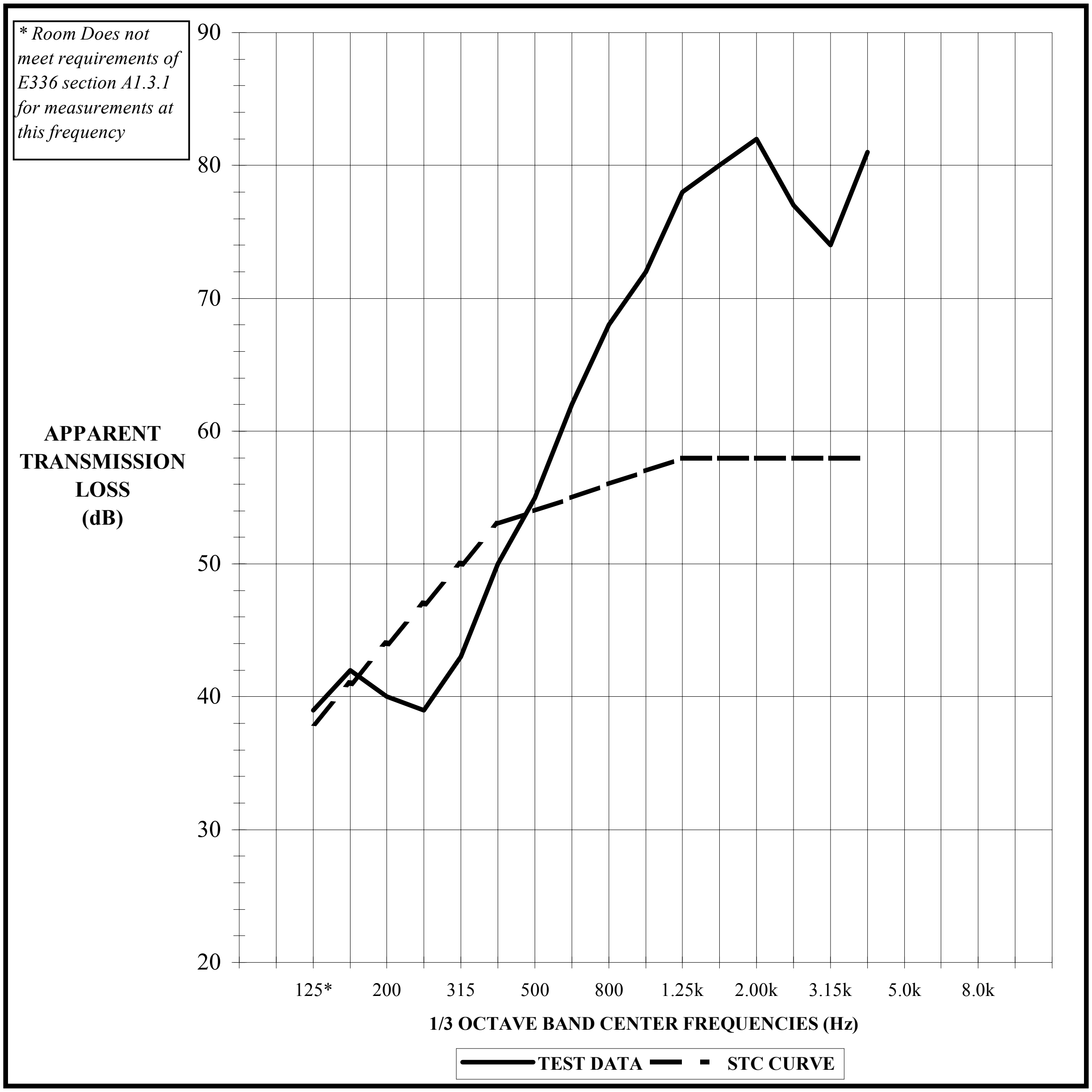
Frequency	125*	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
NR	40	41	40	39	43	51	55	61	66	70	75	78	80	75	73	79
RT	0.53	0.66	0.55	0.55	0.49	0.48	0.55	0.78	0.80	1.03	1.03	1.03	0.96	0.88	0.78	0.88
ATL	39	42	40	39	43	50	55	62	68	72	78	80	82	77	74	81
Deficiencies			4	8	7	3										

Apparent FSTC = 54	NIC = 54	Total Deficiencies = 22	Maximum Deficiency = 8



Wood Stud Party Wall With Closets Open

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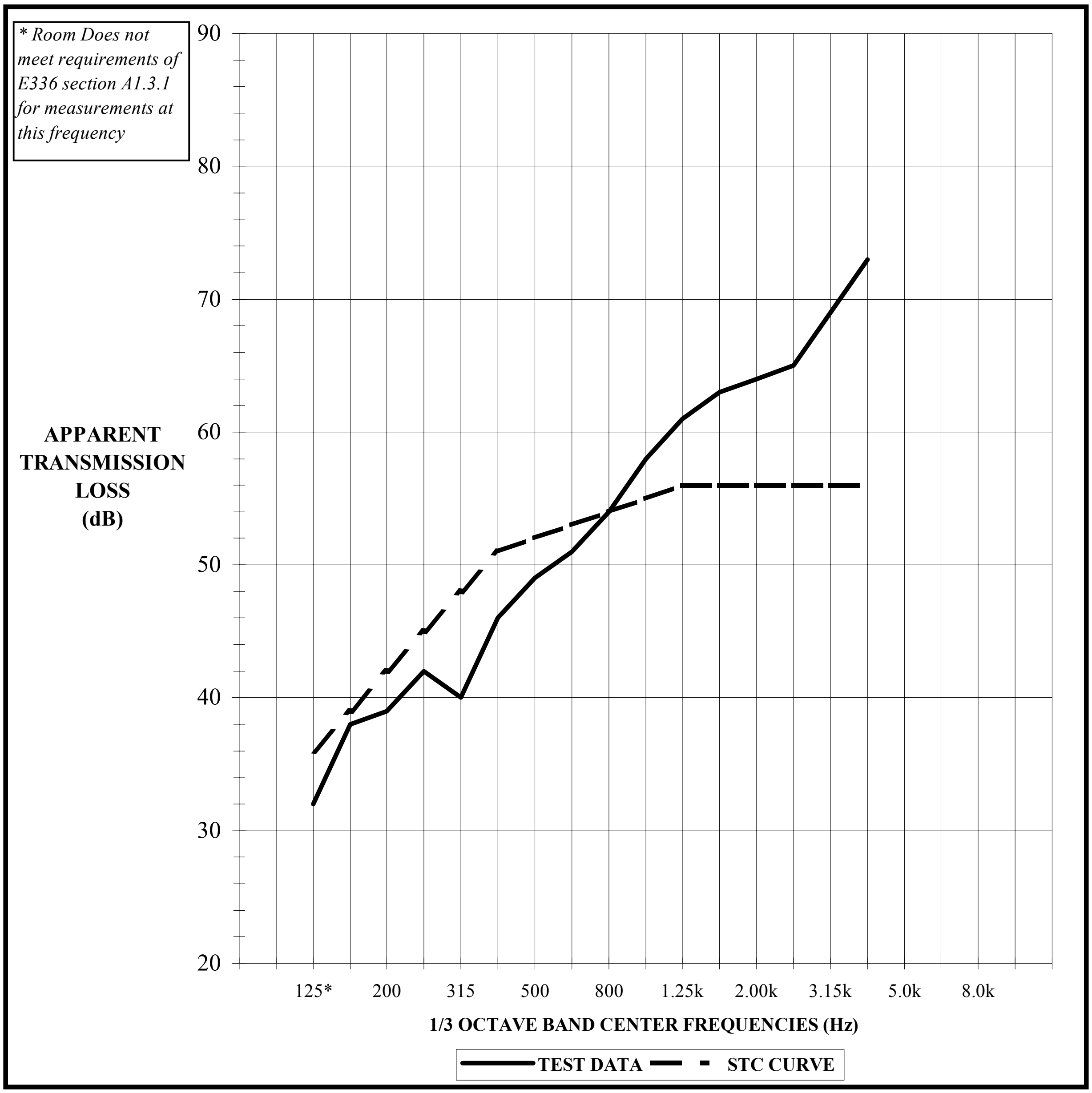
Frequency	125*	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
NR	34	39	41	44	42	48	50	52	55	58	61	63	63	65	69	73
RT	0.45	0.53	0.50	0.45	0.42	0.42	0.53	0.55	0.53	0.58	0.70	0.73	0.75	0.70	0.69	0.75
ATL	32	38	39	42	40	46	49	51	54	58	61	63	64	65	69	73
Deficiencies	4	1	3	3	8	5	3	2								

Apparent FSTC = 52	NIC = 53	Total Deficiencies = 29	Maximum Deficiency = 8



Steel Stud Party Wall With Closets Open (AAC Building)

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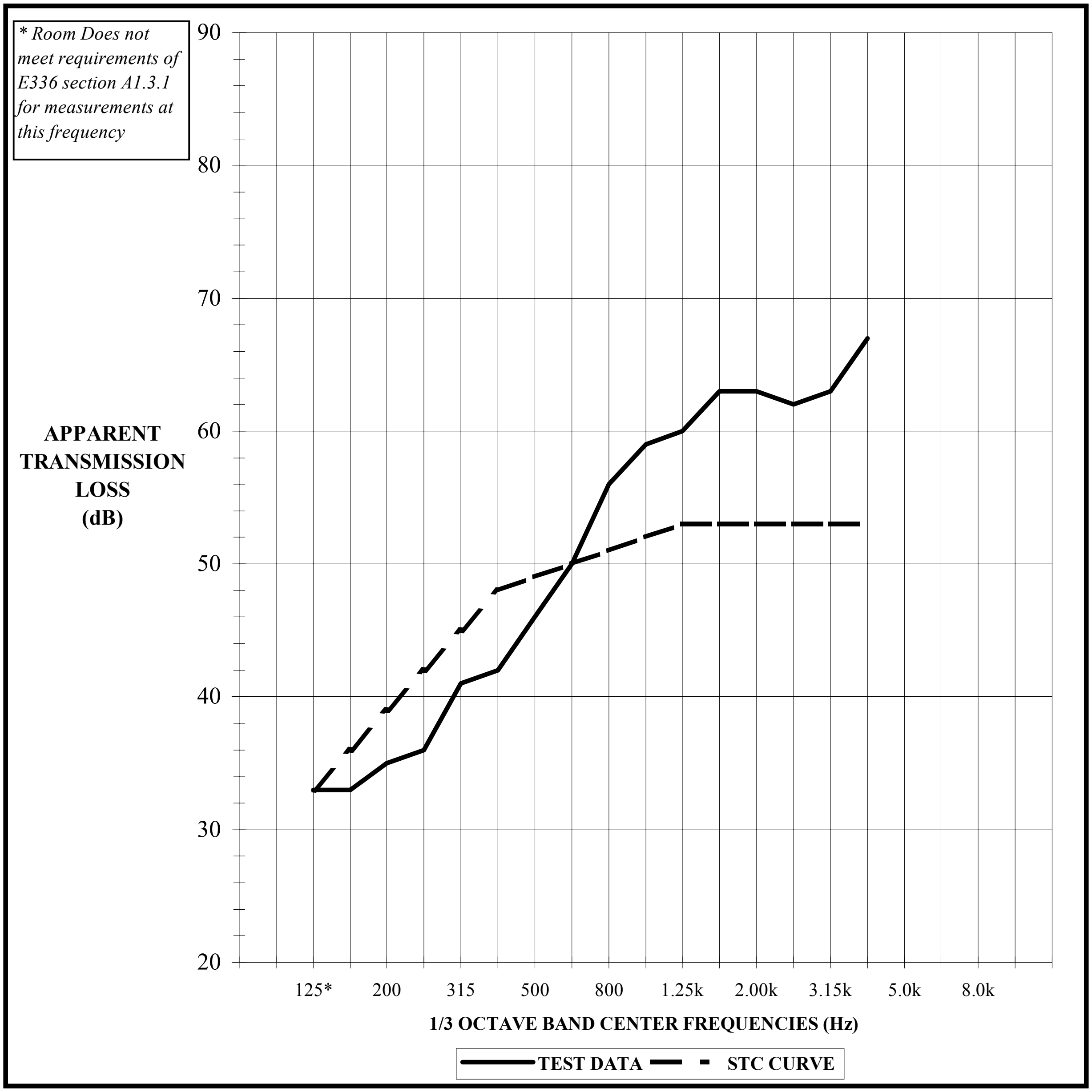
Frequency	125*	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
NR	33	34	35	37	42	44	48	51	57	59	60	62	63	62	63	66
RT	0.73	0.53	0.58	0.50	0.49	0.43	0.40	0.53	0.53	0.65	0.68	0.73	0.74	0.66	0.70	0.74
ATL	33	33	35	36	41	42	46	50	56	59	60	63	63	62	63	67
Deficiencies		3	4	6	4	6	3									

Apparent FSTC = 49	NIC = 50	Total Deficiencies = 26	Maximum Deficiency = 6



Steel Stud Party Wall With Closets Closed (AAC Building)

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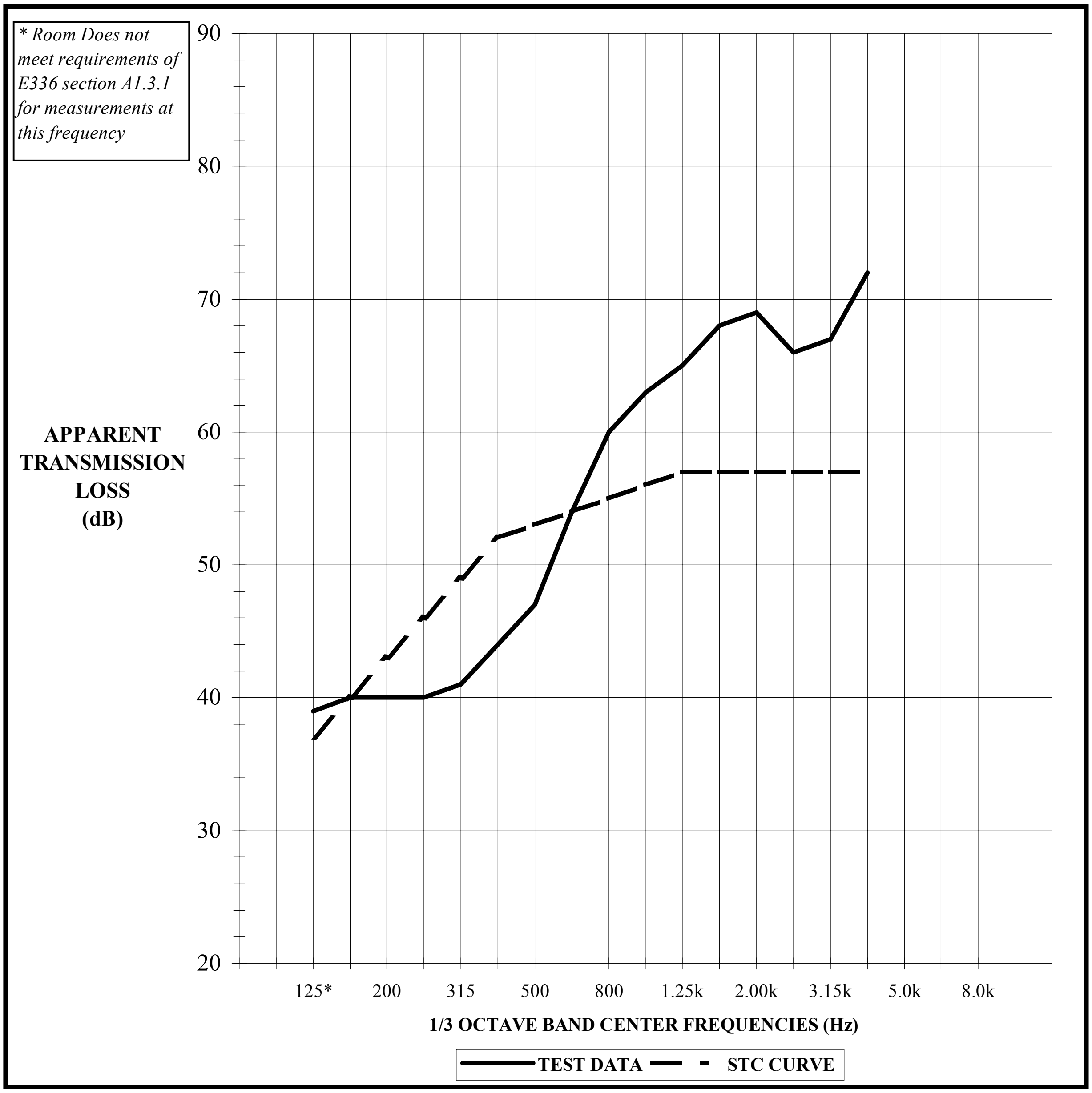
Frequency	125*	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
NR	38	40	40	40	41	45	48	52	58	61	63	65	66	65	66	70
RT	0.65	0.63	0.60	0.53	0.52	0.45	0.46	0.85	0.90	0.85	0.93	0.98	0.92	0.73	0.74	0.80
ATL	39	40	40	40	41	44	47	54	60	63	65	68	69	66	67	72
Deficiencies			3	6	8	8	6									

Apparent FSTC = 53	NIC = 53	Total Deficiencies = 31	Maximum Deficiency = 8



ICF Party Wall With Closets Open

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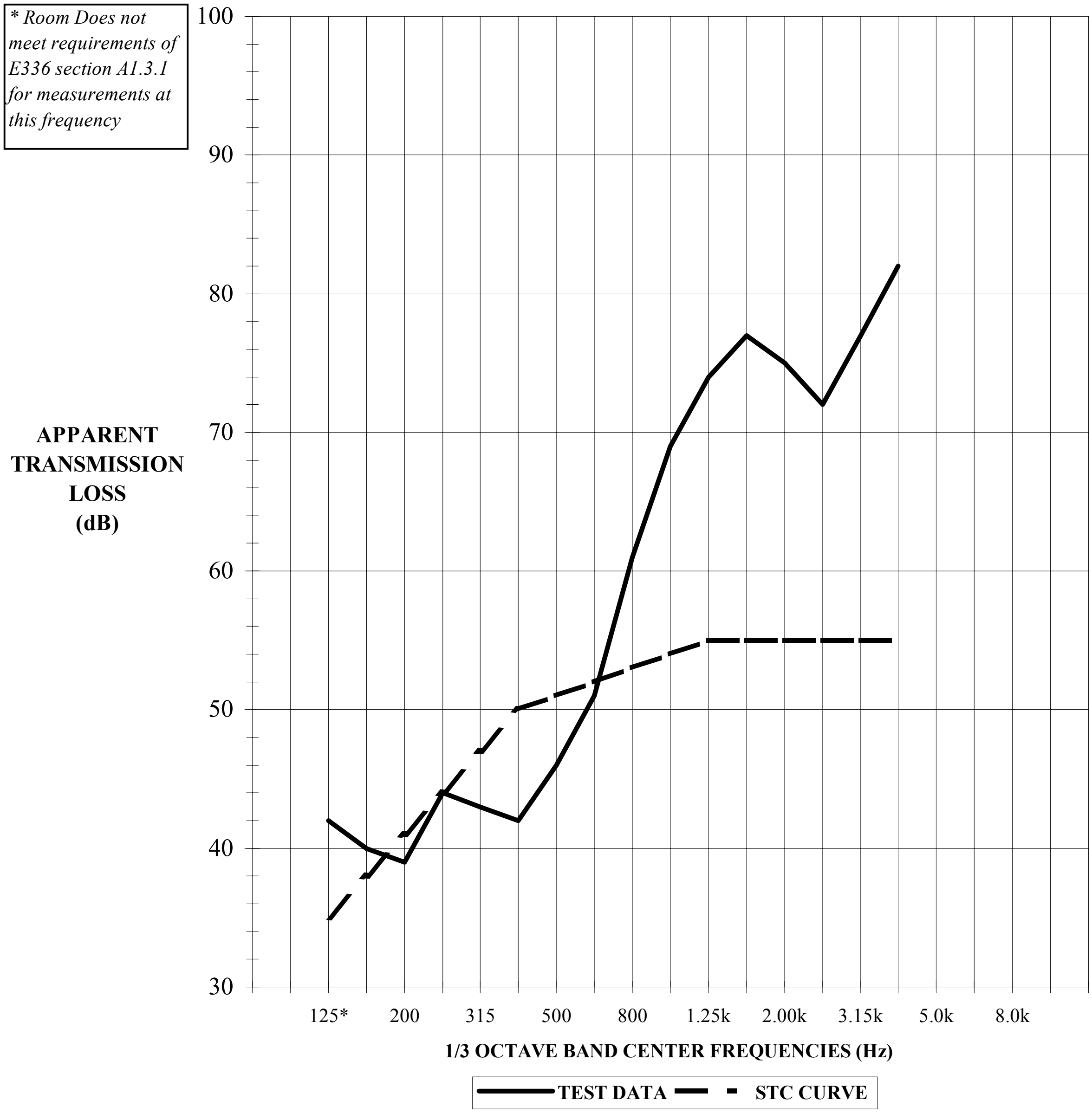
Frequency	125*	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
NR	42	40	40	44	44	44	48	52	62	69	74	77	75	72	77	81
RT	0.76	0.60	0.48	0.55	0.48	0.43	0.44	0.45	0.53	0.60	0.69	0.71	0.70	0.69	0.68	0.72
ATL	42	40	39	44	43	42	46	51	61	69	74	77	75	72	77	82
Deficiencies			2		4	8	5	1								

Apparent FSTC = 51	NIC = 53	Total Deficiencies = 20	Maximum Deficiency = 8

** Room Does not meet requirements of E336 section A1.3.1 for measurements at this frequency*



ICF Party Wall With Closets Closed
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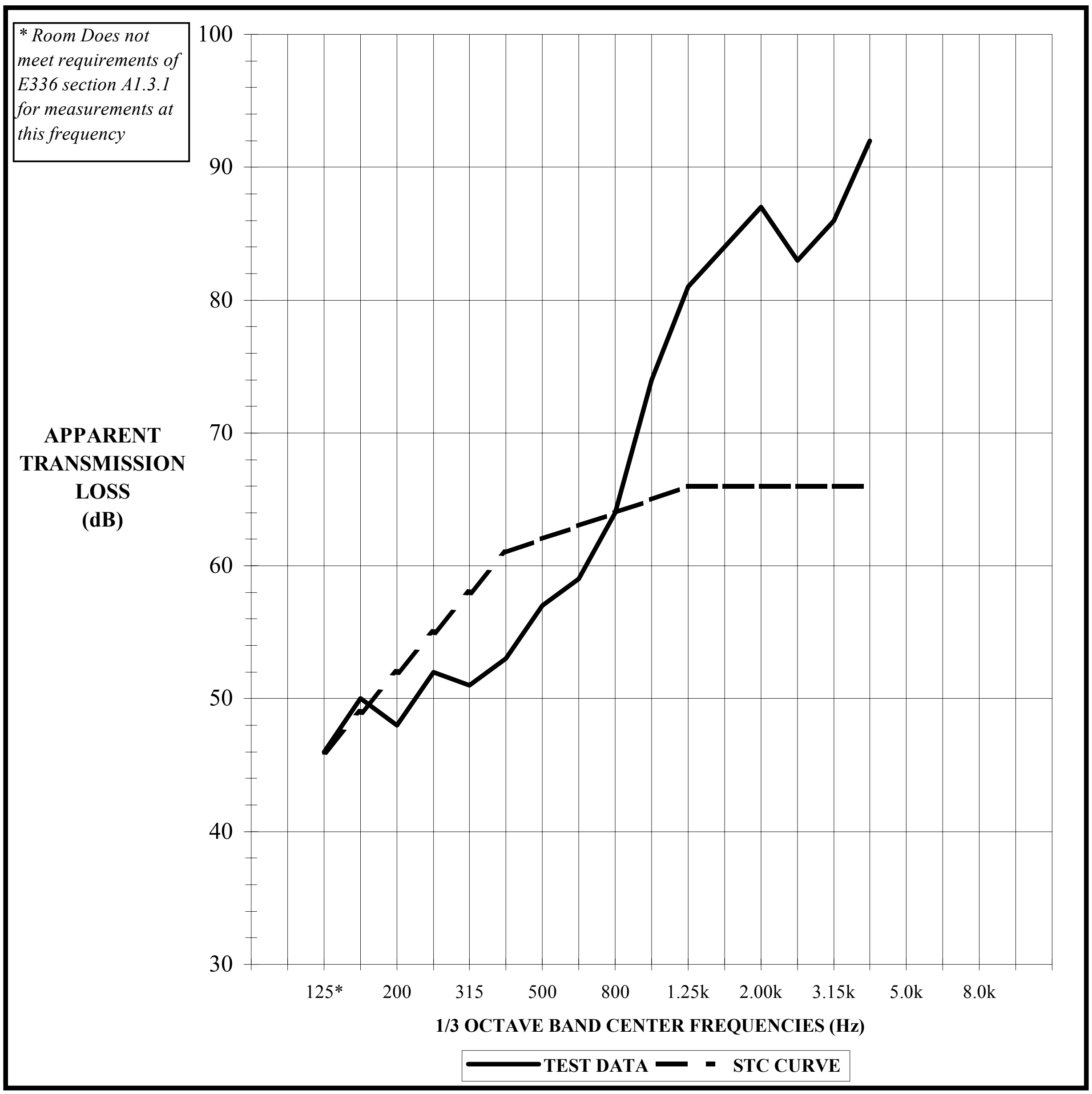
Frequency	125*	160	200	250	315	400	500	630	800	1.00k	1.25k	1.60k	2.00k	2.50k	3.15k	4.00k
NR	46	49	47	52	51	54	57	58	62	72	79	81	85	82	85	91
RT	0.58	0.65	0.75	0.63	0.49	0.48	0.53	0.65	0.73	0.89	0.92	0.88	0.83	0.76	0.65	0.77
ATL	46	50	48	52	51	53	57	59	64	74	81	84	87	83	86	92
Deficiencies			4	3	7	8	5	4								

Apparent FSTC = 62	NIC = 61	Total Deficiencies = 31	Maximum Deficiency = 8



DISCUSSION OF RESULTS

The interior walls between living room and bedroom differed only in the type of stud, and each had a similar door that was the controlling factor in the sound blockage. The living room was the source room. The measurement in steel-stud bedroom was repeated with the closets open and closed. With the closets closed, the sound level in the bedroom increased slightly because of reduced room absorption. Thus, the NIC dropped one dB. When this was accounted for in the calculation of the apparent transmission loss, the results are the same for all tests. Note that the controlling frequency for the ratings is the 4000 Hz octave. This is probably related to the coincidence frequency of the door that is above 4000 Hz.

The Thermosteel party wall is clearly the weakest of those tested. The performance is close to what would be expected based on its construction. The weak performance is demonstrated as being due to the wall rather than flanking by the results with the closets closed. This produced a major improvement in blockage. This would probably improve further with clothes in the closet. The isolation between these bedrooms should be adequate with the closets closed. Problems could occur if the closets are left open.

The other party walls also performed much better even with closets open. The isolation with the ICF wall improved about 10 dB when the closets were closed. This shows that flanking was not a problem for the test of the ICF wall, though the results are not quite as good as would be theoretically expected in a laboratory test. Comparing the wood and steel stud performance with closets open, the wood stud construction appeared to perform better though the two walls would be expected to perform similarly. The comparison of results with closets open and closed for the steel stud wall shows that flanking was significant but not the only cause of the apparent difference between the two walls. Some flanking is to be expected with the continuous wood floor under the wall. The major difference is in the 160-250 Hz range.

The reverberation decay curves at frequencies of 630 Hz and less were sometimes very nonlinear. Interpretation of these curves for measurement of reverberation and absorption is not an exact science though new guidelines in a proposed standard reduce the variation. Different data interpretations could sometimes change the transmission loss at a given frequency by one decibel. However, data were reviewed carefully at frequencies that could affect the single-number ratings and no cases were found where these ratings would be changed.

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