Fan Noise 2003

IMPROVEMENT OF THROUGH-WALL AIR CONDITIONER TRANSMISSION LOSS

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SUMMARY

Packaged Terminal Air Conditioners are often called "through-wall" air conditioners since they are usually installed in a sleeve passing through the exterior building wall. While through-wall air conditioners generate their own noise with internal fans and compressors, they also tend to allow unwanted outside noise to pass through the unit to interior spaces. This paper compares field-tested sound data for fan and compressor noise of six different models and describes how a sound baffle was designed and successfully implemented at a hotel, using standard building materials to reduce noise transmission through a through-wall air conditioner.

INTRODUCTION

A large hotel chain planned a new building for a site between an active railroad and a 6-lane freeway. Through-wall air conditioning units would be installed in each hotel room, through sleeves in exterior walls. Noise concerns included air conditioner noise and intrusions of truck and train noise through exterior walls and windows into guest rooms. Fans, compressors, and airflow through ducts and grilles in air conditioners would generate noise when operating, and the through-wall penetrations would allow unwanted noise outdoors to pass through the equipment to interior spaces.

The hotel owner retained acoustical consultants to provide sound control recommendations for exterior walls and air conditioners. Exterior wall designs were improved and exterior windows would include storm windows to help reduce outdoor-indoor sound transmission. Therefore, the air conditioner was expected to become the primary path for outdoor-indoor noise transmission. Manufacturer's noise data for proposed air conditioner selections were compared with objective criteria and with field noise data from six other air conditioner models, previously evaluated at an existing hotel.

To provide necessary attenuation of intrusive railway noise in rooms facing the railway, noise baffles were designed and installed at the exterior faces of air conditioners. This case study explores the effectiveness of the equipment selections and noise baffles in terms of user satisfaction and acoustical performance measured on-site.

ALLOWABLE CRITERIA

Indoor occupants may tolerate transient intrusive noise levels up to 10 dB greater than continuous ambient noise levels.[1] With ambient noise levels in hotel rooms expected between 35 and 40 dB(A), allowable transient intrusive noise could be tolerated between 45 and 50 dB(A). Transient noise from passing trains, combined with transient noise from louder truck traffic on the highway, was measured on-site and could be expected to range between 80 and 85 dB(A) at a distance of 1 m (3 ft) from hotel façade, facing the railroad. Therefore, the exterior wall, including windows and through-wall air conditioners, would need to provide at least 35 dB(A) noise reduction.

ASHRAE guidelines for mechanical system noise in hotel rooms suggest a balanced noise spectrum between RC 25 and 35 (32-37 dB(A)).[2] However, balanced (non-tonal) air conditioner noise could be allowed between RC 35 and 50 (42-57 dB(A)), since room occupants would be able to control the operation of the equipment in their own rooms. However, fan/compressor noise would not be appropriate for low frequency noise masking.

OBJECTIVES AND STRATEGY

The primary acoustical objectives were to provide air conditioners having a balanced noise spectrum and to develop additional noise control for sound transmission through the equipment in order to be compatible with noise reduction expected of the upgraded exterior wall and window components. The equipment selections and additional noise mitigation measures needed to meet budget constraints and match with the aesthetics and appearance of a standard hotel building design, which was predetermined.

Equipment Noise

In a previous evaluation, equipment noise levels of six different units, from five different manufacturers, were sound tested in nearly identical hotel suites. Noise measurements were conducted using a Larson-Davis 800 spectrum analyzer with precision microphone and pre-amp (ANSI Type I, ± 1 dB).[3] Indoor air conditioner noise was measured approximately 1.3 m (4 ft) from the interior face grille of each unit, with fan and compressors on and again with fan only (compressors off).

Measurement results indicated a relatively narrow range of equipment noise levels and spectra, shown in Table 1 below, ranging from 52 to 57 dB(A) (61 to 67 dBC) on high-cool setting, with compressors on. Noise spectra for most units were very unbalanced, with tonal components, where there are sideband differentials of 6 dB or more between 1/3 octaves,[4] most common in the 63 Hz 1/3 octave band.

Equipment noise with compressors off, with only the fan running, was also typically unbalanced, but compressors added significantly to equipment tonality and noise level. This is illustrated in Figure 1, which shows the average relative additional sound level produced by compressors above fan noise levels, with peaks at the 63 Hz and 500 Hz octave bands.

Equipment would be selected to have low or moderate compressor noise, if possible. Manufacturers' published ratings for equipment sound in terms of dB(A), Bels, Sones, or other single-number sound level rating, would be used as a general indicator only, since these values would not indicate spectral or tonal characteristics. 1/3-octave sound data is not usually available from manufacturers for such equipment.

Table 1: 1/3-octave band sound pressure levels of tested units

(Hz)	Model A	Model B	Model C	Model D	Model E	Model F	Model G
50	58	57	65	59	57	55	60
63	55	64	56	66	63	58	62
80	55	54	59	55	49	51	55
100	51	53	48	48	47	48	50
125	49	53	46	49	51	50	50
160	50	53	55	52	51	48	52
200	47	53	49	49	51	48	50
250	54	53	48	48	48	45	50
315	52	48	46	46	46	42	48
400	46	50	46	47	43	46	47
500	55	54	45	47	41	46	51
630	46	51	44	46	45	42	46
800	44	47	43	46	48	42	45
1000	43	47	44	42	43	40	44
1250	41	42	41	40	40	37	40
1600	38	40	38	38	39	36	38
2000	36	39	34	35	37	33	36
2500	36	39	36	32	35	32	36
3150	35	39	33	31	33	31	35
4000	35	37	33	34	31	31	34
A-wgt	55	57	52	53	53	50	54
C-wgt	63	66	66	66	65	61	65

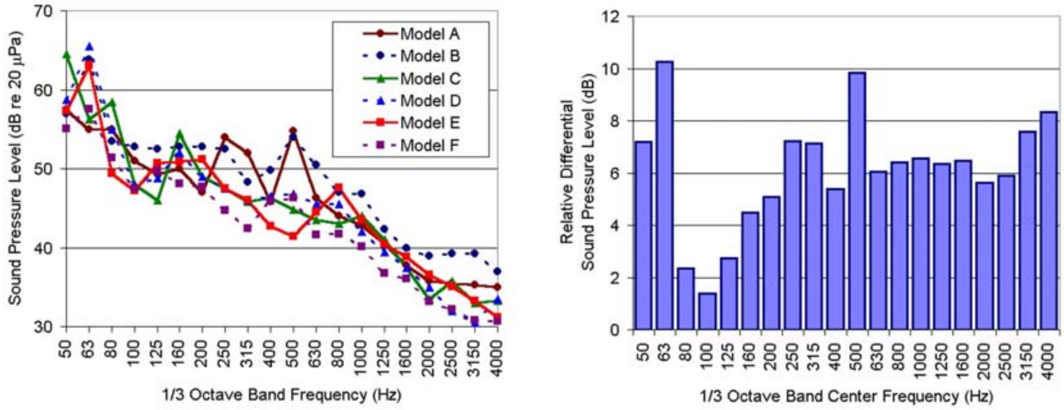

Figure 1: fan/compressor noise summary (left) and relative additional compressor noise above fan noise (right)

The hotel owner wished to install an air conditioner model that had been used successfully in their other hotel buildings. That model met construction budget goals and hotel guests had not complained about equipment noise. Based on the hotel owner's experience and the manufacturer's published sound power rating of 6.25 Bels (62.5 dB(A)),[5] these models were used.

Outdoor-Indoor Sound Transmission

Exterior guest room walls and windows were designed and selected to provide at least 35 dB(A) outside-inside noise reduction. Actual field performance of the combined wall and windows was expected to be around Noise Isolation Class (NIC) 35. The planned air conditioners were rated STC 24-27 according to various lab tests.[5] In order to meet design criteria for allowed train noise in guest rooms, additional reduction of sound transmission through the air conditioners was needed to increase their field performance to approximately NIC 30 or greater. Therefore, a plan was developed to install an additional solid sheet metal sound baffle or hood with acoustical liner to provide a noise barrier and obstruct the direct path of train noise through the unit.

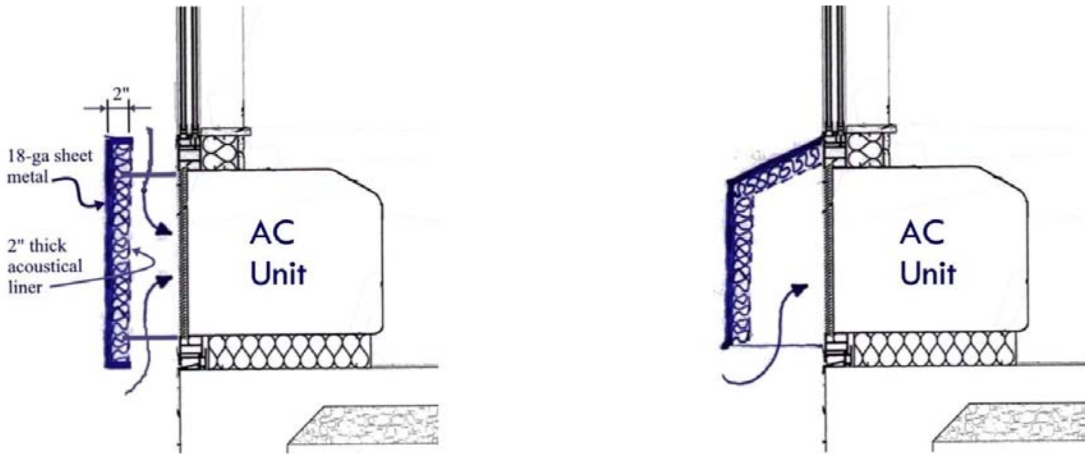

Figure 2: sections through air conditioner showing noise baffle (left) and hood (right) options

The design and effectiveness of the baffle and hood concepts were evaluated using the path-length-difference (d_{diff}) concept[6] that is normally used to predict the sound attenuation ($A_{barrier}$) provided by larger noise barrier walls, according to equation (1). In equation (1), C, the correction factor per frequency, varies from 1 to 4 and N, the Fresnel Number, is determined by wavelength (λ) and the path-length difference according to equation (2):

$$A_{barrier} = 20 \log \left[\frac{(2\pi N)^{0.5}}{\tanh(2\pi N)^{0.5}} \right] + 5 - C \tag{1}$$

$$N = \frac{2}{\lambda} d_{diff} \tag{2}$$

The baffle and hood were sized to provide about 5 dB noise reduction at low frequencies. The barrier skin would have a surface mass of at least 10 kg/m^2 (2.0 lbs/ft^2) in order to provide sound adequate transmission loss along the direct path greater than or equal to the 5 dB expected attenuation due to path-length-difference. Barriers would also be lined with 50 mm (2 in) acoustical liner facing the air conditioner to help reduce sound buildup between the barrier and equipment.

DESIGN IMPLEMENTATION

Windows with storm window inserts were installed at all guest rooms in the hotel building. Special acoustical treatment of exterior framed walls was implemented at rooms facing the railway. On the same face, noise baffles were installed as recommended and designed by consultants. On the opposite face of the building, facing away from the railway, where low frequency noise levels were expected to be reduced, baffles were not installed. The hood configuration, although expected to be more effective than the baffle configuration, was not implemented because of its more bulky appearance, higher cost, and concerns regarding restricted airflow for compressor and motor ventilation on ground-floor units.

Figure 3: outside views of air conditioners without baffle (left) and with baffle (right)

POST OCCUPANCY PERFORMANCE EVALUATION

After construction, we visited the project to measure air conditioner fan and compressor noise and outside-inside sound transmission loss through air conditioning units on opposite sides of the building (with and without the noise baffle). Performance evaluation noise measurements were conducted using a Larson Davis 824 real-time FFT spectrum analyzer with precision microphone and pre-amp (ANSI Type I, ± 1 dB).[3]

Equipment Noise

Equipment noise levels were measured in two guest rooms of the same size. While the noise levels are generally in the lower range of those models tested earlier, similar tonal components are present. It is interesting to note that the noise levels in the 63 Hz octave band differ by 10 dB for the same model on the same setting.

Table 2: sound pressure levels of tested units on high-cool setting

1/3 Octave Band (Hz)	Room 1	Room 2	1/3 Octave Band (Hz)	Room 1	Room 2
50	43	48	**630**	44	43
63	49	59	**800**	43	40
80	43	46	**1000**	41	40
100	43	49	**1250**	39	37
125	49	53	**1600**	38	35
160	50	50	**2000**	35	34
200	51	50	**2500**	34	33
250	46	47	**3150**	33	32
315	43	41	**4000**	32	32
400	42	41	**A-wgt**	51	50
500	44	42	**C-wgt**	58	61

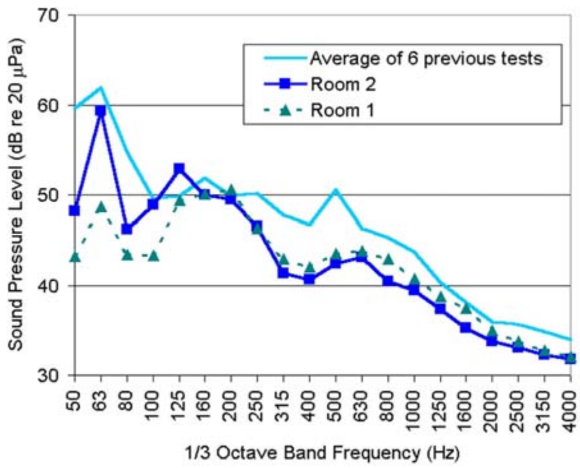

Figure 4: comparison of new air conditioner fan/compressor noise with averaged levels for six different models

Outdoor-Indoor Sound Transmission

Outdoor-indoor transmission class measurements and ratings were conducted in general accordance with ASTM Standard E 966-99, using the "Nearby Microphone Method." [7] The sound source used was random pink noise generated by a Larson Davis 2900 analyzer, balanced through a 7-band equalizer amplified through a 75 watt, portable speaker/amplifier and a second loudspeaker. The second loudspeaker was situated to roughly mimic the height and direction of nearby railway noise sources (train engines) and was oriented facing each tested guest room about 4.5 m (15 ft) from façade and 45° from façade normal. Sound levels inside and outside guest rooms were measured by moving the microphone over a 1 m (3 ft) square area as close to the air conditioner as possible while keeping the microphone properly > 1 m (~ 4 ft) away from face of unit grille and floor surfaces.

Results indicate the baffles effectively reduce sound transmission through air conditioners above 200 Hz. Measured Outside-Inside Transmission Loss (OITL)[7] and Normalized Noise Reduction (NNR)[8] values are presented in Figure 5, below. The predicted additional attenuation of the baffle, determined using equation (1), was added to the measured transmission loss and noise reduction values of the unit without a noise baffle, to estimate the predicted performance with the barrier in place. Predicted values roughly coincide with measured values, except below 200 Hz and between 1250 Hz and 4000 Hz. Sound flanking through window glazing and through seals around sliding window sashes are a likely cause of the dip around 2000 Hz. Low frequency sound flanking through window and wall components may also contribute to inconclusive results below 200 Hz.

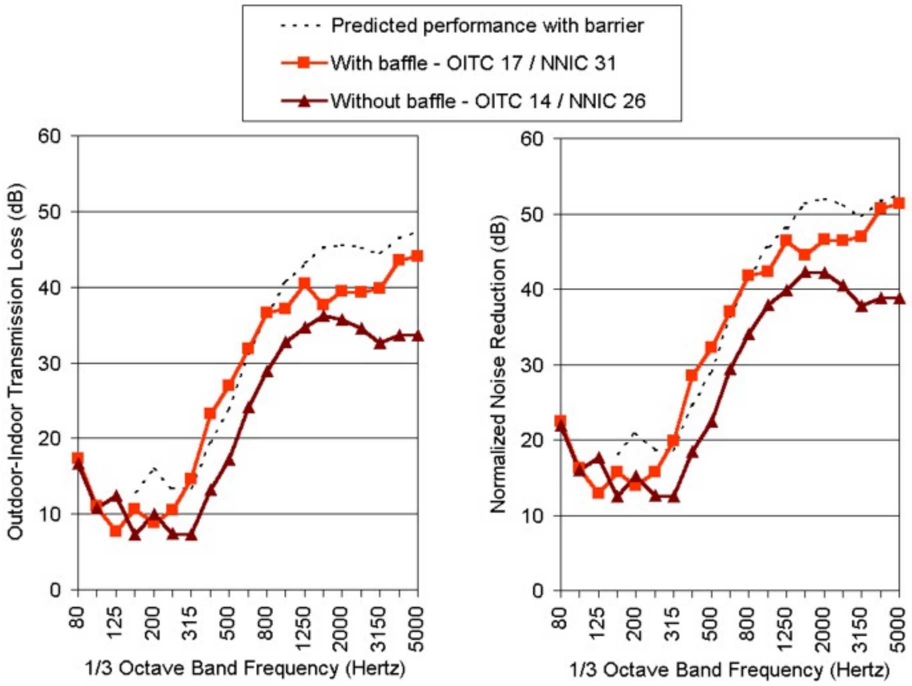

Figure 5: outdoor-indoor transmission loss (left) and normalized noise reduction (right) of air conditioners with baffle and without, compared with expected values

Figure 6: inside (left) and outside (right) views of typical air conditioner with baffle

CONCLUSION

The design efforts in this project focused on providing moderate improvements of through-wall air conditioner noise and sound transmission loss, while abiding strict budgetary constraints. The noise baffles designed and utilized in this project provided the intended reduction of intrusive outdoor noises. Hotel managers and guests have so far been pleased and surprised with the results. While additional mitigation to reduce noise generated by air conditioners was not explored, measured field data indicate that a good place to start reducing noise might be at the compressors, rather than the fans.

ACKNOWLEDGEMENTS

The author wishes to thank Sarah B. Knight and Jack B. Evans, P.E., both members of JEAcoustics staff, for their assistance in performing acoustical tests and reducing data.

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