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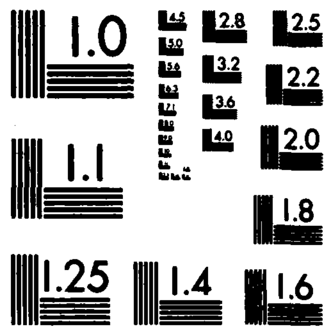

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NATIONAL BUREAU OF STANDARDS-1963-A

Report OEHL 80-6

AD-A154 372

ACOUSTIC EVALUATION AND RECOMMENDED CONTROLS
FOR RUNWAY SUPERVISORY UNITS
LAUGHLIN AFB TX

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USAF Occupational and Environmental Health Laboratory
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

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This technical report has been reviewed and is approved for publication.

WILLIAM E. MABSON, Colonel, USAF, BSC
Commander

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Runway Supervisory Units
Speech Communication
Speech Interference

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The hazardous noise and speech communication environment, and effectiveness of structure sound attenuation are evaluated at five Runway Supervisory Units (RSUs) at Laughlin AFB TX for the USAF Air Training Command. This report presents energy-averaged octave-band spectra and overall sound levels exterior and interior to the RSUs when measured under ambient conditions and with nearby aircraft takeoff operations. Recommendations are provided to reduce the interior noise levels compatible with an environment suitable for critical voice communications.

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The authors gratefully acknowledge the efforts of SSgt Ed L. Cox of this Laboratory for his assistance in the areas of instrumentation and data acquisition; the excellent base-level support of Capt J. Elaine Talarski, USAF Hospital, Laughlin AFB TX; and the assistance of Lt Col Don C. Gasaway, USAF School of Aerospace Medicine, Brooks AFB TX, in the area of data analysis.

ABSTRACT

The hazardous noise and speech communication environment, and effectiveness of structure sound attenuation are evaluated at five Runway Supervisory Units (RSUs) at Laughlin AFB TX for the USAF Air Training Command. This report presents energy-averaged octave-band spectra and overall sound levels exterior and interior to the RSUs when measured under ambient conditions and with nearby aircraft takeoff operations. Recommendations are provided to reduce the interior noise levels compatible with an environment suitable for critical voice communications.

I. INTRODUCTION:

A. At the request of USAF Hospital/SGPM, Laughlin AFB TX, a noise survey was conducted during the period 31 October to 2 November 1979. The survey examined five Runway Supervisory Units (RSUs) located at Laughlin AFB TX to determine the possible existence of hazardous noise exposure to RSU personnel; the nature and extent of the speech interference problem; and possible solutions to the above problems.

B. The type of flight operations at Laughlin AFB involve initial jet training in the T-37 aircraft, and transition jet training in the T-38 aircraft. The five RSUs are used to control the air traffic on approach, landing, and/or takeoff on a particular runway.

C. The function of the RSUs is critical in insuring safety of flight operations in the terminal area; i.e., preventing a training aircraft from straying into adjacent flight tracks, or operating onto an occupied runway. High noise levels, which create speech interference problems, result from the close proximity of the RSUs to the active runways. Speech intelligibility is of paramount importance in a critical situation, especially since many of the students are foreign military students who have difficulty understanding English.

D. The five RSUs are South Lariat (Bldg 680), South Lariat (Bldg 681), South Honcho (Bldg 1710), North Lariat (Bldg 670), and North Honcho (Bldg 1705). The locations are shown in Figures 1 and 2. The general design of the RSUs is similar to an air traffic control tower (ATCT). Specifically, the design of four of the units, which is approximately twenty years old, was meant to be used as a portable ATCT at forward operating bases. The tower construction is lightweight. These units are presently placed on steel frame or concrete block towers, approximately five to twenty-five feet above the ground. The remaining RSU, North Lariat (Bldg 670), is a permanent facility, constructed by Base Civil Engineering. The entire RSU, including the tower, is of more substantial construction than the other units.

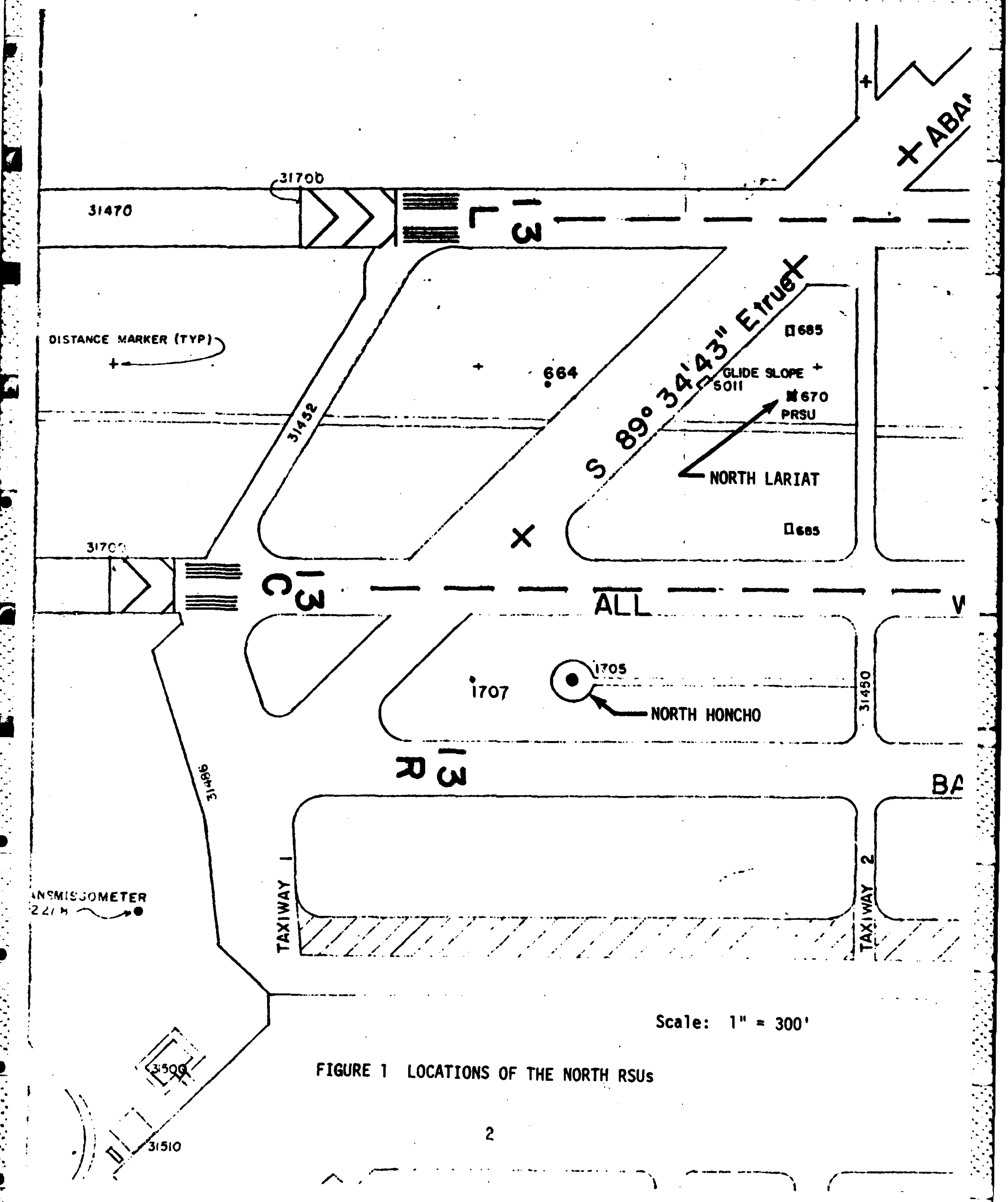
II. METHODOLOGY:

A. Field Measurements:

1. Approximately 200 noise measurements were performed inside and outside the five RSUs during T-37 and T-38 operations (primarily takeoffs). For most operations, measurements were taken simultaneously inside and outside the RSU.

2. The acoustic data were recorded using a NAGRA IV-SJ portable, 2-channel, battery-operated magnetic tape recorder. The transducer of choice was the GR 1962-9601 one-half inch Electrit microphone with an air foam windscreen and mounted on a tripod. Some additional data were acquired with a GR 1982 precision sound level meter.

3. Where possible, interior background noise data (with and without air conditioner operating) were recorded to eliminate these interferences from the test data during analysis.



Scale: 1" = 300'

FIGURE 1 LOCATIONS OF THE NORTH RSUs

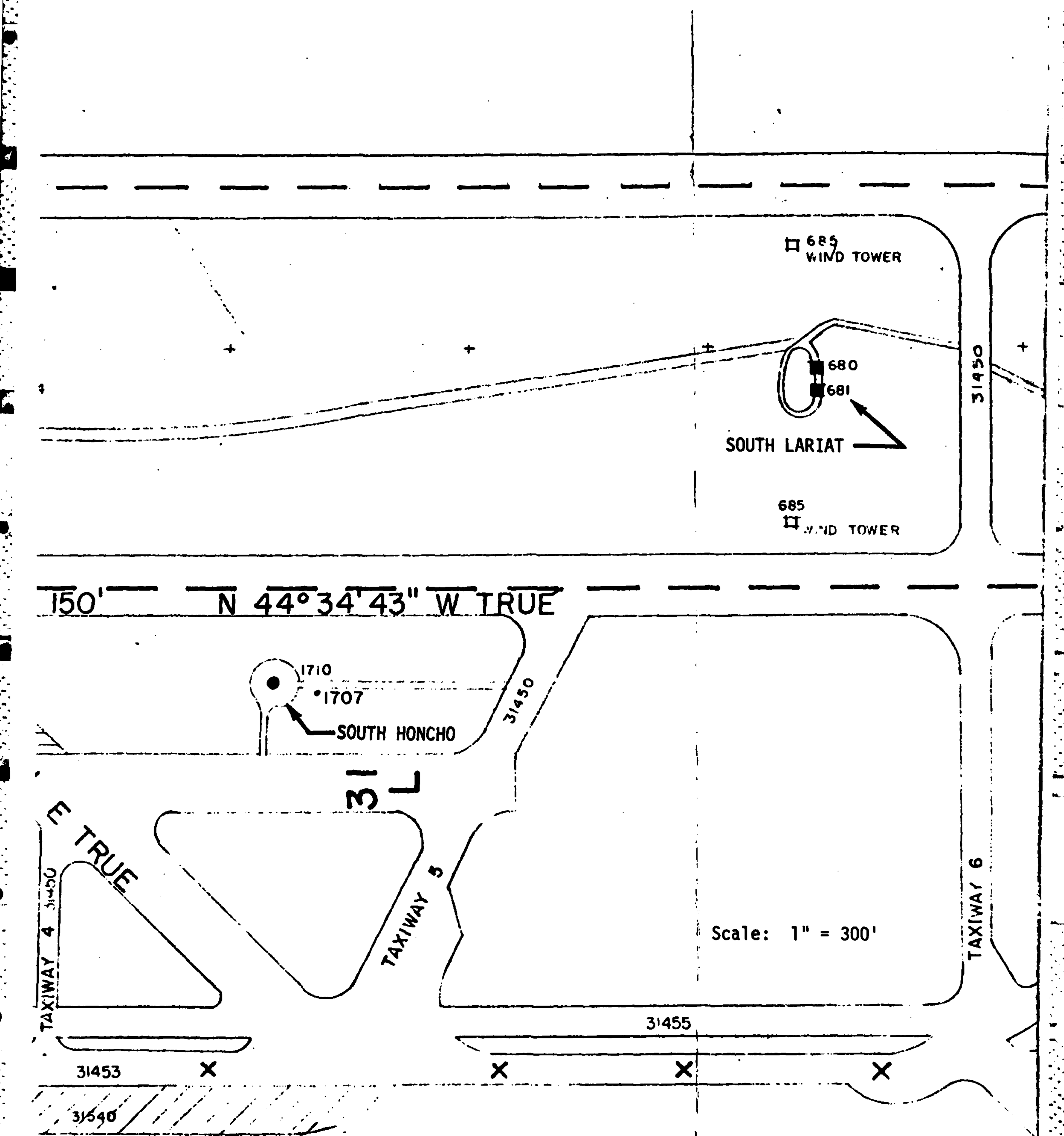


FIGURE 2 LOCATIONS OF THE SOUTH RSUs

B. Data Analysis/Processing:

1. Prior to analysis, the recording-playback system was corrected over a frequency range of one-third octave bands centered from 25 to 20,000 Hz to effect a flat system response. These corrections included the microphone response to account for the incidence (random) of the sound on the microphone diaphragm.

2. The recorded acoustic data were then analyzed into one-third octave-band sound pressure levels over this same frequency range using a GR 1921-9701 Real Time Analysis System located at the USAF School of Aerospace Medicine, Audiology and Hearing Conservation Section, Brooks AFB TX. Approximately one hundred and twelve usable spectra were retained and manually processed to provide calculated noise data as discussed below. Each of the one-third octave-band spectra was resolved into an octave-band spectra, from which calculated values of A- and C-weighted overall sound levels and preferred speech interference level (PSIL)* were determined.

III. Results:

A. RSU Noise Levels During T-38 Takeoff Operations: The interior-exterior paired noise data were grouped according to RSU, type of aircraft, type of operation (takeoff, missed approach, etc.), and number of aircraft per operation. Data involving all T-37 operations and T-38 operations other than takeoffs were set aside because of their significantly lower noise levels when compared with T-38 takeoff operations. There were no significant differences in the noise levels of single aircraft takeoffs versus paired takeoffs. The remaining grouped spectra and weighted sound levels were energy-averaged to obtain one pair of average spectra and associated weighted levels for each group. Likewise, the PSIL data were arithmetically averaged to obtain an average interior-exterior PSIL for each group. All interior octave-band noise data were corrected to remove the influence of any background noise caused by the air conditioner. The criteria and correction procedure to account for the influence of background noise are given in Table 1. When the correction procedure showed that the air conditioner had a substantial influence on the interior noise level, the datum for that octave band was deleted. These data, given in Table 2 and shown graphically in Figures 3 through 7, show the interior and exterior noise levels at each RSU during T-38 takeoffs, and represent the maximum noise experienced by RSU personnel. The values for noise reduction (NR), given in Table 2 and shown in Figures 8 through 12, are the arithmetic differences between exterior and interior noise levels. No difference values for PSIL are reported because there is no technical basis for such a measure.

B. RSU Interior Ambient Noise Levels: Those data concerning interior ambient noise levels, without the influence of aircraft, were grouped according to RSU and air conditioner operating condition, and then averaged as outlined above. Arithmetic differences between the levels during the ON versus OFF condition show the contribution of the air conditioner to the ambient noise environment. These data are given in Table 3 and presented in Figures 13 through 17. The data for the North Lariat RSU (Bldg 670) were acquired using the sound level meter which has a higher noise floor than the magnetic tape recording system. When the noise levels fell below the noise floor of the sound level meter, the data were reported as being "less than 25," or deleted.

*The PSIL is a measure, expressed in dB. of the effectiveness of voice communication in a noise environment. It is the arithmetic average of the levels of the three octave bands centered on 500, 1000, and 2000 Hz.

TABLE 1 CORRECTION CRITERIA AND PROCEDURE TO ACCOUNT FOR THE INFLUENCE OF BACKGROUND NOISE

If	Then
$15 \leq \text{RSPL} - \text{SPLN}$	Do not correct RSPL
$5 \leq \text{RSPL} - \text{SPLN} < 15$	Correct RSPL for influence of background noise
$\text{RSPL} - \text{SPLN} < 5$	Reject RSPL

$$\text{CSPL} = 10 \log \quad \text{antilog} \frac{\text{RSPL}}{10} \quad - \text{antilog} \quad \frac{\text{SPLN}}{10}$$

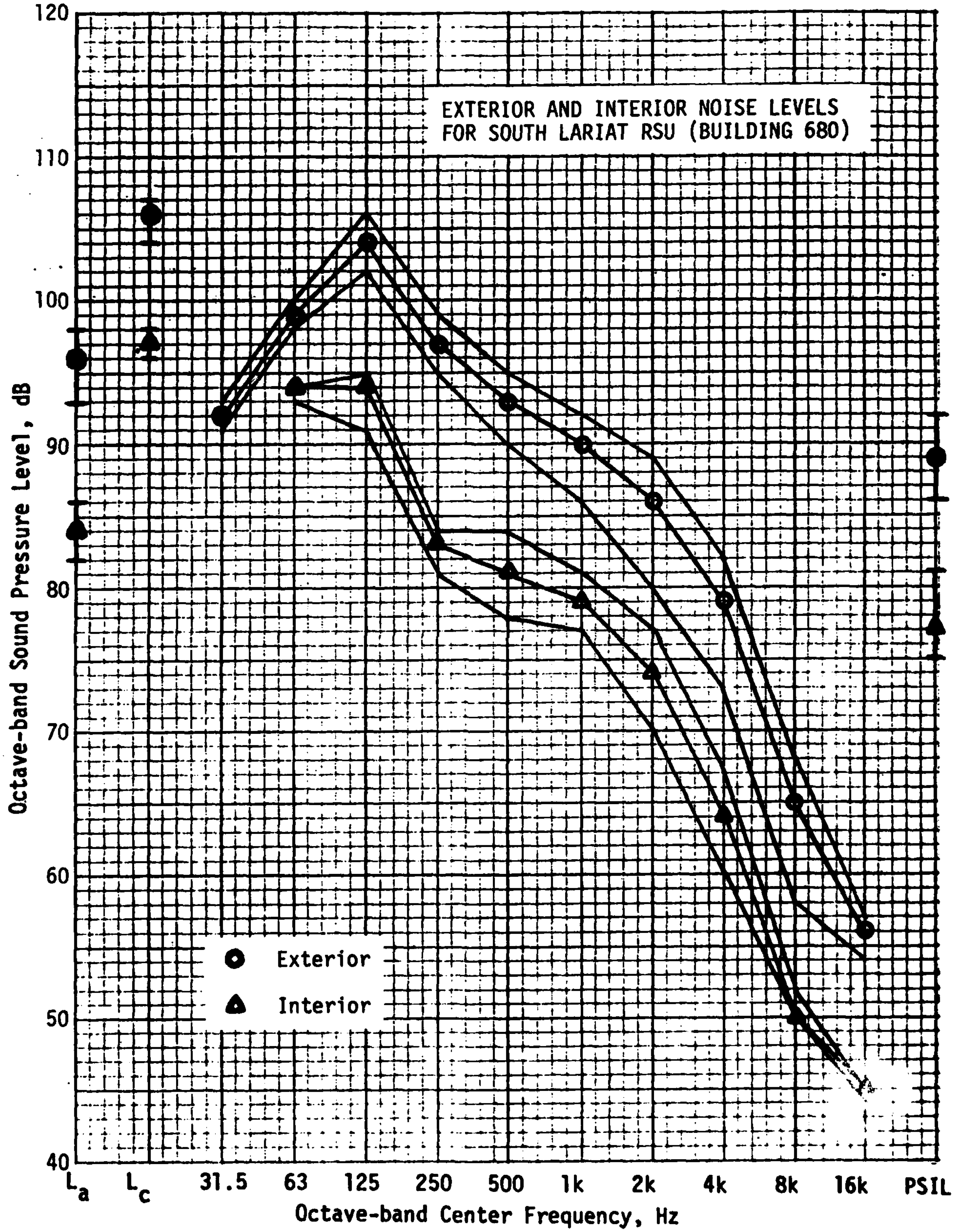
RSPL = Raw octave-band sound pressure level

SPLN = Background octave-band sound pressure level for the same octave band as the RSPL above

CSPL = Corrected octave-band sound pressure level for the same octave band as the RSPL above

TABLE 2 - RSU EXTERIOR AND INTERIOR NOISE LEVELS

			OCTAVE BAND CENTER FREQUENCY, Hz										
LOCATION	L_a	L_c	31.5	63	125	250	500	1000	2K	4K	8K	16K	PSIL
					N. Honcho (1705)								
Interior	95	105	86	99	102	92	95	89	86	81	73	61	90
Exterior	117	120	102	111	114	112	115	111	110	106	97	84	112
Noise Reduction	22	15	16	12	12	20	20	22	24	25	24	23	-
					N. Lariat (670)								
Interior	83	96	81	93	92	85	83	75	70	63	48	46	76
Exterior	109	112	92	99	102	101	107	106	101	95	84	71	104
Noise Reduction	26	16	11	6	10	16	24	31	31	32	36	25	-
					S. Honcho (1710)								
Interior	90	99	-	89	96	92	90	83	80	72	61	55	84
Exterior	105	113	95	104	110	106	104	99	94	90	80	68	99
Noise Reduction	15	14	-	15	14	14	14	16	14	18	19	13	-
					S. Lariat (680)								
Interior	84	97	-	94	94	83	81	79	74	64	50	45	77
Exterior	96	106	92	99	104	97	93	90	86	79	65	56	89
Noise Reduction	12	9	-	5	10	14	12	11	12	15	15	11	-
					S. Lariat (681)								
Interior	84	96	-	90	94	84	79	77	77	61	-	-	78
Exterior	101	108	93	101	105	101	99	95	91	87	72	57	95
Noise Reducton	17	12	-	11	11	17	20	18	14	26	-	-	-



EXTERIOR AND INTERIOR NOISE LEVELS
FOR SOUTH LARIAT RSU (BUILDING 680)
Exterior
Interior
120
110
100
90
80
70
60
50
40
Octave-band Sound Pressure Level, dB
L_a
L_c
31.5
63
125
250
500
1k
2k
4k
8k
16k
PSIL
Octave-band Center Frequency, Hz

FIGURE 3

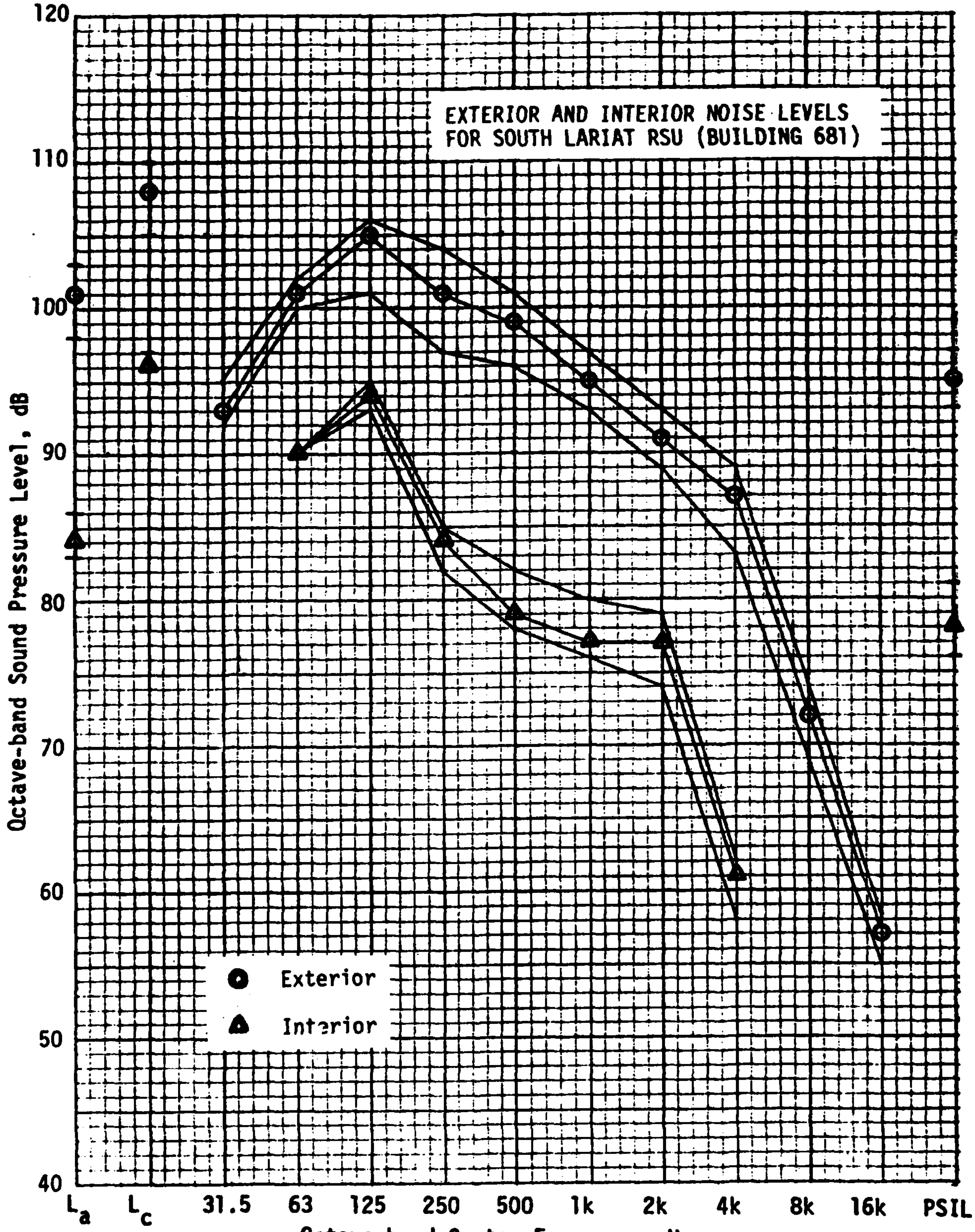

EXTERIOR AND INTERIOR NOISE LEVELS
FOR SOUTH LARIAT RSU (BUILDING 681)
Exterior
Interior
Octave-band Sound Pressure Level, dB
Octave-band Center Frequency, Hz
120
110
100
90
80
70
60
50
40
L_a
L_c
31.5
63
125
250
500
1k
2k
4k
8k
16k
PSIL

FIGURE 4

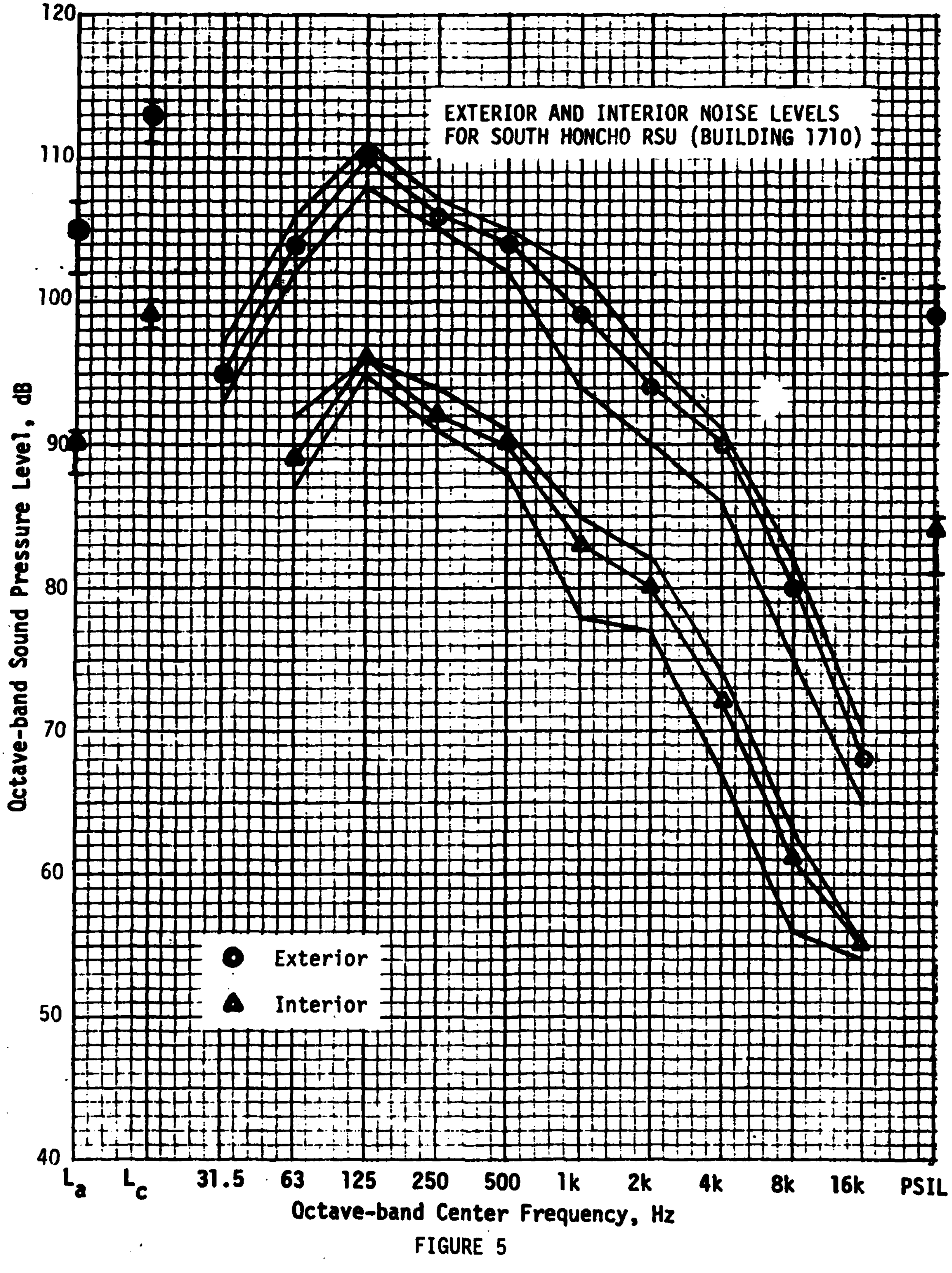

EXTERIOR AND INTERIOR NOISE LEVELS
FOR SOUTH HONCHO RSU (BUILDING 1710)
Exterior
Interior
Octave-band Sound Pressure Level, dB
120
110
100
90
80
70
60
50
40
L_a
L_c
31.5
63
125
250
500
1k
2k
4k
8k
16k
PSIL
Octave-band Center Frequency, Hz

FIGURE 5

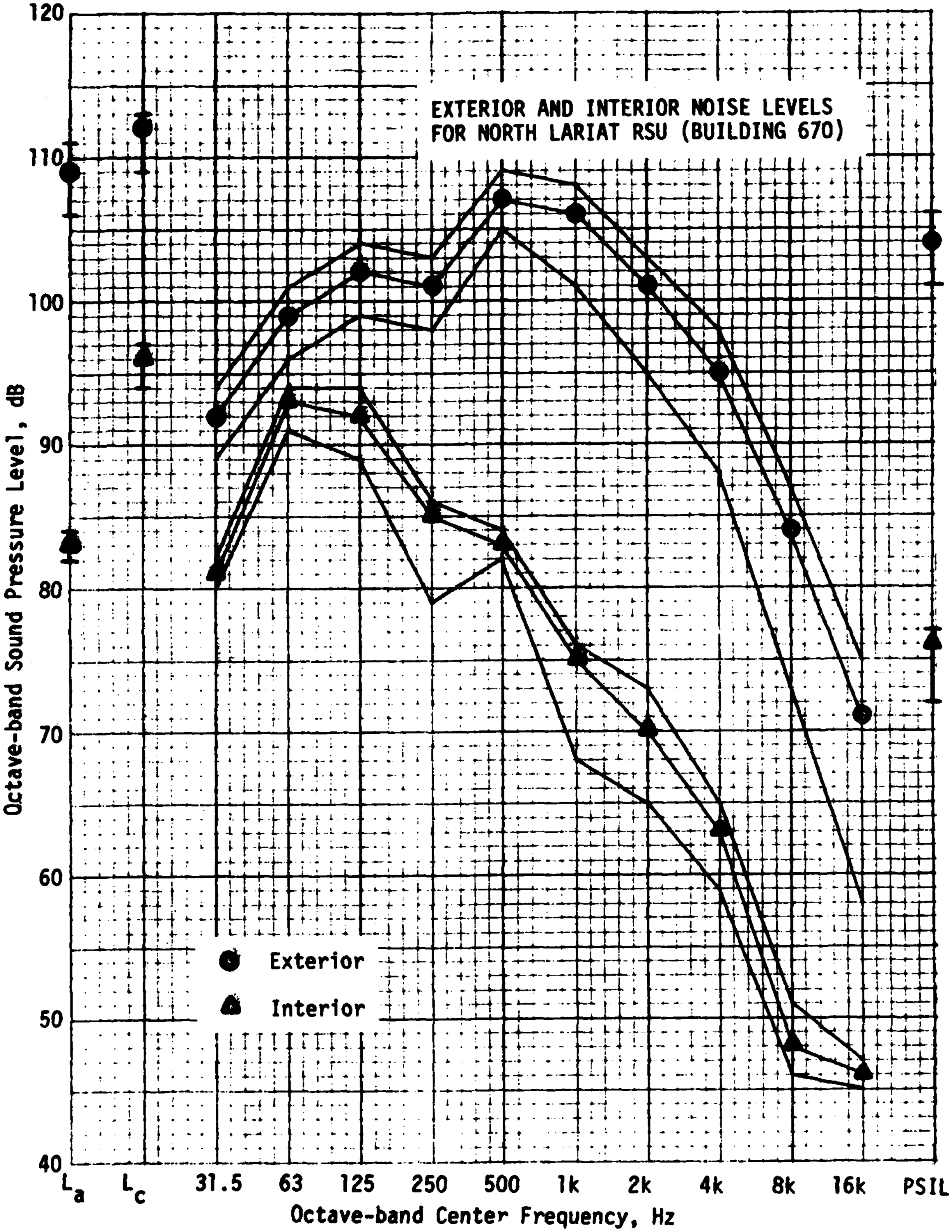

EXTERIOR AND INTERIOR NOISE LEVELS
FOR NORTH LARIAT RSU (BUILDING 670)
Exterior
Interior
Octave-band Sound Pressure Level, dB
120
110
100
90
80
70
60
50
40
L_a
L_c
31.5
63
125
250
500
1k
2k
4k
8k
16k
PSIL
Octave-band Center Frequency, Hz

FIGURE 6

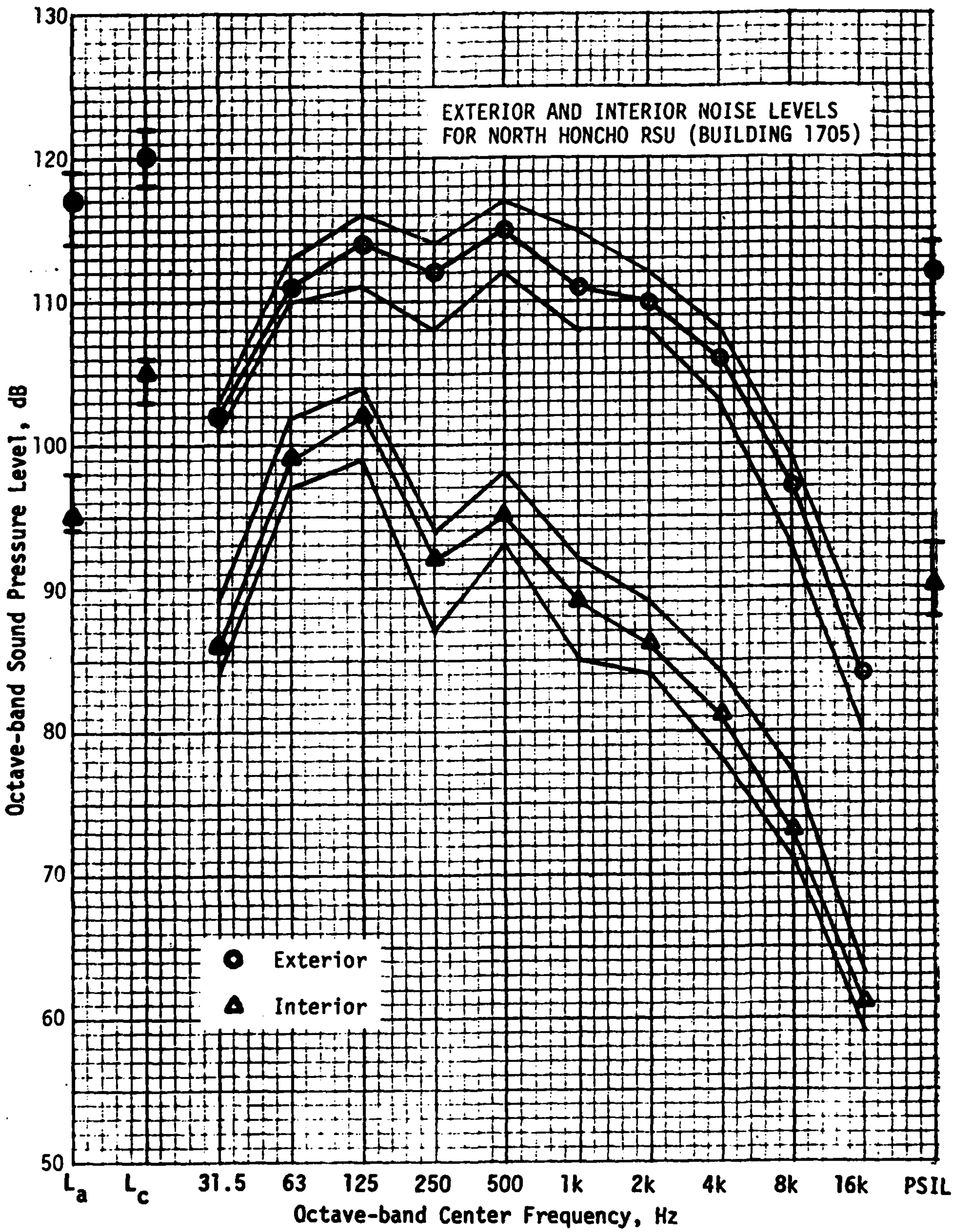

EXTERIOR AND INTERIOR NOISE LEVELS
FOR NORTH HONCHO RSU (BUILDING 1705)
Exterior
Interior
Octave-band Sound Pressure Level, dB
130
120
110
100
90
80
70
60
50
La
Lc
31.5
63
125
250
500
1k
2k
4k
8k
16k
PSIL
Octave-band Center Frequency, Hz

FIGURE 7

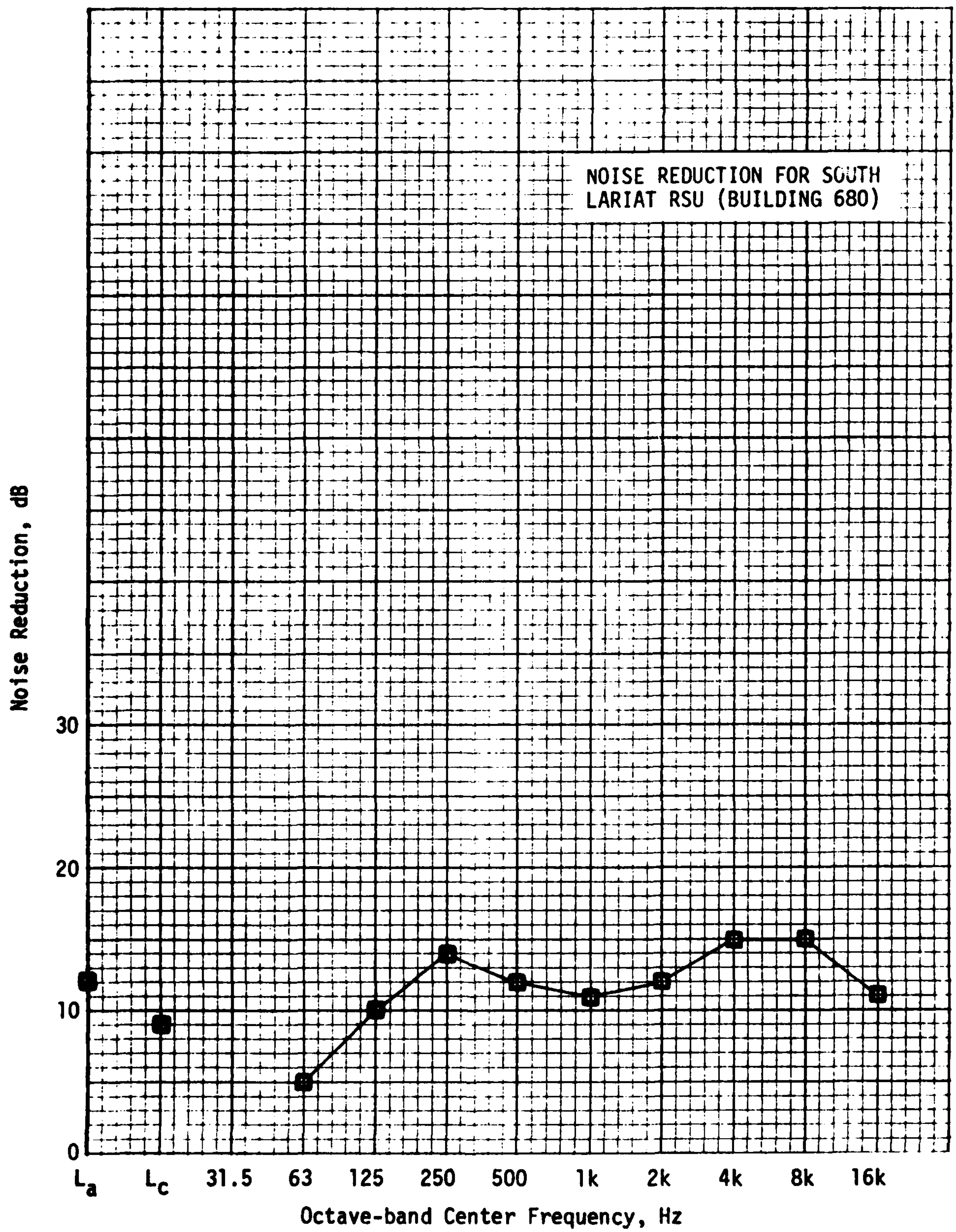

NOISE REDUCTION FOR SOUTH LARIAT RSU (BUILDING 680)
Noise Reduction, dB
30
20
10
0
L_a
L_c
31.5
63
125
250
500
1k
2k
4k
8k
16k
Octave-band Center Frequency, Hz

FIGURE 8

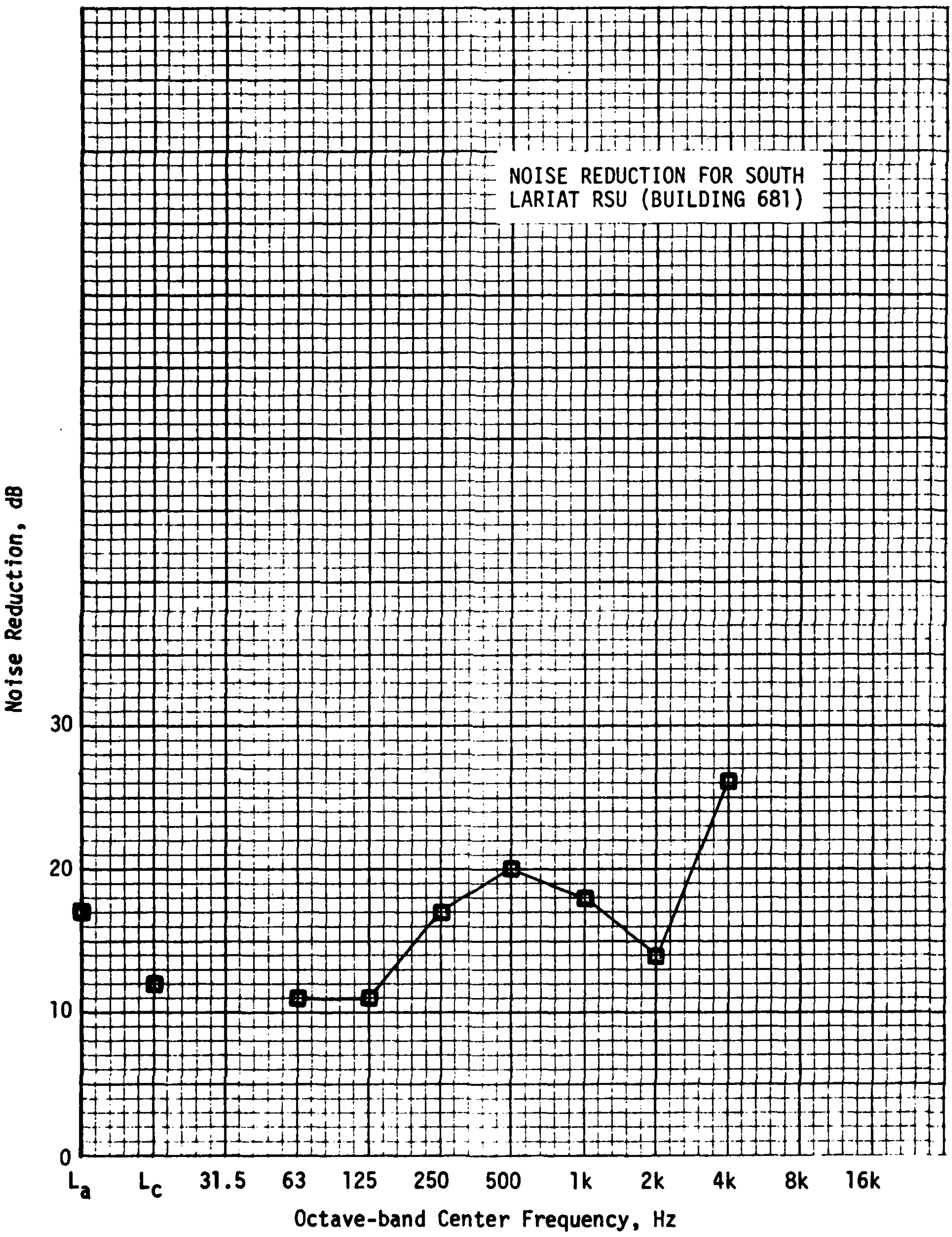

NOISE REDUCTION FOR SOUTH LARIAT RSU (BUILDING 681)
Noise Reduction, dB
30
20
10
0
L_a
L_c
31.5
63
125
250
500
1k
2k
4k
8k
16k
Octave-band Center Frequency, Hz

FIGURE 9

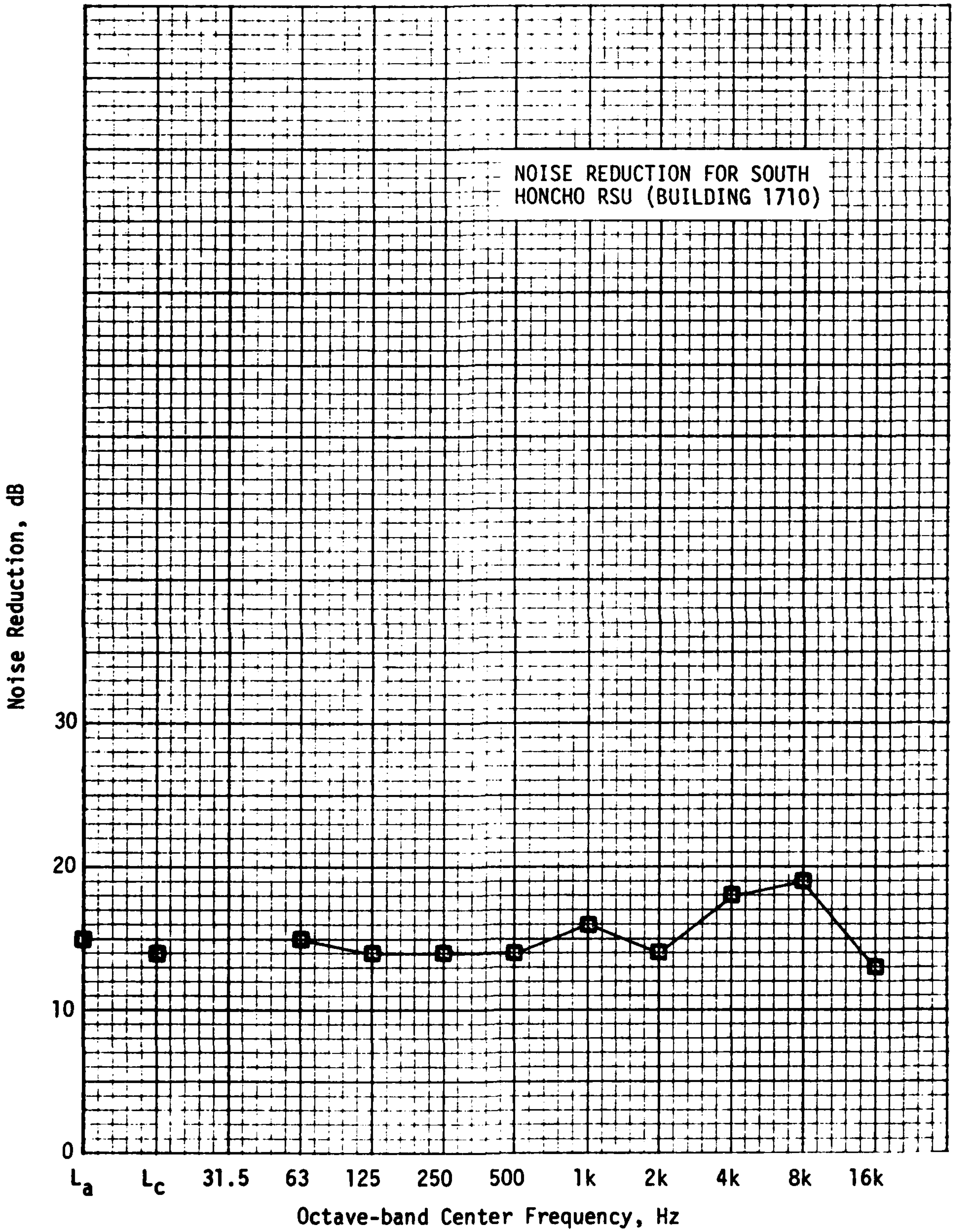

NOISE REDUCTION FOR SOUTH HONCHO RSU (BUILDING 1710)
Noise Reduction, dB
30
20
10
0
L_a
L_c
31.5
63
125
250
500
1k
2k
4k
8k
16k
Octave-band Center Frequency, Hz

FIGURE 10

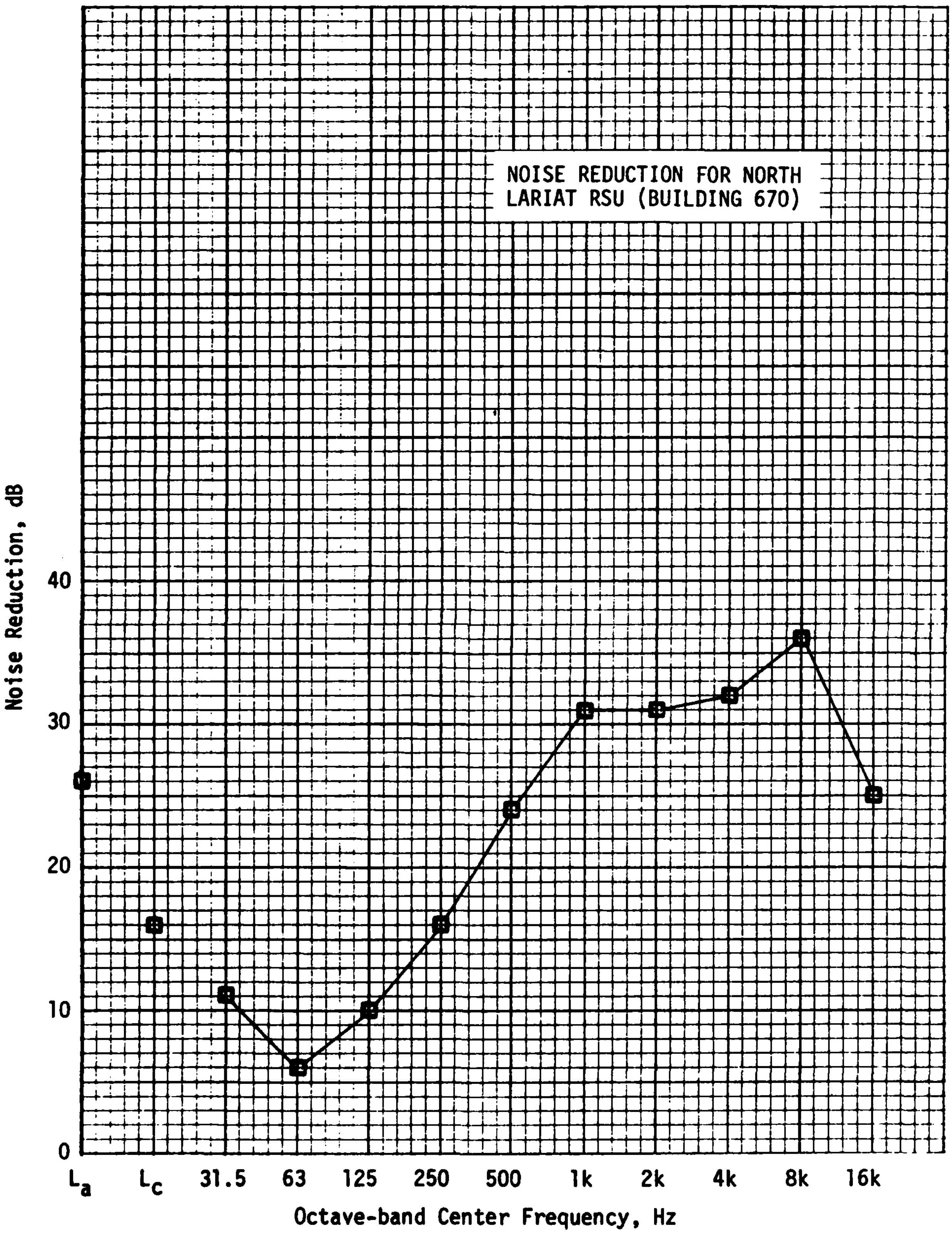
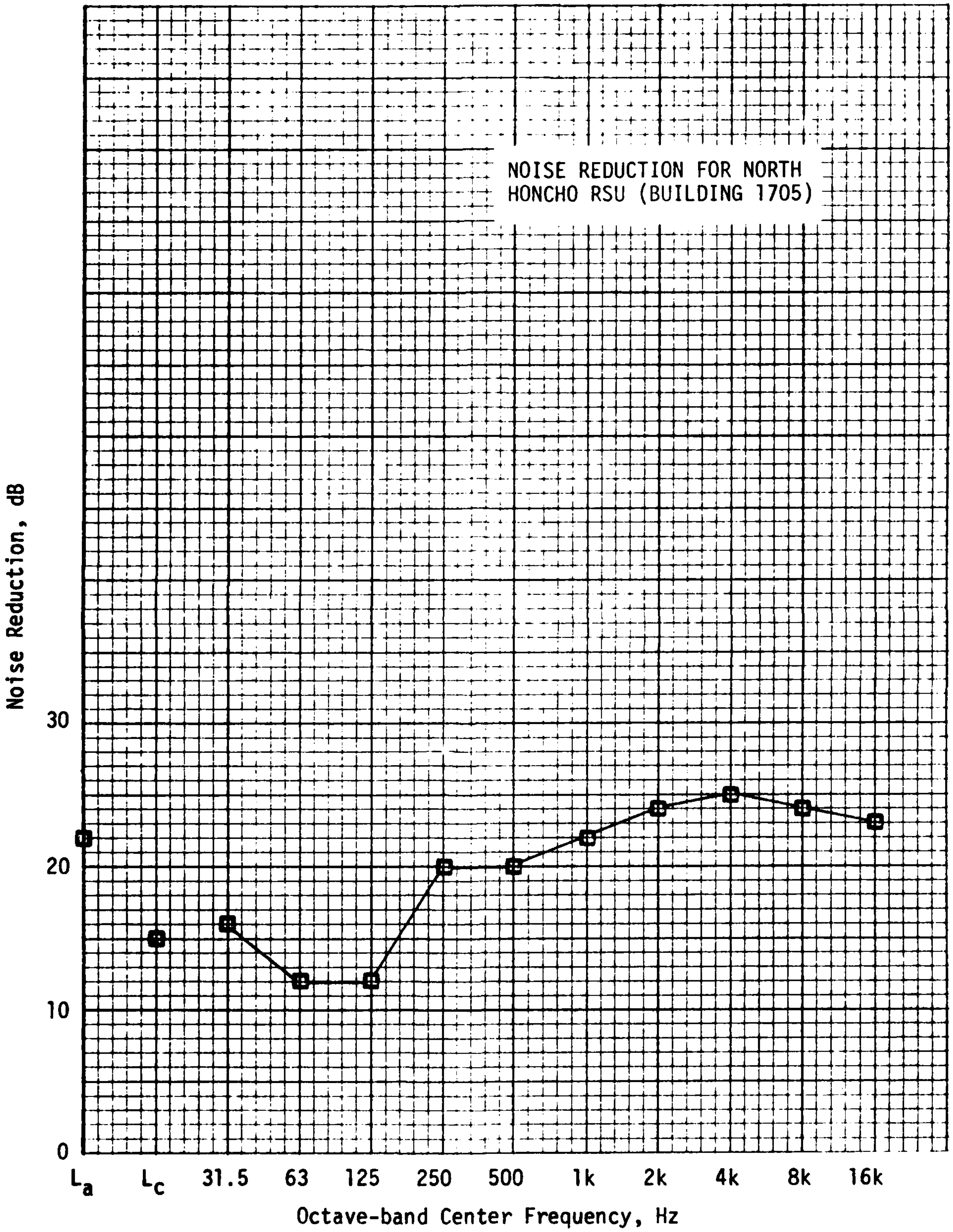

NOISE REDUCTION FOR NORTH
LARIAT RSU (BUILDING 670)
Noise Reduction, dB
0
10
20
30
40
La
Lc
31.5
63
125
250
500
1k
2k
4k
8k
16k
Octave-band Center Frequency, Hz

FIGURE 11



NOISE REDUCTION FOR NORTH HONCHO RSU (BUILDING 1705)
Noise Reduction, dB
30
20
10
0
L_a
L_c
31.5
63
125
250
500
1k
2k
4k
8k
16k
Octave-band Center Frequency, Hz

FIGURE 12

TABLE 3 - RSU INTERIOR AMBIENT NOISE LEVELS

			OCTAVE BAND CENTER FREQUENCY, Hz										
CONDITION	L_a	L_c	31.5	63	125	250	500	1000	2K	4K	8K	16K	PSIL
N. Honcho (1705)													
Air Conditioner on	71	82	78	77	72	79	66	58	53	48	40	37	59
Air Conditioner off	40	52	50	47	42	47	35	27	24	20	15	17	28
Difference	31	30	28	30	30	32	31	31	29	28	25	20	-
N. Lariat (670)													
Air Conditioner on	48	62	52	60	57	48	42	45	34	26	<25	<25	40
Air Conditioner off	33	44	39	36	36	36	<25	<25	<25	<25	<25	<25	<25
Difference	15	18	13	24	21	12	>17	>20	> 9	> 1	-	-	-
S. Honcho (1710)													
Air Conditioner on	71	88	86	81	82	72	69	61	60	54	49	47	64
Air Conditioner off	60	73	59	68	71	63	57	51	46	38	38	37	51
Difference	11	15	27	13	11	9	12	10	14	16	11	10	-
S. Lariat (680)													
Air Conditioner on	72	86	82	81	84	71	68	66	60	52	44	37	65
Air Conditioner off	62	75	61	70	73	64	61	49	49	43	31	28	53
Difference	10	11	21	11	11	7	7	17	11	9	13	9	-
S. Lariat (681)													
Air Conditioner on	72	89	86	88	81	70	67	66	62	56	49	45	65
Air Conditioner off	-	-	-	-	-	-	-	-	-	-	-	-	-
Difference	-	-	-	-	-	-	-	-	-	-	-	-	-

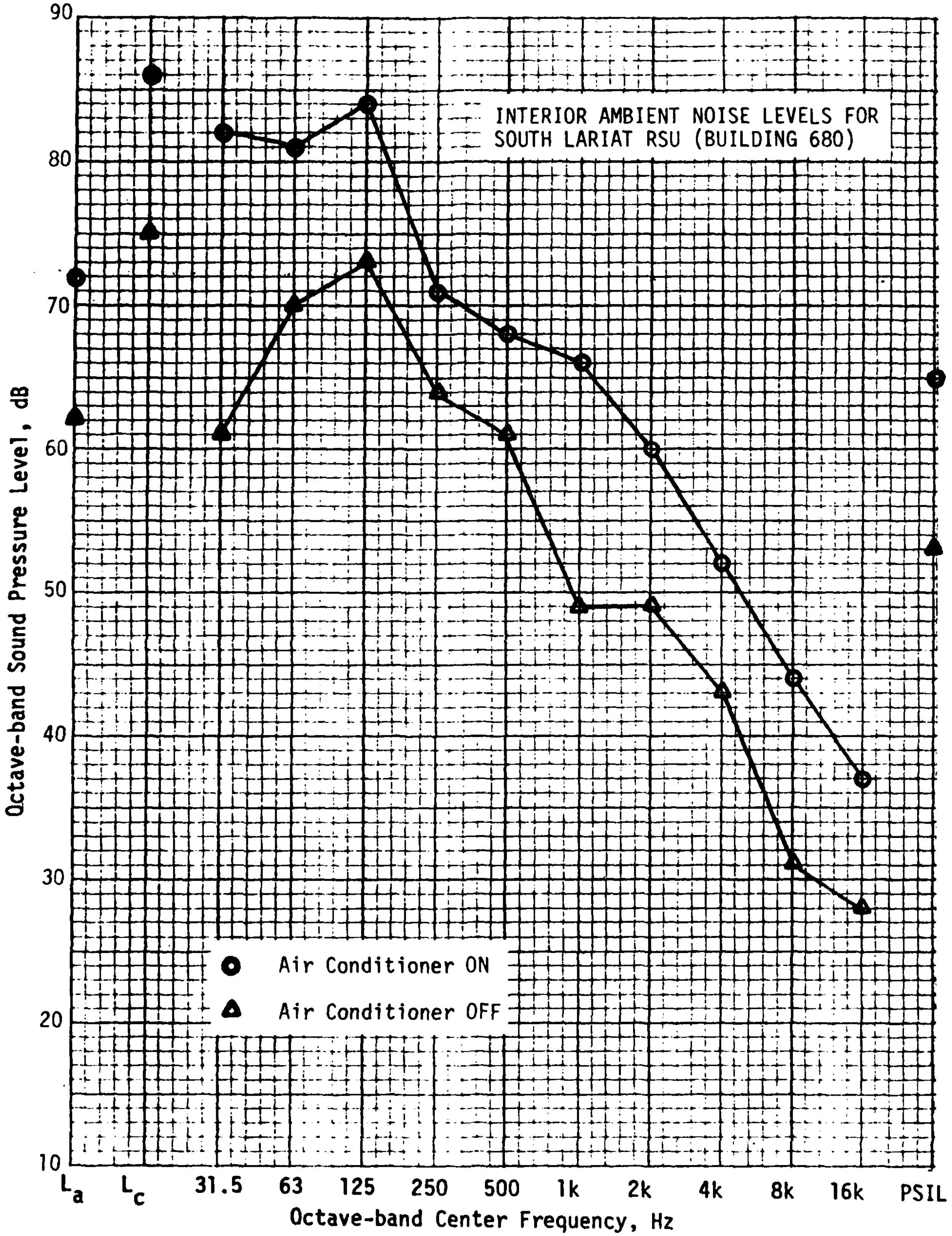

INTERIOR AMBIENT NOISE LEVELS FOR SOUTH LARIAT RSU (BUILDING 680)
Air Conditioner ON
Air Conditioner OFF
Octave-band Sound Pressure Level, dB
90
80
70
60
50
40
30
20
10
L_a
L_c
31.5
63
125
250
500
1k
2k
4k
8k
16k
PSIL
Octave-band Center Frequency, Hz

FIGURE 13

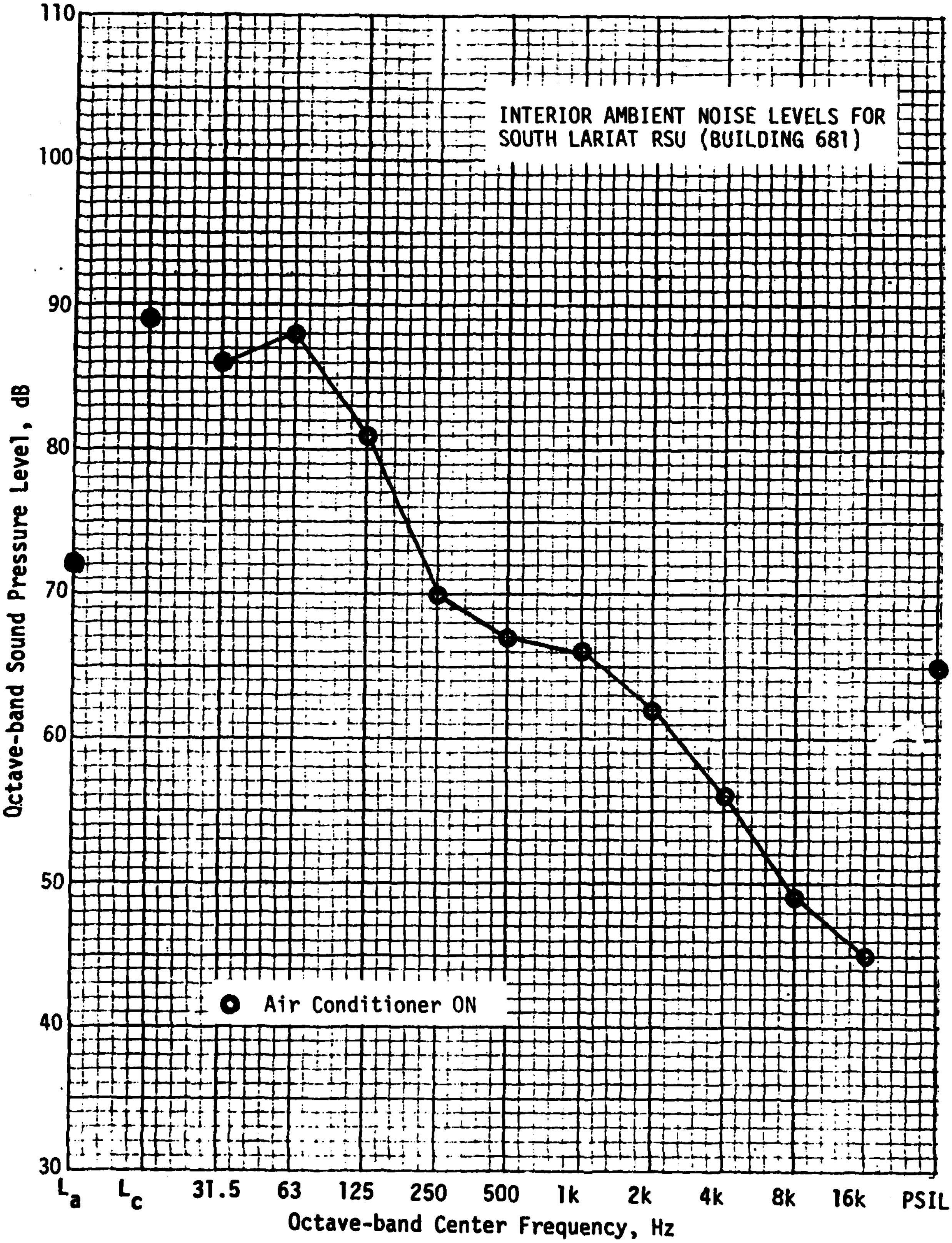

INTERIOR AMBIENT NOISE LEVELS FOR
SOUTH LARIAT RSU (BUILDING 681)
Air Conditioner ON
110
100
90
80
70
60
50
40
30
Octave-band Sound Pressure Level, dB
L_a
L_c
31.5
63
125
250
500
1k
2k
4k
8k
16k
PSIL
Octave-band Center Frequency, Hz

FIGURE 14

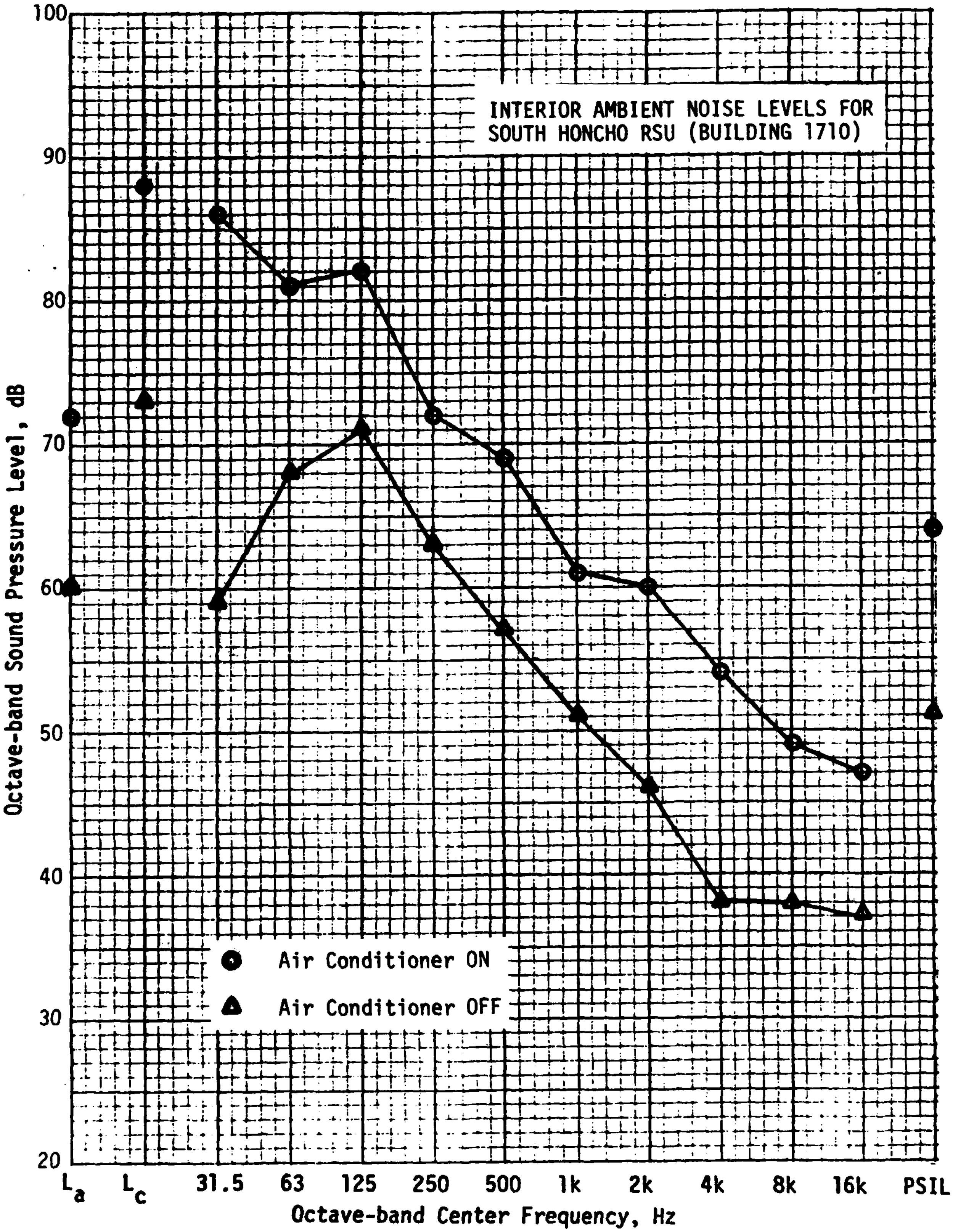

INTERIOR AMBIENT NOISE LEVELS FOR SOUTH HONCHO RSU (BUILDING 1710)
Air Conditioner ON
Air Conditioner OFF
100
90
80
70
60
50
40
30
20
Octave-band Sound Pressure Level, dB
L_a
L_c
31.5
63
125
250
500
1k
2k
4k
8k
16k
PSIL
Octave-band Center Frequency, Hz

FIGURE 15

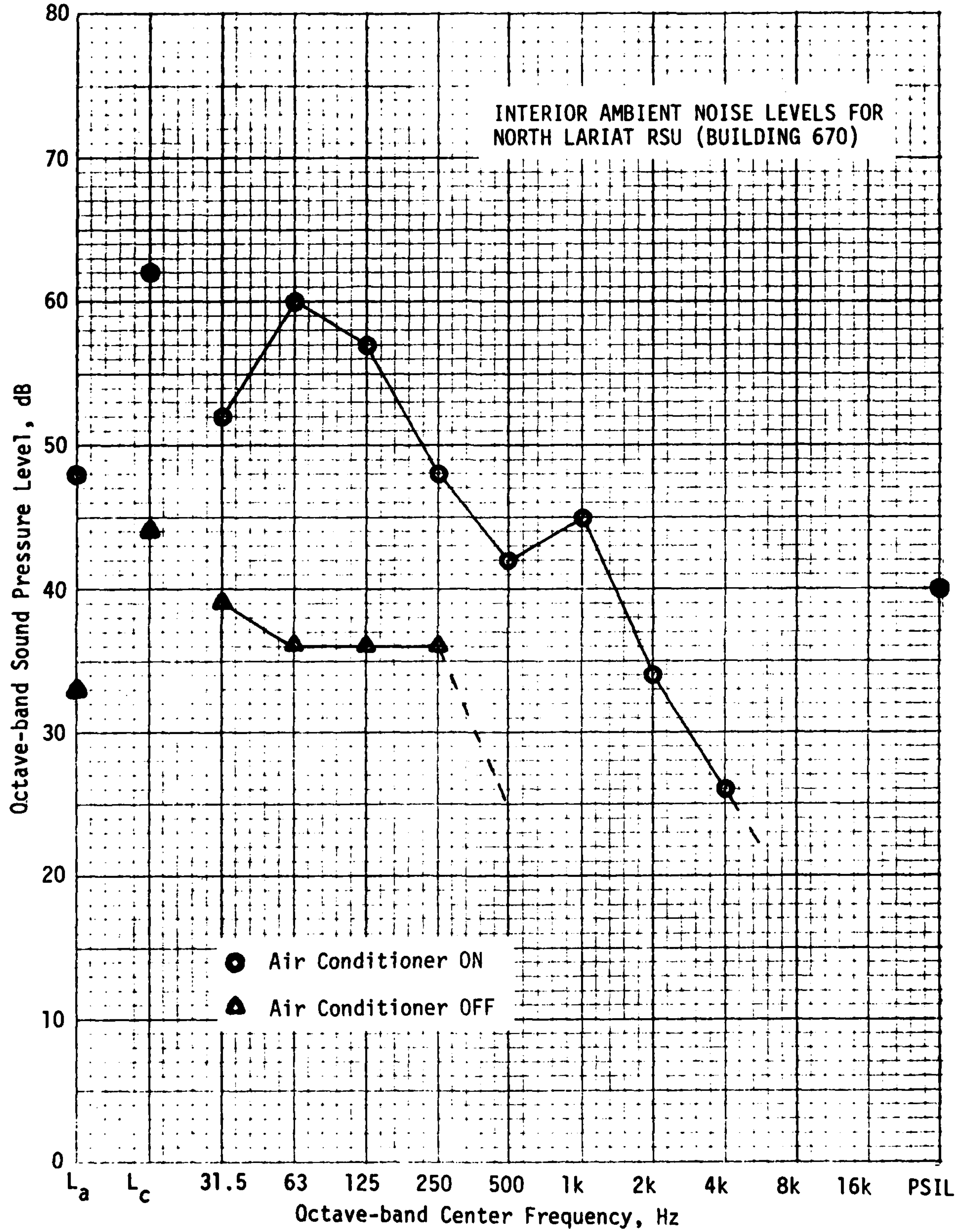

INTERIOR AMBIENT NOISE LEVELS FOR
NORTH LARIAT RSU (BUILDING 670)
Octave-band Sound Pressure Level, dB
80
70
60
50
40
30
20
10
0
Air Conditioner ON
Air Conditioner OFF
L_a
L_c
31.5
63
125
250
500
1k
2k
4k
8k
16k
PSIL
Octave-band Center Frequency, Hz

FIGURE 16

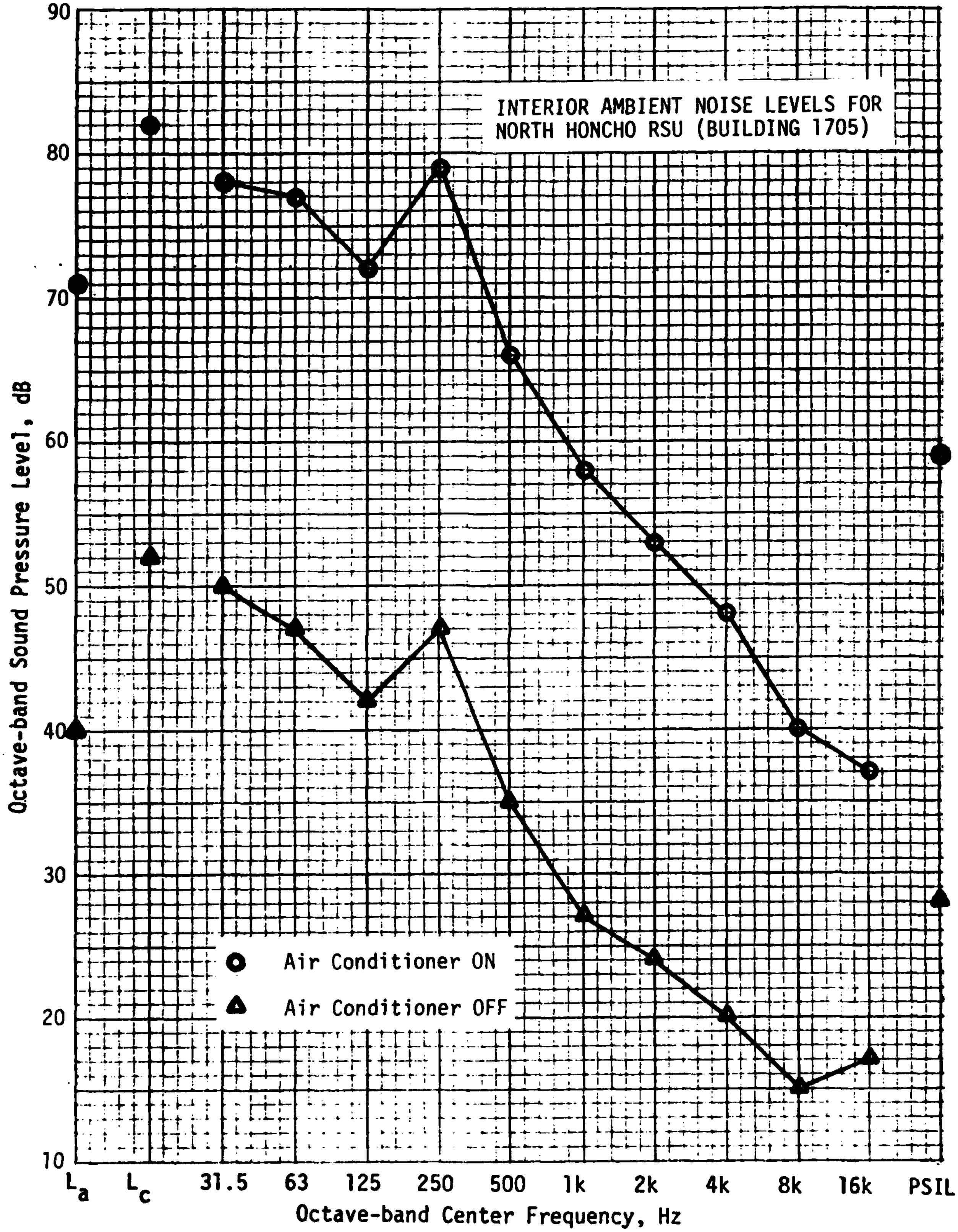

INTERIOR AMBIENT NOISE LEVELS FOR NORTH HONCHO RSU (BUILDING 1705)
Air Conditioner ON
Air Conditioner OFF
Octave-band Sound Pressure Level, dB
90
80
70
60
50
40
30
20
10
L_a
L_c
31.5
63
125
250
500
1k
2k
4k
8k
16k
PSIL
Octave-band Center Frequency, Hz

FIGURE 17

The noise data for the South Lariat RSU (Bldg 681) with the air conditioner OFF is not available but should be very similar to the data for the South Lariat RSU (Bldg 680), as they are identical units.

C. Exterior Noise Levels at Tower Height vs Ground Level: RSU personnel questioned whether the noise level at the North Honcho RSU (Bldg 1705) would be lower if the structure was located on the ground. A series of paired simultaneous exterior measurements were taken during T-38 takeoffs and averaged as above. The data were acquired at tower height (on the catwalk) and on the ground below. These data are given in Table 4 and shown in Figure 18.

IV. DISCUSSION:

A. As shown in Table 2, the average interior noise levels during T-38 takeoffs range from 83 to 95 dBA, while the average exterior noise levels range from 96 to 117 dBA. These high A-weighted overall sound levels appear to identify an environment hazardous to hearing, but these values which occur only during T-38 takeoff operations are maximum levels of short duration. RSU personnel man the unit for a four-hour period only several times a month. For North Honcho, AFR 161-35, Table 3, identifies 70 minutes as the maximum permissible daily exposure duration to a sustained level of 95 dBA on a routine basis. It is highly improbable that these personnel receive exposure to hazardous noise for the reasons stated above.

B. The PSIL is a measure to judge effective voice communications. Voice communication is affected by the speaker's voice level, the proximity between the speaker and the listener, and the level and frequency/temporal characteristics of the masking background voice. Maximum PSILs range from 76 to 90 dB during takeoff operations. With respect to the speech communication environment, the PSIL is greatest in North Honcho and lowest in North Lariat. According to AFR 161-35, the quality of person-to-person voice communication in North Honcho is rated as "extremely difficult" with a shouting voice at one to six feet between individuals, while electrically-aided voice communication is rated as "unsatisfactory." In comparison, at North Lariat, the person-to-person voice communication quality is rated as "slightly difficult" with a shouting voice at three to six feet between individuals; electrically-aided communication is "very difficult." As previously stated in the Introduction, speech intelligibility is critical to the operations performed in the RSUs. The existing environment constitutes a possible safety hazard. Consequently, these units are found to be unacceptable for voice communications.

C. Air Force Communications Service Regulation (AFCSR) 88-1, paragraph 2.a.(9), specifies a maximum interior ambient noise level for air traffic control towers (ATCT) of 55 dBA. The ambient noise is the background or general noise (including air conditioner noise) other than that caused by the source of interest (aircraft). Also the FAA sets desirable noise levels from 50 to 60 dBA for ATCT facilities to avoid "interference, discomfort, or annoyance" to operator personnel. Although these criteria are directed to ATCTs, we feel that the RSU is performing the same functions, often in a more demanding and critical manner. As can be seen from the data (Table 3), only North Lariat meets these criteria with an interior ambient noise level of 48 dBA with the air conditioner ON. All of the other units range from 71 to 72 dBA.

TABLE 4 - EXTERIOR NOISE LEVELS AT TOWER HEIGHT
VS GROUND LEVEL FOR N. HONCHO RSU

			OCTAVE BAND CENTER FREQUENCY, Hz										
LOCATION	L_a	L_c	31.5	63	125	250	500	1000	2K	4K	8K	16K	PSIL
Tower Height	102	105	79	89	95	98	99	97	97	90	77	58	
Ground Level	102	104	80	86	89	97	100	97	95	90	75	57	
Difference	0	1	-1	3	6	1	-1	0	2	0	2	1	

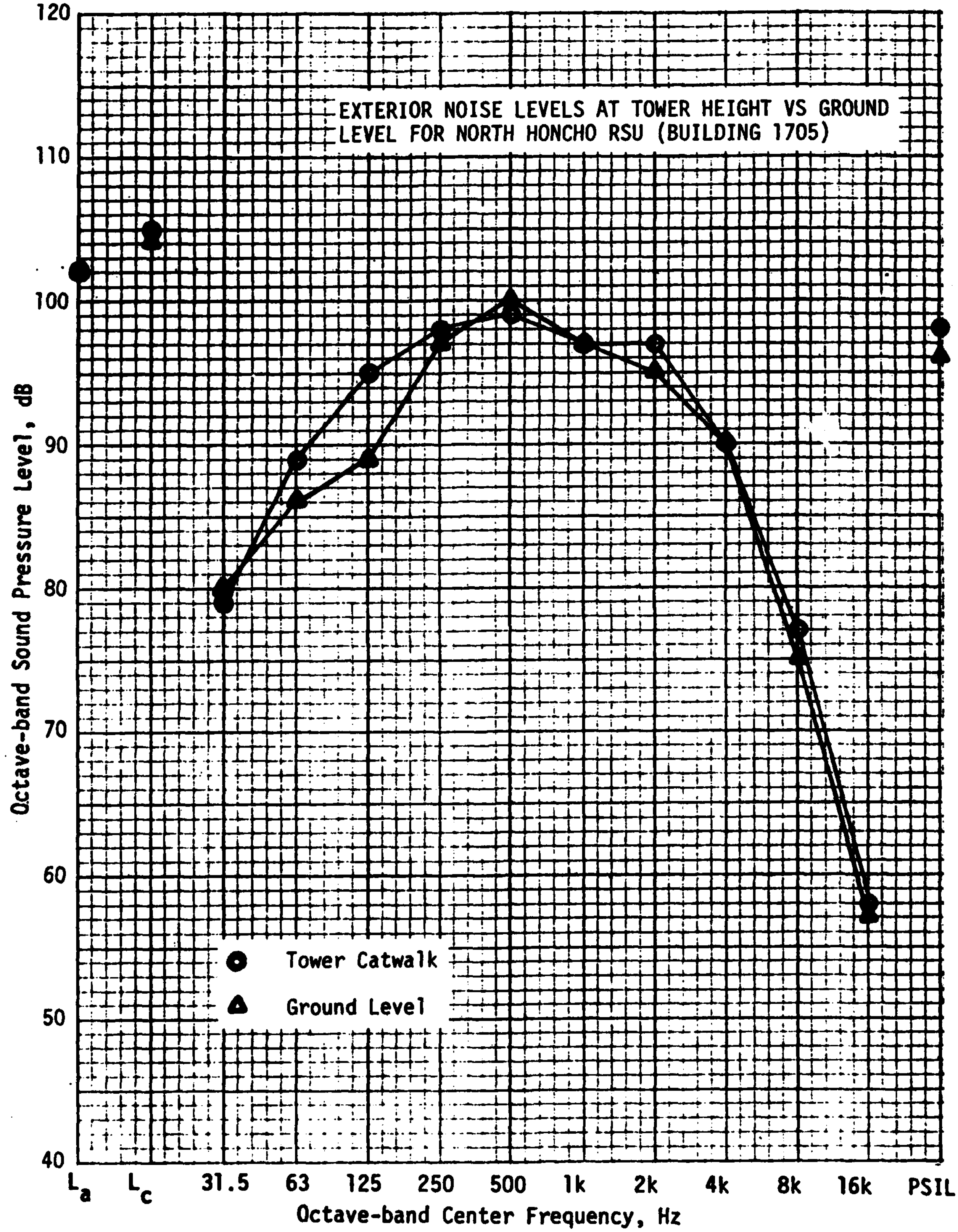

EXTERIOR NOISE LEVELS AT TOWER HEIGHT VS GROUND LEVEL FOR NORTH HONCHO RSU (BUILDING 1705)
Tower Catwalk
Ground Level
Octave-band Sound Pressure Level, dB
120
110
100
90
80
70
60
50
40
L_a
L_c
31.5
63
125
250
500
1k
2k
4k
8k
16k
PSIL
Octave-band Center Frequency, Hz

FIGURE 18

D. Because runway utilization is predominantly to the southeast (Runway 13), the north RSUs are heavily used, while the south units are seldom used.

1. The two major factors affecting the interior noise levels in North Honcho are the proximity of the RSU to the adjacent runway centerlines (see Figure 1), and its position relative to the start of takeoff roll.

a. The distance from North Honcho to either runway centerline is approximately 250 feet, whereas North Lariat is approximately 535 feet to the center runway. While it is advantageous from an operational point of view to site an RSU as close as possible to the runway, a trade-off between proximity and exterior noise level must be made. Theoretically, the noise level increases by 6 dB for every halving of the distance between the source and receiver. Air Force Manual 86-8, paragraph 20, allows an RSU to be located as close as 150 feet from the near edge of the runway. North Honcho is located essentially at this minimum distance (175 feet from the near edge of Runways 13C or 13R). The predicted exterior noise level for North Lariat (285 feet further away) is 7 dB lower for takeoffs on the center runway. In fact, an average decrease of 8 dB was measured.

b. For T-38 operations, which occur almost exclusively on Runways 13C and 13L, the J85 engines are at maximum power (Military Power with Afterburner) shortly after brake release. The distance from brake release to the aircraft's location when maximum noise is experienced by the RSU is shorter on Runway 13C than on Runway 13L. Because of the shorter distance on Runway 13C, the aircraft has not achieved as high an airspeed as the same type of aircraft using Runway 13L. Therefore, the duration of the maximum noise experienced by North Honcho will be greater than the duration experienced by North Lariat. The noise from the runway (Runway 13R), which is used exclusively for T-37 takeoffs, has a minor impact at North Honcho when compared with T-38 takeoffs.

2. Another factor affecting the interior noise levels in North Honcho is the construction of the unit. While not as bad as the three south RSUs, North Honcho was found to be in a very deteriorated condition. Leaks in the door seals appear to be a significant pathway for noise into this unit. The air conditioning unit and its associated ductwork provides another noise pathway. The noise reduction of the window panes could also be improved upon. Because of its more favorable location and its improved construction, North Lariat is superior to the other RSUs in terms of the A-weighted overall sound level.

The physical condition (acoustic leaks), and hence the noise reduction of the South RSUs, is worse than both north units. Also, the south RSUs are mounted on a steel frame support structure without a skirt, allowing noise to penetrate the floor. However, because of the physical location of the south RSUs with respect to the point of brake release and the type of aircraft involved, the maximum exterior noise is lower than that at the north RSUs. As a result, the interior acoustical environment (A-weighted overall sound level and PSIL) of all south units is comparable with North Lariat.

E.1. Noise reduction (NR)* as a measure can be misleading, as it does not account for other acoustic characteristics of the interior surfaces (i.e., the degree of absorbance or reflectance of sound). The measurements needed to account for such characteristics were beyond the scope of this project. Nevertheless, NR is an acceptable, albeit crude, indicator of RSU wall transmission performance.

E.2. Even though the noise reduction value for North Honcho is greater than the NR values for the three south units, the interior noise levels at North Honcho remain well above those of the south RSUs, for the reasons stated in paragraph D.1.a. and D.2. (nearness to the external source). The noise reduction value for North Lariat is only slightly better than for North Honcho, and is due to the internal room characteristics of North Lariat (i.e., the size and the acoustical absorption characteristics of the internal room surface area).

F. The difference in exterior levels at tower height versus at ground level (as shown in Table 4) is insignificant, both in terms of the A-weighted overall sound level and the critical speech communication frequencies (500, 1000 and 2000 Hz octave bands). There is no advantage in locating a unit at ground level in terms of noise. However, visibility of the surrounding area is greatly improved when the unit is elevated.

G. The suggested use of electronically-aided voice communication devices (e.g., modified H-133 headset with muzzle microphone) is probably limited in this environment and may further complicate working conditions by creating confusion and inducing fatigue. See Appendix A for a more detailed discussion of such a device. Because of the functional inconvenience of these devices, the emphasis should focus on engineering controls for improved communication environment rather than on personal communication devices.

V. <u>CONCLUSIONS</u>: The following conclusions are drawn from the discussion above:

A. The interior noise environment is not hazardous to hearing.

B. During takeoff operations, the speech communication environment is unsatisfactory and unsafe for all RSUs.

C. When aircraft operational noise is excluded, only the North Lariat RSU has an interior ambient noise level acceptable for speech communications.

D. Factors influencing the RSU interior noise levels are:

1. The distance from the runway to the RSU (distance-level trade-off).

2. The position of the RSU relative to the start of takeoff roll.

3. Construction (leaks, inferior noise reduction characteristics of the walls and windows).

*Noise reduction, expressed in dB, is the simple arithmetic difference between the exterior and interior overall sound pressure levels (OASPL). NR values, as used in this report, are based on C-weighted overall sound levels, because the OASPLs were not conveniently available. However, the C-weighted values are almost identical to the unweighted overall levels.

4. High noise levels and structure-borne vibration generated by the heating, ventilation and air conditioning (HVAC) equipment.

E. Increased use of sound absorbing materials on interior surfaces will result in reduced interior noise levels.

F. Locating the RSUs on ground level versus above the ground will not affect the exterior noise levels.

G. The use of electronically-aided voice communication devices does not provide a satisfactory solution to the speech communication problem.

VI. RECOMMENDATIONS: The recommendations are divided into those which can be done locally in a short time, and those which are more extensive, costly and therefore, long-term solutions. In the first case, the noise reduction techniques should be carried out by stages on a single unit, starting with the least expensive, easiest fixed, then progressing up through the more difficult, extensive and costly changes. In this way, one can properly gauge the progress of the control effort at each stage. Only after this process should other RSUs be modified, and then using only those techniques and materials found to be appropriate.

A. Interim Control Measures:

1. Walls.

A sound barrier or wall blocks the transmission of airborne sound from one place to another. The more massive and airtight, the more effective such walls become. Unfortunately, there is a trade-off between increasingly effective isolation and increasing mass of the wall (about 5 dB improvement for each doubling of mass). Large mass walls are difficult to build and very expensive. If a wall is divided into separate layers, preferably with no rigid connections between layers, a substantial increase in transmission loss performance occurs. Further attenuation occurs if sound-absorbing material is placed in the intervening airspace. To have any effect on low frequency noise, such as that generated by jet aircraft, the airspace should be at least six inches thick. A typical wall would be constructed as follows:

a. An outer wall constructed of 20-gauge sheet steel or aluminum.

b. Bond sheet lead or lead-loaded vinyl (a "limp wall" having a large surface weight, >2 lb/ft^2) to the inside face of this wall by a rubber-based contact adhesive.

c. Insert an airspace at least six inches thick and filled with a sound-absorbing material such as fiberglass wool, between this outer wall and an inner wall.

d. An inner wall of 22-gauge sheet metal.

e. Finally, face the interior (to room) surface of this wall with a sound-absorbing material such as 3/8-inch thick polyurethane foam bonded to perforated vinyl or tufted fiber skin to resist scuffing and abrasion.

f. Seal with a resilient nonsetting caulking compound any opening or penetration through the walls to the outside, including joints and corners, or holes through the floor to the tower cavity below.

Replace the painted acoustical tile in North Lariat.

2. Floor

a. In addition to the approach outlined above, install a short pile carpet above a 3/8- to 1/2-inch thick closed cell foam or rubber pad. The surface treatment of the interior walls and floor with sound-absorbing material is needed to reduce reflected sound levels. Remember, though, that almost one-half the interior surface area is glass, a highly reflective surface, which cannot be treated.

b. A skirt, the interior surface of which is lined with sound-absorbing material (fiberglass wool batts), installed around the support structure will reduce noise transmitted through the floor. Better performance can be achieved by mounting the RSU on a concrete block tower base. Again, line the interior surface with sound-absorbing material.

3. Door.

Construct the door in the same manner as the walls. Double seal any cracks around the door and floor threshold using soft resilient gasket or closed cell foam gasket-type material (see Figure 19).

4. Windows.

Windows are the weakest acoustical barrier in the wall and can nullify an otherwise excellent wall design. This is especially true in the case of the RSU with its large window surface area. At a minimum, the window installation should consist of two 1/4-inch thick panes of glass, each encased in a U-shaped soft, resilient gasket (e.g., neoprene rubber) with a 3-inch airspace between the panes. Line the perimeter surfaces within the framing (between the panes) with sound-absorbing material (acoustical tile). Visual problems such as parallax and multiple images, and the problem of moisture condensation between the panes of glass, must be considered in any design.

5. HVAC Equipment.

In order to reduce the interior ambient noise levels, treat or modify the heating, ventilating and air conditioning (HVAC) system as follows:

a. Install the air conditioning unit (motor-blower and the heating/air conditioning equipment) on a concrete pad on grade and separated from the RSU.

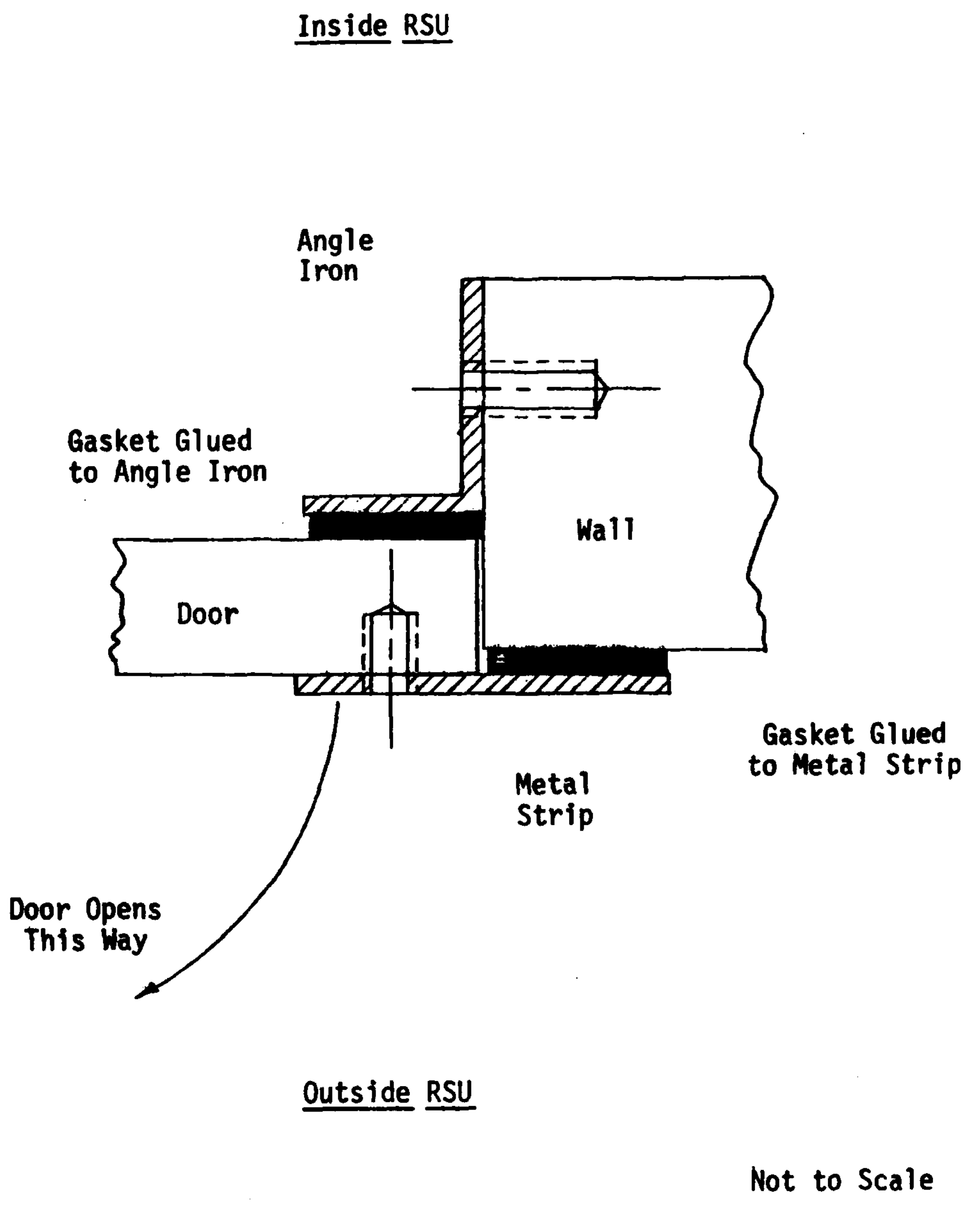


FIGURE 19 DOUBLE-SEALED DOOR

b. Vibration isolate the A/C unit from the mounting pad.

c. Install flexible canvas or plastic couplings on all ductwork connected to the A/C unit.

d. Noise can easily penetrate thin-walled ductwork and then travel down the duct run. Therefore, ventilation and exhaust ducts should be constructed of galvanized steel and lagged. Also route the ductwork to the RSU using an S-bend.

e. Fully line the ducts with 2-inch thick sound-absorbent material or equip with sound silencers, because metal ducts are extremely efficient transmission paths of airborne noise (see Figure 20).

f. Avoid sharp corners; use rounded duct corners or turning vanes.

g. Support the ductwork on resilient mounts or hangers to permit free expansion and contraction.

6. The use of electronically-aided voice communication devices is not recommended at this time.

B. <u>Long-term Recommendation</u>: Recommend ATC initiate an acquisition program to design and develop an entirely new RSU of modern design and using state of the art materials for ATC-wide use. The design should address all environmental needs, not just noise. Replacement with a new RSU of the same design as presently used is totally inadequate.

The Statement of Need should state specific requirements for performance, addressing the following:

1. hazardous noise exposure,

2. speech/radio communication environment,

3. thermal stress,

4. useful floor space,

5. visibility (adequate viewing area, minimization of obstructing members and blind spots, parallax, multiple images, and glare),

6. human engineering of equipment, and

7. sanitation facilities.

At a minimum, the RSUs are performing the same function as a standard ATCT plus critical observation of training aircraft during takeoff, approach, and landing operations.

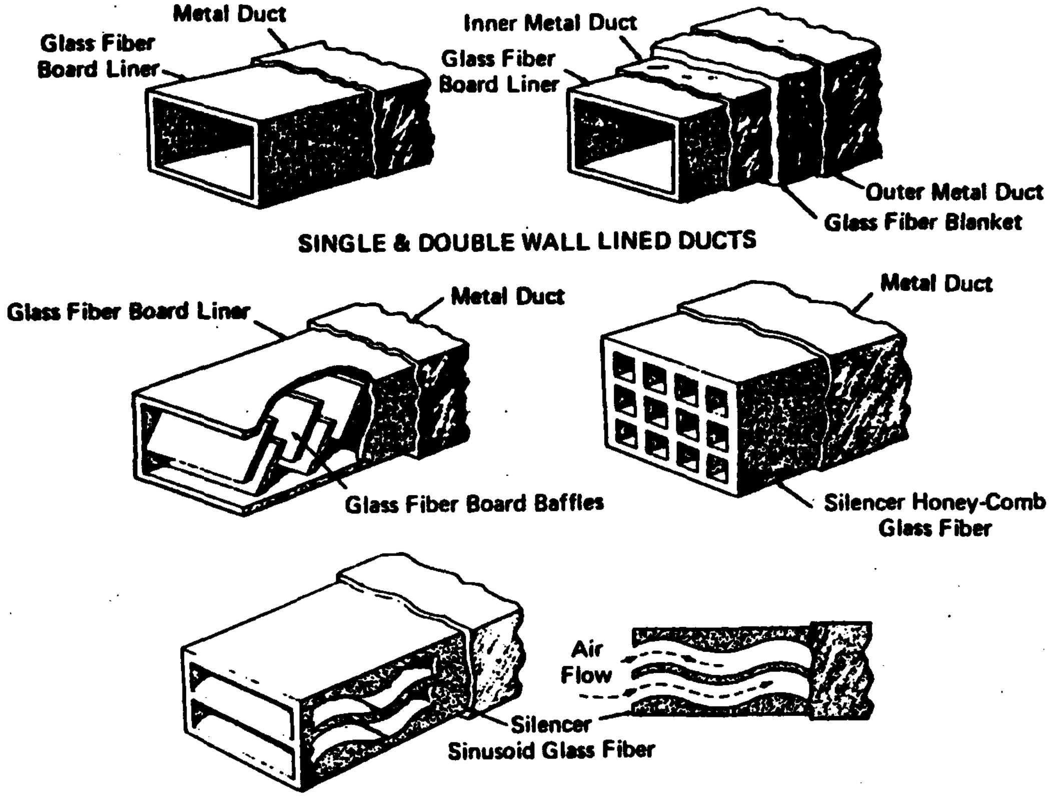


FIGURE 20 VARIOUS TYPES OF ACOUSTICAL DUCT LINING, BAFFLES, AND SILENCERS

C. List of Representative Sources

1. Development, Manufacture, and Installation of Engineered Noise Control Systems:

Industrial Acoustics Company, Inc.
1160 Commerce Avenue
Bronx NY 10462
(212)931-8000

2. Noise Control Materials:

a. Industrial Noise Control
312 Stewart Avenue
Addison IL 60101
(312)834-2000

b. The Soundcoat Company, Inc.
175 Pearl Street
Brooklyn NY 11201
(212)858-4100
Texas representative: Blair Engineering, Inc.
PO Box 35758
Houston TX 77035
(713)776-0011

c. Specialty Composites Corporation
Delaware Industrial Park
Newark DE 19713
(302)738-6800

d. Noise Control Division of Canada Metal Company, Ltd.
721 Eastern Avenue
Toronto, Ontario, Canada M4M 1E6
(416)465-4684

e. Sorber Soundproofing Division
8 Aaron Street
Framingham MA 01701
(617)879-2140

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7. Miller, R.K. and W.V. Montone, "Handbook of Acoustical Enclosures and Barriers," The Fairmont Press, Inc, 1978.

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APPENDIX A

EAR INSERT COMMUNICATIONS UNIT FOR HIGH INTENSITY GROUND NOISE ENVIRONMENTS

MEMO Technology Application

Subject: Ear Insert Communications Unit for High Intensity Ground Noise Environments

Initiator: 6570 AMRL (BBA)
WPAFB, Ohio

Introduction

Air Force aircraft ground maintenance operations produce noise environments that exceed 140 dB at some personnel locations. Safety and communication problems occur when noise levels exceed 135 dB even with maximum available protection. These problems may be relieved by a terminal equipment modification that improves both hearing protection and voice communication effectiveness of the protector-communication headset. Acquisition of appropriate components and modification of the hearing protector-communication headset can be accomplished locally with a minimum of resource expenditure. This document provides detailed information and instruction for implementing the change. Although the specific components listed have been utilized successfully, substitution of equivalent items should also prove satisfactory.

Current Air Force Technology

The current Air Force standard hearing protector-ground communication headset (H-133) with microphone-noise shield, is designed to operate in broad band noise fields at levels of about 135 dB and below. Field experiences indicate that the H-133 does not provide adequate hearing protection or satisfactory voice communication in noise levels in excess of 135 dB. No efforts are planned or underway to improve or replace the current AF standard H-133 ground communication headset unit.

Operational Problems

Air Force aircraft ground maintenance and flight line noise environments of 135 dB and higher create problems for personnel wearing the standard H-133 ground communication headset, depending on duration, with respect to, (a) increased hearing risk due to excessive noise exposure at the ear, (b) degraded voice communication due to temporary hearing loss and to the masking effect of the noise which increase the probability of communication errors and (c) reduced daily time on the job due to limitations imposed by the daily allowable noise exposures defined in AFR 161-35, Hazardous Noise Exposure. Problems associated with these very intense exposures have already been identified relative to some ground operations with F-15, F-16, T-33 and earlier, with the F-111 aircraft.

General Technology and Application

It is well established that the reception of voice communication in noise with conventional electroacoustic transducers and noise shields is generally maximized with (a) a good noise excluding earmuff and (b) communications equipment with the signal coupled to the ear via some form of well-fitting insert device. In a "Study and Investigation of Specialized Electroacoustic Transducers for Voice Communication in Aircraft" (AD document 212459 and Appendices 1 to 6, AD 212210) reported in 1960, use of insert unit coupling of the communication signal to the ear under a noise excluding helmet is identified as the most effective approach to this problem. The usefulness of this combination communications-noise exclusion concept is limited by the response of the human ear which will overload when the communication signal is too high.

The technology underlying this approach substantially eliminates some problems with communications headsets in which conventional receivers are mounted in earmuffs. The earmuff requires a large internal volume for maximum effectiveness, whereas the communications receiver requires a very small volume for the most effective coupling of the signal to the ear. The approach described herein provides very efficient coupling because the receiver must drive only the very small volume under the earplug (a few cc). The large volume required for the earmuff performance is also retained. Also, the (custom molded) insert device provides additional hearing protection to that provided by the earmuff which results in a highly desirable speech-to-noise ratio.

This technology concept has been applied to a specific AF ground communication-in-noise problem. It involves a simple modification of the standard H-133 ground communication unit that results in substantial improvement in both hearing protection and voice communication in severe noise environments. The modification utilizes a custom molded ear insert earplug attached to a miniature receiver that is worn under the H-133 earmuff. Specifically, the standard earphone (H-136) is removed from one earcup and the wires are reconnected to a miniature receiver-earplug device. Greater hearing protection is obtained from the earplug worn in combination with the earmuff than from the earmuff alone. Communication is more effective with the improved signal-to-noise ratio under the earplug resulting from the increased noise exclusion and a stronger communication signal from the miniature receiver. A simple plug-in adaptor box will allow the incoming signal to be adjusted to a level at which efficient voice communication may be maintained.

Specific Application

This technology has been applied to ground maintenance noise problems for the F-15 and F-16 aircraft programs at Edwards AFB and its superiority over the H-133 ground communication units in this special situation has been demonstrated.

Benefits to Air Force

The most direct benefits apply to AF ground maintenance and flight line personnel and involve increased safety and effectiveness. Specifically these include (a) improved hearing protection, (b) satisfactory voice communication, (c) retention of personnel in high level noise for longer periods of time each day (AF 161-35, Limiting Values for Total Daily Exposure) and (d) features such as less discomfort, increased confidence in voice messages, and the like, which also are realized.

Modification Instructions

Table 1 contains a list of the components used in the modification illustrated in the various figures. Any equivalent component that is compatible with the equipment operation and use is acceptable. In addition to the equipment modification, individual custom molded earplugs must be obtained for the ears in which communication will be accomplished.

Custom Molded Ear Inserts. Custom molded ear insert earplugs are fabricated from individual impressions of the ears in which the devices are to be worn. The impressions, which should be taken only by qualified and trained personnel, are sent to a fabricator who constructs from the impression a mold that is used to make the actual earplug device. The earplug must be identified to the fabricator as a "communication insert with snap ring adaptor" to accept hearing aid or button type receivers. Otherwise, the custom molded earplugs provided by the fabricator may be solid and not prepared with snap ring to accept the miniature receiver.

It is critical that the custom molded unit be well fit and that the portion that extends into the ear canal of the wearer be sufficiently long to accomplish a good seal. Substantial amounts of hearing protection may be lost when the canal portion of the earplug is too short to provide an adequate acoustic seal. Some AF installations have the capability to provide custom molded ear insert devices. However, most installations may find it necessary to procure these units from a reliable vendor. It is not advisable for inexperienced personnel to attempt to take ear impressions. Advice regarding vendors and the making of impressions of ears for use in fabricating the custom molded earplugs may be obtained locally or from AMD, AMRL/BBA, 255-3607 or 255-3660, (Autovon 785-3607) if desired.

Terminal Equipment Modification. The actual modification of the H-133 communication headset may be accomplished by completing the following steps.

Step 1. The earmuff sponge filler inserts and the H-136 earphones (Figure 1) are removed from each of the earcups and the two wires (red and green) disconnected from the earphones using a very small Allen wrench. Neither H-136 receiver is replaced.

Step 2. The two wires from the earcup to which the insert receiver will be attached are then connected to one part of the mating plugs (Mosley connector) by tightening the slotted retaining screws. (See Figures 2 and 3). The two wires from the other earcup are insulated from one another (taped) and replaced in the earcup along with the sponge filler inserts.

Step 3. The cable from the Telex receiver is cut to a length of about 12 inches. The leads are stripped and tinned or are soldered to pins that fit into the other part of the Mosely connector and are held in place by tightening the slotted retaining screws. (Figures 2 and 3).

Step 4. The Telex receiver is "snap" attached to the custom insert earmold (Figure 3) by the standard snap ring connector. An assembled modified system is shown in Figure 2 prior to attachment of the Mosely connector to the existing receiver mounting post inside the earcup.

Step 5. A 1/8" hole is drilled into the center of the Mosely connector which is assembled and attached to the inside of the earcup on the existing receiver mounting post, using a #4, 5/8" self-tapping screw. The earcup filler materials are replaced in the earcup over the connector.

Adaptor Box. The level of the communication signal at the ear is substantially greater with the ear insert system than with the conventional H-136 receiver for the same gain setting. An adaptor box, with appropriate plugs, is inserted in the communication system before the earmuff system to allow the user to adjust the signal to an appropriate level. In practice, this means reducing the level of the communication signal to within a comfortable range. Ideally, the signal should be adjusted to the lowest level that will provide satisfactory voice communication in the specific noise environment. Pictorial views of the adaptor box are presented in Figures 4 and 5 and the electronic schematic in Figure 6. The diode circuit constitutes a safety feature that limits the transmission of very intense signals through the adaptor box. This adaptor network can be assembled in accordance with the schematic and the illustrations using the appropriate components listed in Table 1. The physical characteristics of the box are not critical and can be any reasonable size or shape, however, the electronic characteristics must be satisfied to insure proper operation. The open adaptor box is shown connected to the earmuff system in Figure 7.

Utilization: Wearing the Device

Some practice may be required in donning and removing this system. The earmuff headband can be placed behind the neck, as shown in Figure 8, or with the headband over the head with earcups forward resting on the cheeks. The custom molded unit is then inserted into the appropriate ear (Figure 8) and a standard insert earplug is placed in the other ear. The earmuffs are then placed in position over the ears as shown in Figure 9, taking care to insure that the wire is entirely inside the earcup. If the earcup cushion rests on the wire an acoustic leak will occur and a loss of low frequency protection may be expected. The same procedure is followed, in reverse order, to remove the units. It would be desirable to use a receiver wire that is permanently coiled so that it would automatically retract during donning of the earmuff and thus decrease the need to manipulate the wire under the muff and the possibility of resulting air leaks. However, an appropriate pre-coiled wire could not be found at the time the systems were prepared for use in the field.

Summary

This memo describes a ground communications headset modification that will improve hearing protection and voice communication at reasonably small cost. The critical factors to insure the increased performance are (1) an insert type coupling of the communication signal and (2) good noise excluding earmuffs. Although these conditions can be satisfied in other ways, the components and procedures described herein have proven successful in the operational situation.

TABLE 1

Component Parts List*

Item	Description	Manufacturer and Model	Number Required	Cost
1.	Receiver, "Button" Type	Telex, 15 ohm	1	2.95
2.	Cable	Telex, CMT-92	1	2.65
3.	Connector	Mosley, 301	1	0.75
4.	Connector	Mosley, 311	1	0.75
5.	Potentimometer	HMP 5000 ohm (Centralab RY4NAYSD502A)	1	2.13
6.	Diode	ECG 5081	2	0.85
7.	Resistor	27 ohm	1	0.25
8.	Plug	U-93 A/U 5935-00-66420626	1	2.73
9.	Jack	U-92 A/U 5935-00-665-5125	1	2.20
10.	Miniature Case	Aluminum 4" x 2.5" x 1.6" CU30002A' FSN5975-825-5421	1	0.60
11.	Ear Impression Mix**	T-4 (24 bottles)	1 unit	8.45
12.	Custom Ear Insert**	Silicone	2	8.00 each

*These parts were used in successful modification; equivalent items are acceptable.

**This manufacturer provided satisfactory materials and service. Note that the liquid "setting solution" in the impression mix kits usually has a shdf-life of about 6 months.

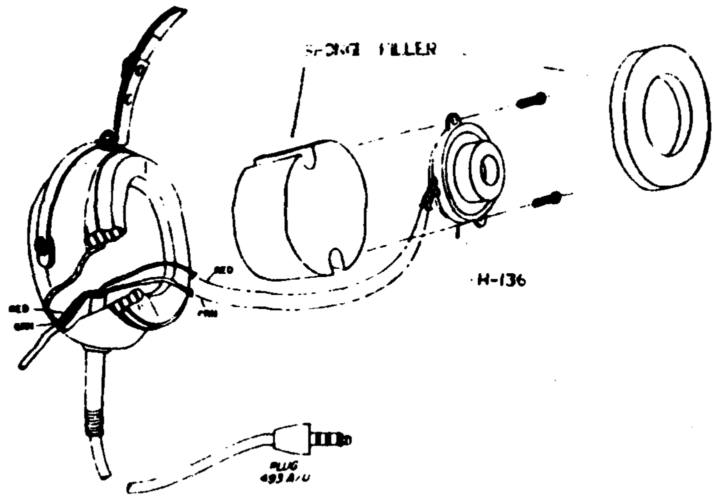


FIGURE 1

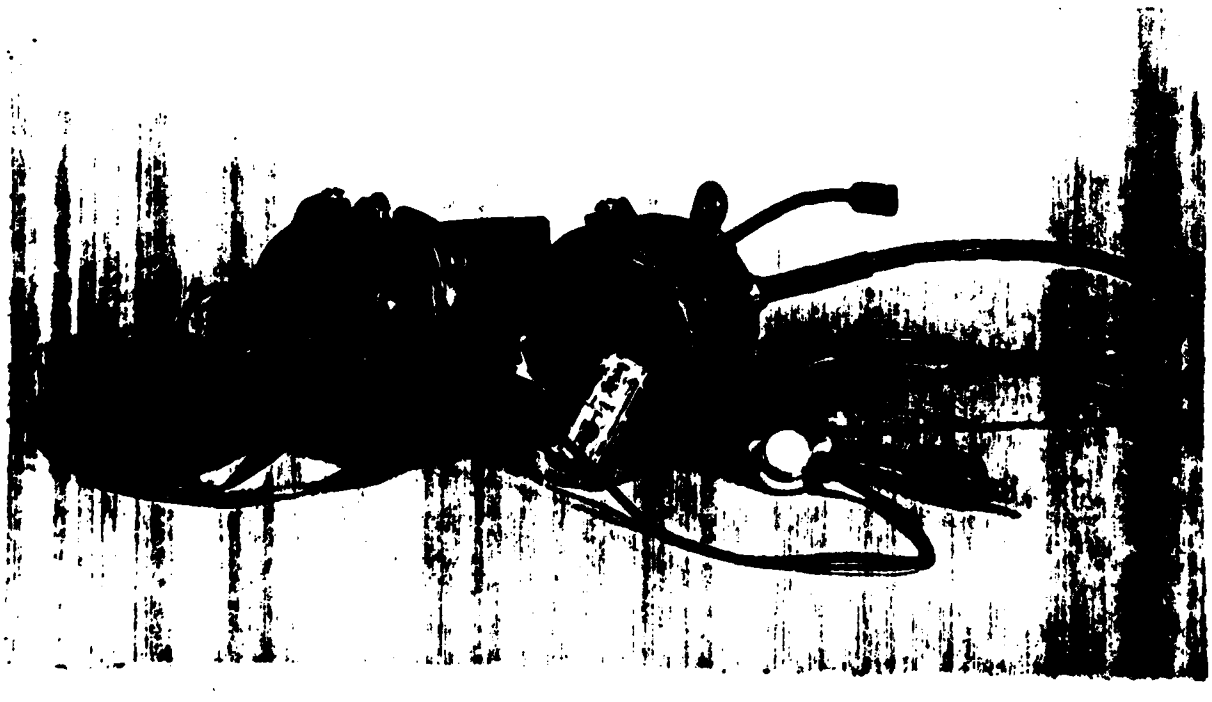


FIGURE 2

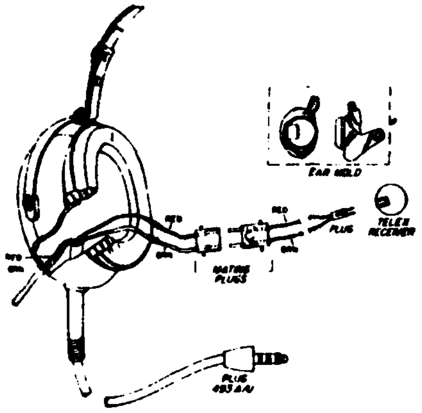


FIGURE 3

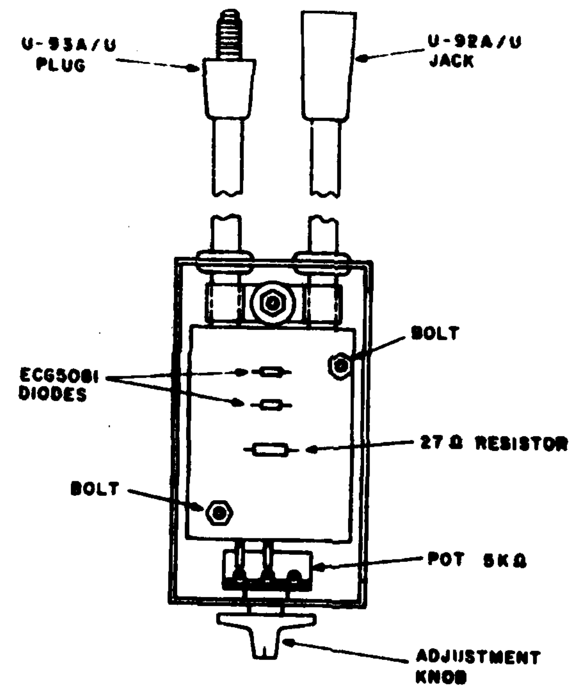
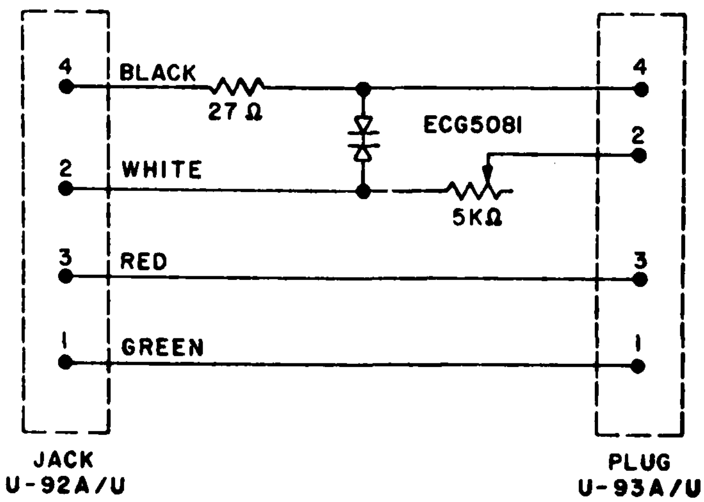


FIGURE 4


4
BLACK
27 Ω
ECG5081
2
WHITE
5KΩ
3
RED
1
GREEN
JACK
U-92A/U
PLUG
U-93A/U

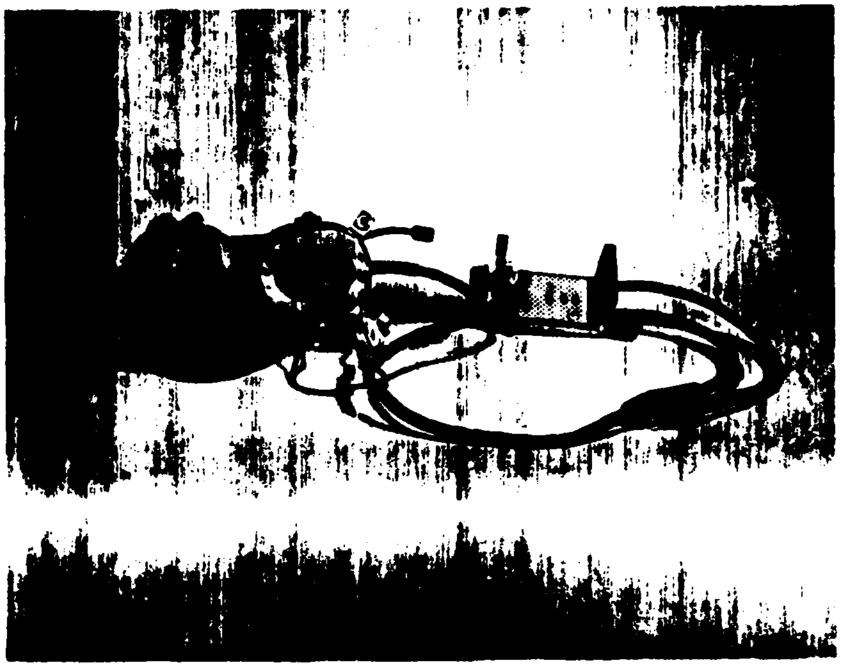


FIGURE 7

Figure 8

DISTRIBUTION

	COPIES
ATC/DOTA Randolph AFB TX 78148	2
ATC/SGPA Randolph AFB TX 78148	7
47 FTW/DO Laughlin AFB TX 78840	1
47 FTW/DOOB Laughlin AFB TX 78840	1
47 FTW/DOTA Laughlin AFB TX 78840	1
47 FTW/SE Laughlin AFB TX 78840	1
47 CES/CC Laughlin AFB TX 78840	1
85 FTS/DOV Laughlin AFB TX 78840	1
86 FTS/DOV Laughlin AFB TX 78840	1
USAF Hosp/SGPM Laughlin AFB TX 78840	1
USAF Clinic/SGPM Randolph AFB TX 78148	1
AFMSC/SGPA Brooks AFB TX 78235	1
AFSC/SGP Andrews AFB MD 20443	1
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USAFSAM/NGEA Brooks AFB TX 78235	1

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