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FOR HEALTH & ENVIRONMENT

NOISE ASSESSMENT OF THE ROCKET SLED TEST TRACK OPERATION AT HOLLOMAN AFB NM

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Final Report

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USAF Occupational and Environmental Health Laboratory
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Brooks Air Force Base, Texas 78235-5501

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This report presents the results of noise data measurements of the Holloman AFB rocket sled test track operations. Impulse and community noise measurements were made to determine the impact of the rocket sled noise on the surrounding community. A worst case sled run was measured and used to determine that the rocket sled has very little impact on the community for a worst case rocket sled run and little or no impact for the majority of the runs. Recommendations were made to limit the number of people exposed to the rocket sled noise and require test track personnel to wear hearing protection. Sonic boom measurement equipment should be purchased to document all sonic booms created by the rocket sled.

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CONTENTS

I. INTRODUCTION

A. Purpose: This report provides the results of noise data analysis recorded during the 11-16 Apr 88 noise survey conducted by USAFOEHL and the noise data the Holloman 833 Medical Group/SGPB collected 20-30 Apr 88. This survey evaluated the noise characteristics of the Holloman Rocket Sled Test Track Operations at Holloman AFB NM. The 6585th Test Group had requested a noise survey be performed by the base bioenvironmental shop. Since this particular noise survey was beyond the bioenvironmental shop's capabilities, they in turn requested USAFOEHL send a noise team to do on-site monitoring and assess the noise from the test track operations.

B. Problem: The 1972 environmental assessment for the 6585th Test Group was no longer valid, and a new assessment had to be completed in order to continue mission essential operations. The 6585th Test Group needed to include an assessment of test track noise in the new environmental assessment.

C. Scope: This report provides the results of an in-depth community noise survey and impulse noise levels from a worst case sled run. The report discusses the most current measurement and evaluation techniques of impulse noise created by sonic booms. The report recommends reducing the number of people being exposed and requiring test track personnel within six miles of the test track wear earmuffs or plugs. Also, sonic boom measuring equipment should be purchased to document noise exposures.

II. DISCUSSION

A. Methodology. There were several different measurements required to assess the impact of sonic booms including composite average day-night sound level (CLdn) and sound exposure level using both A- and C-weighting (SEL and CSEL). (Complete definitions of these measurements can be found in Appendix E.) CLdn, SEL and CSEL measurements were used to determine annoyance due to auditory stimulation and building vibration while peak pressure measurements were made to determine possible structural damage and health effects. Two different types of noise surveys were performed: CLdn measured at ten sites with noise dosimeters, and noise recordings at two of the ten sites to determine the impulse noise generated by the rocket sled. Appendix A, Figure A.1 shows the ten locations. Table A.1 is a listing of the sites. When appropriate, corrections were made for meteorological conditions.

1. Day-night Levels: The average day-night sound level (Ldn) was measured at the ten sites chosen by representatives of Holloman AFB and USAFOEHL personnel to represent locations where people work or rest. Locations in close proximity to the test track were also selected where impacts might be produced by test track noise. Noise dosimeters were used at each site to measure the Ldn by recording 24 hour periods. Each dosimeter was attached approximately 1.75 meters above the ground to poles, fences, or trees. The dosimeters used one hour averaging intervals. In order to calculate a Ldn, the dosimeter used a doubling rate of 3 decibels (dB). Ten dB was added to each hourly Average Sound Level (Lavg) from 2200 to

0700. Each dosimeter also calculated a peak noise level, an intrusive noise level, a median noise level, and a background noise level. (The definitions of these noise levels are defined in Appendix E.) It should be noted only four of the ten sites are reported due to equipment problems. Appendix A, Figures A.2 through A.5 show the location of these four sites.

USAFOEHL collected three nonconsecutive 24 hour periods between 1900, 11 April 88 and 2100, 15 April 88. The 833rd Medical Group/SGPB collected data on five more nonconsecutive days between 20 and 30 April 88. Appendix B, Tables B.1 through B.4 list the Lavgs for each hour of the Ldn data and the Ldn for that site and time period. The hourly values shown do not include the 10 dB added for the 0700 to 2200 time period to compute Ldn. In Appendix B, Tables B.5 through B.8 the peak (as defined by the level exceeded 1% of the time during the sampled period), intrusive, median, and background noise levels are also reported.

2. Impulse Noise Levels: An additional noise measurement technique was used at sites 1 and 3. These noise measurements were made during times when the rocket sled was being fired. Appendix C, Figure C.1 shows the actual measurement points at sites 1 and 3. The noise data were collected on audio tapes using portable tape recording systems. The tapes were later analyzed at USAFOEHL. The microphones of the systems were attached to tripods at an approximate height of 1.75 meters. At site 1, the microphones were parallel to the ground and pointed parallel to the test track. At site 3, the microphones were perpendicular to the ground because the exact location of the test track was not known. After returning to USAFOEHL, these recorded noise data samples were then transferred to a Nicolet digital storage scope and the peaks were determined and recorded on a digital storage disk. Figures C.2 and C.3 are the waveforms created by the sonic boom on 13 April 1988 at positions 1 and 3. Also, a fast fourier transform was performed on these waveforms to determine which frequencies contained the most energy.

3. Composite Day-night Levels: A composite day-night average sound level (CLdn) was determined by logarithmically adding the Ldn for the day of interest and the individually measured CSEL for the event. The CSEL for the event was determined by playing the recorded tapes through a sound level meter which calculated CSEL and SEL. The combined Ldn and CSEL are reported in Appendix C, Table C.1.

B. Standards: There have been several groups, including the EPA, which have discussed the measurement and limitation of noise associated with sonic booms. No one standard has been adopted as law. However, the information contained in this report is based on the methodologies developed by these groups.

1. Military: The impulse noise limit used by the Air Force[1], Army[7] and OSHA[6] to preserve health in an occupational setting without protective equipment is 140 dB or 200 Pascals (Pa) (4.18 pound per square foot [psf]) peak sound pressure level. However, there are no nonoccupational criteria.

2. National Aeronautics and Space Administration (NASA): NASA studies show no structural damage, excluding glass or window breakage, will occur at pressures below 11 psf (527 Pascals or 148.4 dB). As for glass breakage, an average of only 1 pane in 833 panes can be expected to be broken by sonic booms of 4 psf.[3] Appendix D has a full discussion of damage assessment for health and structure damage including glass breakage.

3. EPA: The EPA has recommended a Ldn criteria of 55 dB. For sonic boom peak sound pressure levels, the following formula is used by EPA to determine little or no public annoyance for daytime levels:

$$\text{Peak Level} = 35.91/N^{0.5} \text{ Pascals}$$

N = the number of events in a 24 hour period.

For a single event this would be a level of 35.9 Pascals or 125 dB peak. There is no legal standard for impulse noise. There are only studies of possible hearing damage and nonauditory effects of impulsive sound with recommendations based on these studies.

a. Hearing: EPA concluded a peak sound pressure level of 145 dB should not be exceeded. This would prevent a permanent hearing loss no greater than 5 dB after 10 years of daily exposure.[12]

b. Nonauditory effects: Impulses 10 dB greater than background noise are potentially startling or sleep-disturbing. However, there is no clear evidence of any permanent effect on public health and welfare.

4. HUD: The Department of Housing and Urban Development (HUD) uses a standard of 65 dB for a Ldn criterion around airports. Also, Bolt Beranek and Newman, Inc. (BBN) prepared a noise assessment guideline for HUD.[11] Appendix C, Figure C.4 is the recommendation BBN made to determine whether or not an area is acceptable for a housing development sponsored by HUD. The number of events allowed versus the energy average sound exposure level is used to define a line between acceptable and unacceptable levels. A single event producing 107 dB is one limiting point.

C. Results:

1. Military: The peak sound pressure at site 1 was 148.5 dB and site 3 was 140.3 dB (Appendix C, Table C.1). Sites 1 and 3 exceeded the military standard of 140 dB for impulse noise.

2. NASA: The peak sound pressure at site 1 was 11.1 psf and site 3 was 3.4 psf. NASA tests show building structures in good repair should not be damaged at boom overpressures less than about 11 psf. Site 1 exceeded this value while site 3 did not. Also, at site 3, the probability of window breakage was approximately 0.00075 or 1 pane in 1333 panes. At site 1, a probability was not defined for a boom of that magnitude but was greater than 1 pane in 250 panes.

3. EPA: Both the Ldn and the CLdn at all sites measured and reported exceeded the EPA standard of 55 dB. The median Ldn for site 1 was 73.6, site 2 was 61.2, site 3 was 63.0, and site 6 was 63.0. (Appendix C, Table C.2).

4. HUD: The sites located off base were within the HUD standard for acceptable housing areas of 65 dB. A CLdn was calculated for sites 1 and 3. The CLdn for site 1 was 73.8 dB and

for site 3 was 63.1 dB. (Appendix C, Table C.2). The SEL at site 1 was 89 dB and 85 dB at site 3 (Appendix C, Table C.1). The SEL at both locations were acceptable according to the guidelines developed for HUD of 107 dB for a single event SEL (Appendix C, Figure C.4). For Sites 1 and 3, the majority of the energy was located below 70 Hertz (Hz). The peak energy for site 1 was concentrated at 10 Hz, and for site 3 at 5 Hz.

D. Observations: Rather than measure a large number of sonic booms produced by various types of sleds it was decided to measure the largest expected sonic boom produced in recent history. If this worst case run produced little or no effect, the most practical and cost efficient noise impact survey of the test track would have been accomplished and lesser booms would be expected to create significantly less impact or no impact. Therefore, on 13 April 88, USAFOEHL personnel measured one of the worst cases of noise expected by test track personnel. Also, it should be noted, peak pressures from sonic booms increase as vehicle speed increases from Mach 1 to Mach 1.5 and then start to decline. In this case, the test track vehicle speed was approximately 1.5 Mach.

1. Sites: Even though Ldns were only obtained on four of the ten sites, sufficient data was collected to make decisions about noise from rocket operations.

2. Ldn: Due to the way the Ldn is mathematically calculated, the peak from the sonic boom will have little effect on this daily average. Also, the primary energy created by the sonic boom is low frequency. An A-weighted Ldn will not weigh this energy as significant. CLdn or composite Ldn takes this into account by adding the CSEL of the event times the number of events to the Ldn. Since the CSEL uses a C-weighting scale, low frequencies are more heavily weighted than with A-weighting. However, since there is only one sled run per day, the peak still has little effect.

3. Impulse measurement: In Appendix C, Table C.1 and Figure C.2, there appears to be minor electronic overload or clipping at site 1. The clipping was due to the wrong attenuation setting on the tape recorder. Also, listed in the same table is information obtained by Air Force Weapons Laboratory (AFWL) at site 3.[5] The difference is less than 3 dB for peak levels and less than 1 dB for peak to peak measurements.

4. Propagation of Sound: The sound generated by the test vehicle approximated the sound propagation of a line source. The sound created by a line source decreases 3 dB for every doubling of distance. Using this assumption, a peak level can be determined at different sites around the test track. This was done to calculate the peak level at the property boundary in Appendix C, Table C.1.

5. Standards: There is no standard for nonoccupational impulse exposures. Therefore, the guidelines used to determine whether or not an area is acceptable for habitation would be of greater concern. The test track noise at the property line of the White Sands Missile Range does not exceed any HUD impulse standards. The most widely accepted and used standard is HUD standard of 65 dB. The once a year worst case rocket sled will probably not do any structural or permanent health damage to anyone in the surrounding community because of the infrequency of the loud sonic boom.

6. Vibration: House vibration typically occurs in the 10-30 Hz frequency range.. Therefore, the sonic booms created by the rocket sled runs can be expected to induce vibration in surrounding buildings.

7. Sonic Boom Measurement Equipment: If in the future, there is litigation by home owners about glass and structure damage, the Holloman test track should be prepared to confirm or deny these allegations. This can be accomplished by buying sonic boom measuring equipment and documenting all future sled runs. The Armstrong Aerospace Medical Research Laboratory (AAMRL) at Wright-Patterson AFB OH is currently deploying this type of instrumentation. The name of the instrument is Boom Event Analyzer and Recorder System (BEARS). Appendix F has a description of the equipment. In addition, there is talk of bigger and louder sleds combined with detonation of high explosives. If in the future, these possibilities become reality, the test track could document them and be able to update the environmental impact statement.

III. CONCLUSIONS

A. Community outside Holloman AFB and White Sands Missile Range: Even the worst cases of noise created by rocket sled runs would have minimal effects on the community. The community around the test track would not be expected to have any permanent or temporary health effects created by the sonic boom. However, there could be a startle effect on unsuspecting individuals up to 10 miles away from the track when a large sonic boom occurs. There are no known health effects related to the startle effect. The energy from the sonic booms will not do any structural damage to any buildings located off the missile range. There is a chance that large sonic booms might damage windows. However, the chance of glass breakage at the property line of the missile range east of the test truck is only 1 in 100 and six miles away from the test track it is 1 in 833. Therefore, it is safe to say that on the majority of test track runs there is no impact at all, and, in the worst-case scenario, there is only a small chance of window breakage.

B. White Sands Missile Range Reservation and Holloman AFB: Test track personnel exposed to the noise created by the rocket sled and located within six miles of the test track should wear hearing protection. Those individuals on the base or military reservation who are incidently exposed--that is those who do not work at the test track on a continuous basis do not require any protection. Also, there is a chance of window breakage of buildings on the base and military reservation.

IV. RECOMMENDATIONS

A. Limit the number of military personnel and families within six miles of the test track when a large sonic boom is expected.

B. As a minimum, require individuals routinely associated with test runs and located within six miles of the test track wear earmuffs or plugs.

C. Purchase sonic boom measuring equipment such as described in Appendix F and use it to document all sonic booms.

REFERENCES

1. AFR 161-35, Hazardous Noise Exposure (9 April 1982)

2. AFM 19-10, Planning in the Noise Environment (15 June 1978)

3. "Assessing Noise Impact of Air Force Flying Operations." USAF/LEEVX (Mar 1984)

4. Carrol, Michael M. "Introduction to Noise and Acoustic Terminology." Community Noise Control: Prediction, Measurement, and Regulation, A two day conference/Dec 2-3, 1976/San Francisco CA, Continuing Education in Engineering, University Extension, and The College of Engineering, University of California, Berkeley (Dec 1976)

5. "Far Field Airblast Measurements on the HEDI Sled Test Event." AFWL/NTESG, Kirtland AFB NM (Jun 88)

6. Johnson, Daniel L. "Highlights of the Guidelines for Environmental Impact Statements with Respect to Noise." Aerospace Medical Research Laboratory Technical Report No. AMRL-TR-78-14, (Dec 1979)

7. MIL-STD-1474B(MI), Noise Limits for Army Materiel (18 June 1979)

8. Thackray, R.I., R.M. Touchstone, and J.P. Bailey, "Reaction to Sonic Booms: A Report of Two Studies and a General Evaluation of Startle Effects." Aviation, Space, and Environmental Medicine (April 1975)

9. Thuman, Albert and Richard K. Miller, Fundamentals of Noise Control Engineering. New Jersey: Prentice-Hall, (1986)

10. U.S. Army Corps of Engineers, Construction Engineering Research Laboratory (CERL). "Community Reaction to Impulse Noise: A Final 10-Year Research Summary." CERL Technical Report N-167 (Revised), (June 1985)

11. U.S. Department of Housing and Urban Development, Washington DC, Office of Policy Development and Research, "Technical Background for Noise Assessment Guidelines," pp. III-48-55, HUD0002272 (Jan 1980)

12. U.S. Environmental Protection Agency. "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety." EPA Report No. 550/9-74-004, (Mar 1974)

APPENDIX A

Noise Measurement Locations

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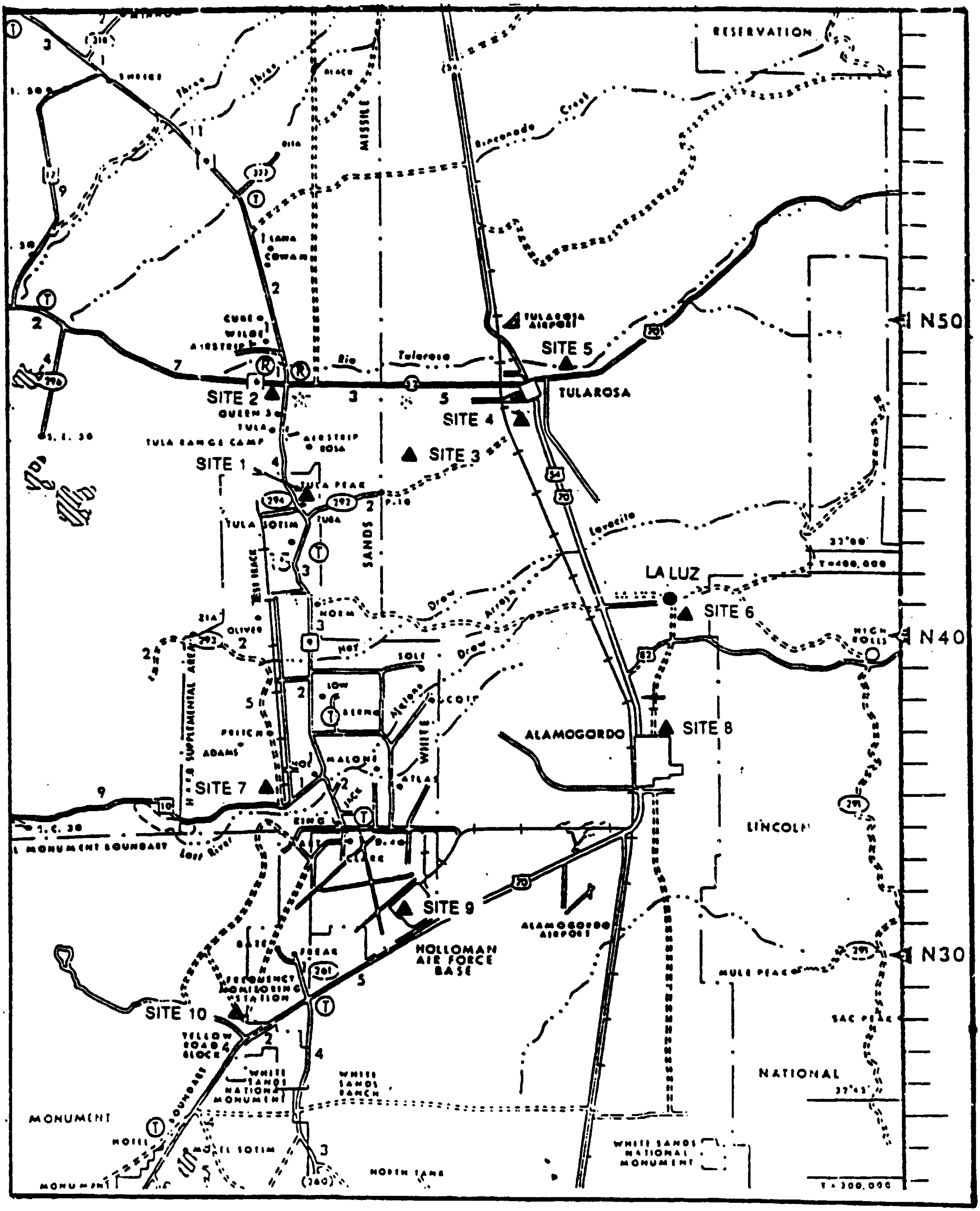


FIG A.1. LOCATIONS OF ALL TEN SITES

FIGURE A.2. SITE 1: TULA PEAK

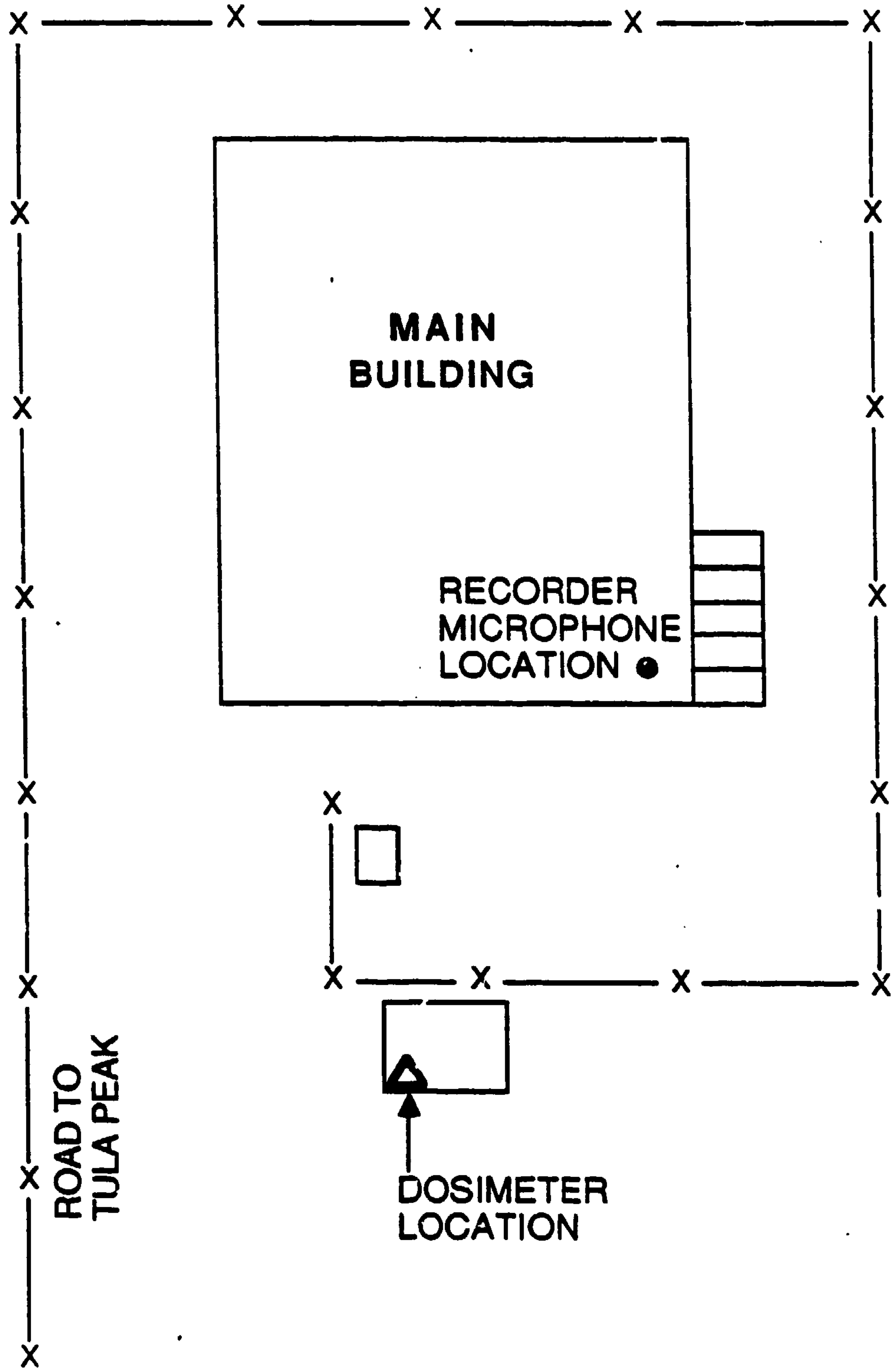
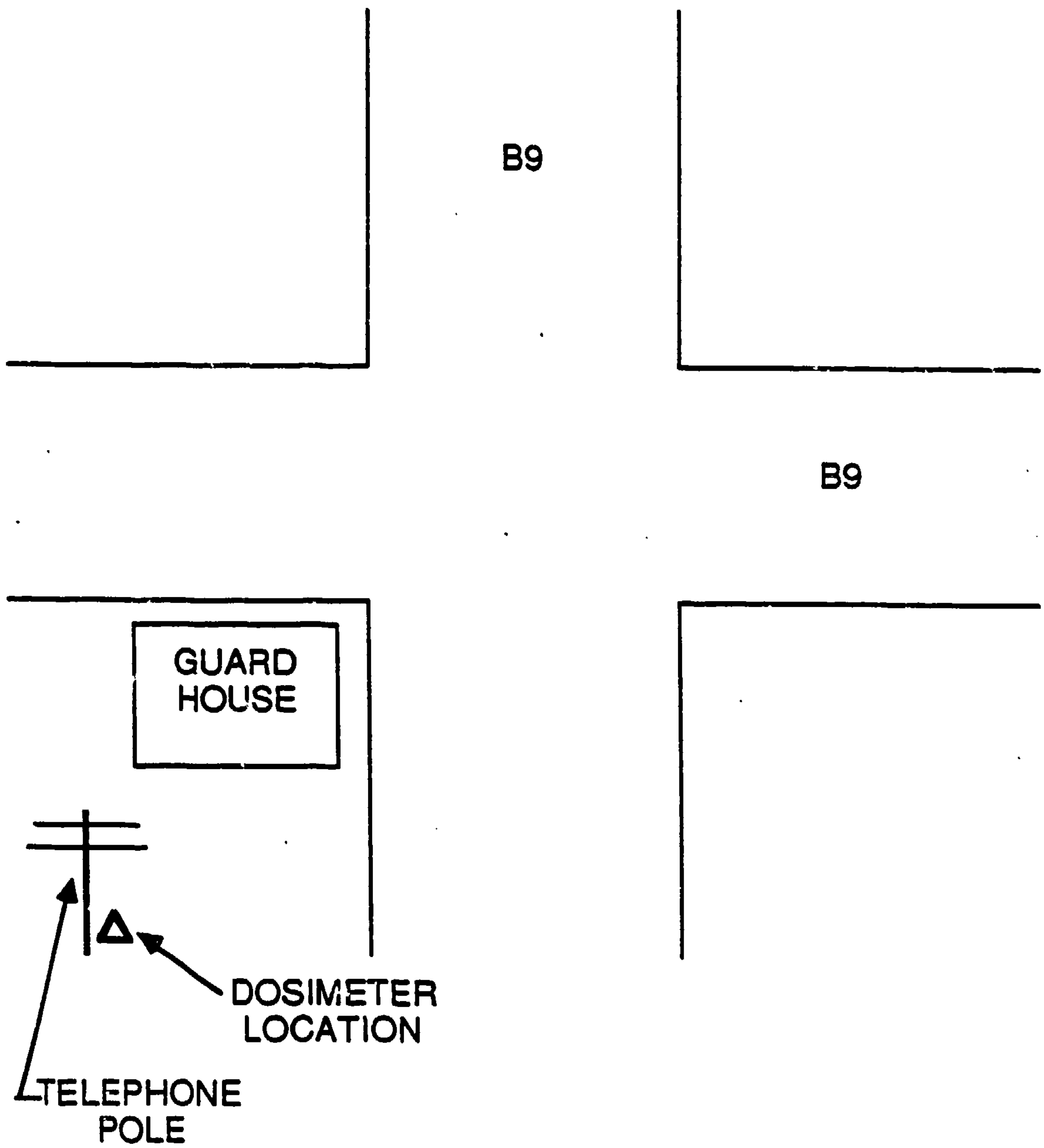


FIGURE A.3. SITE 2: TULA GATE



EHL-RT-8-2 880719

FIGURE A.4. SITE 3: TULAROSA (MAJ WILDMAN'S POSITION)

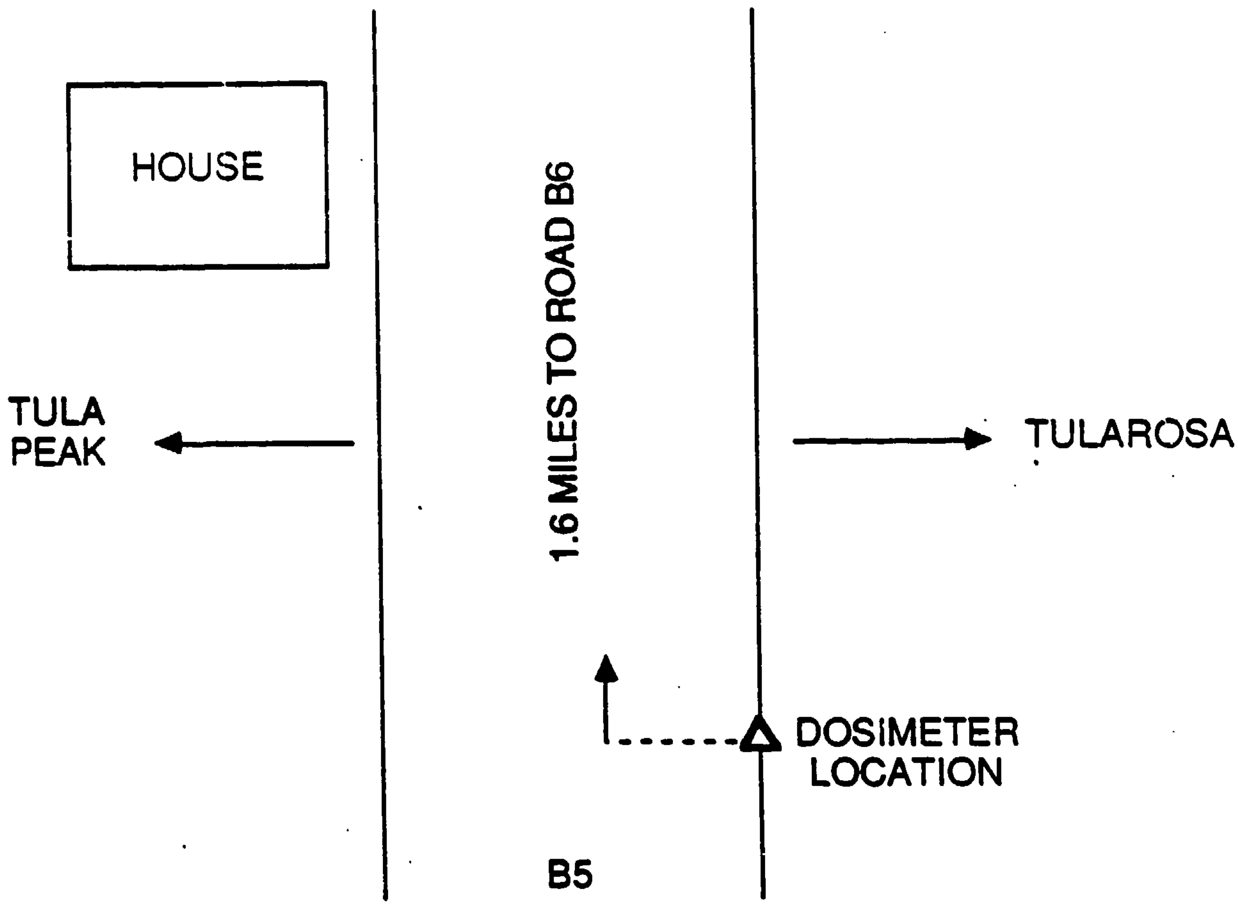


FIGURE A.5. SITE 6: LA LUZ

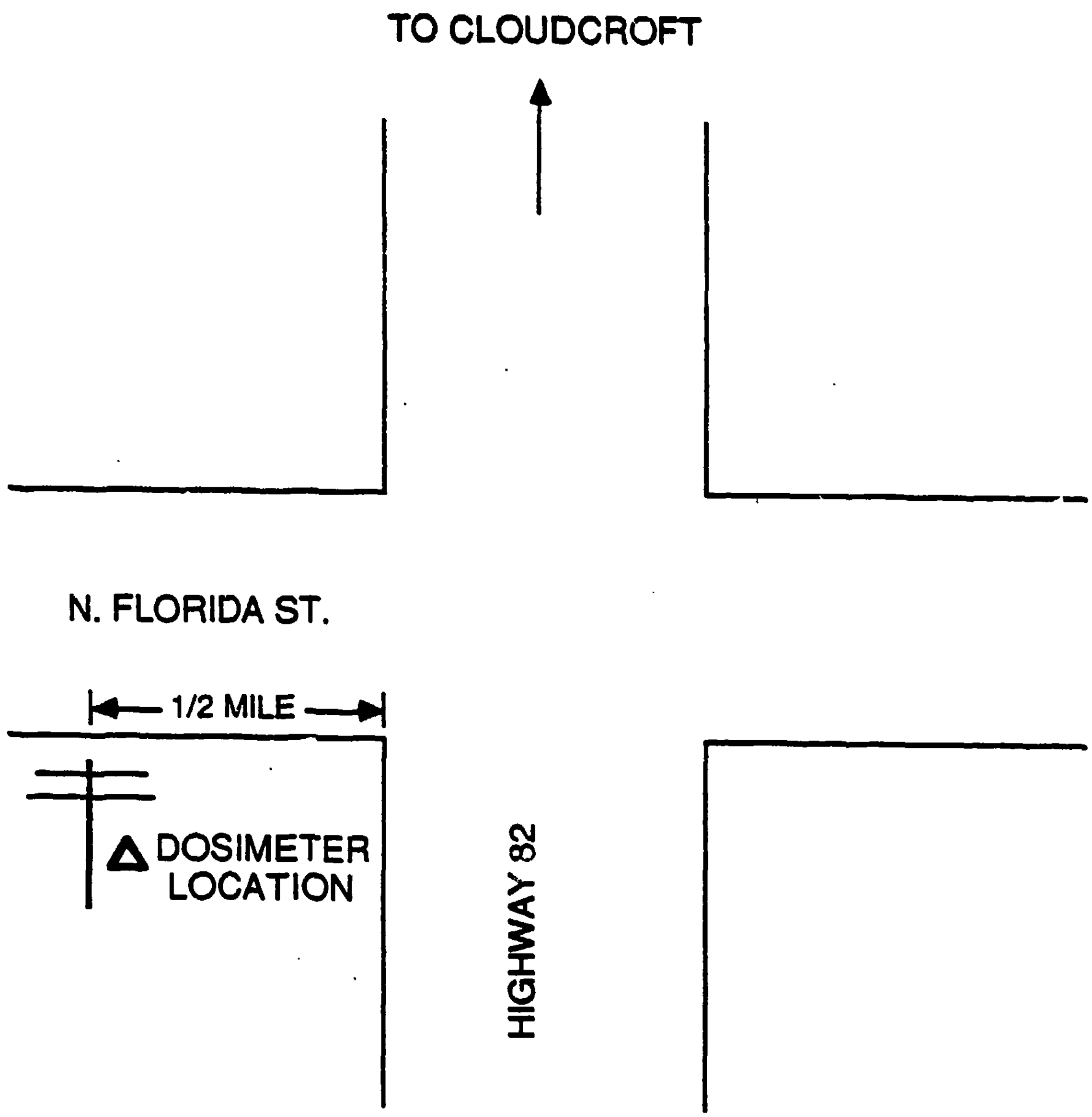


TABLE A.1. Holloman Test Track Site Locations

Site 1:	Tula Peak Dosimeter mounted on building south of and lower in elevation than main parking pad.
Site 2:	Tula Gate Dosimeter mounted on telephone pole behind guard building.
Site 3:	Tularosa/Maj Wildman's position Drive from Tula gate on road B6 turn right on B5 go 1.6 miles and mount on fence post
Site 4:	Tularosa/Sgt Williams' House
Site 5:	Tularosa/B&C Pipe Fitting
Site 6:	La Luz Drive highway 82 towards Cloudcroft and turn left on to N. Florida St., drive for 1/2 mile. On left side of road, mount dosimeter on telephone pole.
Site 7:	Ratscat Gate
Site 8:	Alamogordo North Park Housing Development on light pole in front of main office.
Site 9:	Holloman AFB, Lt Hewitt's House, 3412 Sequoia
Site 10:	White Sands National Park (Visitors Center)

APPENDIX B

Ldn Data

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Table B.1. Hourly Lavg (dB(A)) Measured by Metrosonics Noise Dosimeter to Determine Ldn

SITE 1: TULA PEAK, HOLLOMAN AFB NM

DATE:	4/13-14	4/14-15	4/20-21	4/21-22	4/25-26	4/27-28
START TIME:	16:00	21:00	07:00	14:00	13:00	13:00
Ldn:	75.5	67.4	70.6	89.4*	74.2	72.9
TIME:						
07:00	47.1	57.3	58.7	67.1	54.	55.5
08:00	60.3	57.0	66.5	68.0	57.1	69.5
09:00	73.4	60.8	64.1	70.4	60.5	72.4
10:00	72.8	57.5	70.0	80.8	66.2	72.6
11:00	75.2	63.3	73.5	85.7	62.4	71.8
12:00	82.5	62.9	71.6	81.7	61.7	72.1
13:00	79.7	61.3	71.3	89.6	68.0	59.4
14:00	76.0	62.3	71.1	91.8	68.6	60.8
15:00	70.7	56.8	71.0	96.8	71.5	58.3
16:00	62.8	57.0	70.3	101.0	73.0	51.8
17:00	51.9	43.9	72.9	82.2	77.6	50.0
18:00	62.9	44.4	74.1	80.2	78.7	54.0
19:00	57.1	55.1	61.7	78.3	75.5	57.1
20:00	64.4	77.5	55.4	69.5	81.1	55.6
21:00	57 6	55.7	50.8	56.5	79.2	56.5
22:00	64.1	51.2	47.6	50.8	72.3	65.3
23.00	64.2	44.9	50.6	66.5	64.6	53.5
00:00	65.4	59.1	63.3	55.9	48.2	60.5
01:00	70.3	57.9	57.4	57.6	44.1	65.5
02.00	70.9	60.3	58.2	64.0	46.9	60.8
03:00	64.7	51.2	56.7	53.4	46.3	68.1
04:00	69.8	45.7	57.7	59.0	43.3	73.4
05:00	55.4	51.0	67.4	56.5	46.2	40.4
06:00	45.6	65.4	63.8	64.2	46.9	56.5

* This was an unusual day due to an increase of approximately 20 sorties performed by Fighter Wing and Training Wing.

Note: Values shown do not include the 10 dB added to Lavgs between 2200-0700 to compute Ldn.

Table B.2. Hourly Lavg (dB(A)) Measured by Metrosonics Noise Dosimeter to Determine Ldn

SITE 2: TULA GATE, HOLLOMAN AFB NM

DATE:	4/11-12	4/13-14	4/14-15	4/20-21	4/21-22	4/25-26	4/27-28	4/29-30
TIME:	19:00	16:00	21:00	07:00	14:00	13:00	13:0	16:00
Ldn:	59.2	60.9	59.1	61.9	72.6*	62.2	61.4	58.7
TIME:								
07:00	50.7	49.6	57.3	55.5	55.3	64.9	57.7	52.7
08:00	58.9	54.9	60.2	60.3	60.5	63.1	64.4	52.1
09:00	60.3	62.1	61.3	59.5	67.4	61.6	61.3	47.9
10:00	53.6	60.8	51.5	59.6	75.7	62.5	61.3	53.9
11:00	52.6	62.5	62.0	61.9	69.6	61.0	64.4	52.5
12:00	55.3	64.8	58.7	63.6	73.8	59.5	59.7	56.7
13:00	57.7	67.6	54.4	63.3	72.2	59.3	57.6	57.2
14:00	54.4	63.5	54.3	61.2	79.6	57.9	56.3	59.3
15:00	53.1	61.7	55.4	62.8	79.0	59.9	55.5	62.3
16:00	53.6	59.5	60.8	60.7	80.7	61.3	51.2	55.9
17:00	58.4	54.7	52.9	60.4	74.1	63.2	61.8	55.3
18:00	50.8	54.5	45.3	59.1	69.8	62.0	48.8	54.1
19:00	45.7	46.3	46.7	46.6	66.6	55.3	46.3	49.4
20:00	46.8	46.9	49.6	45.8	50.7	48.5	50.0	45.4
21:00	47.1	45.8	46.1	45.7	55.4	48.1	47.8	46.2
22:00	51.4	49.5	47.5	49.6	51.2	51.4	49.6	45.7
23:00	47.9	50.9	49.3	50.5	49.6	48.8	46.2	51.2
00:00	47.2	50.2	52.8	52.7	51.1	52.2	53.7	52.0
01:00	52.1	50.7	52.1	54.6	50.8	53.9	47.6	53.2
02:00	45.4	44.9	43.7	50.6	52.1	45.6	44.3	57.3
03:00	47.5	45.2	45.7	51.8	54.1	52.8	46.7	43.6
04:00	50.1	49.9	50.8	49.1	51.5	51.8	52.9	44.6
05:00	56.1	52.1	54.8	59.4	48.3	57.9	58.4	47.8
06:00	56.9	54.7	52.3	54.6	53.0	56.9	57.9	47.7

* This was an unusual day due to an increase of approximately 20 sorties performed by Fighter Wing and Training Wing.

Note: Values shown do not include the 10 dB added to Lavgs between 2200-0700 to compute Ldn.

Table B.3: Hourly Lavg (dB(A)) Measured by Metrosonics Noise Dosimeter to Determine Ldn

SITE 3: TULAROSA NM (Maj Wildman's Position)

DATE:	4/11-12	4/13-14	4/14-15	4/20-21	4/21-22	4/25-26	4/27-28	4/29-30
START TIME:	19:00	16:00	21:00	07:00	14:00	13:00	13:00	16:00
Ldn:	53.2	58.5	55.7	68.9	74.8*	62.0	62.9	62.3
TIME:								
07:00	58.0	49.7	50.4	47.7	62.1	49.2	53.8	49.8
08:00	46.4	52.1	48.2	54.7	66.3	52.0	65.0	49.9
09:00	55.0	49.0	45.1	59.3	69.6	54.5	67.6	53.6
10:00	47.9	54.1	47.1	67.8	73.2	54.2	71.0	57.6
11:00	55.3	59.0	49.3	70.1	74.7	55.8	70.5	61.9
12:00	50.6	65.3	50.8	71.9	74.0	56.7	68.8	64.4
13:00	46.9	66.0	48.8	76.3	76.4	62.6	48.6	64.9
14:00	48.9	62.1	52.7	73.9	78.3	66.3	53.7	68.6
15:00	50.4	59.6	57.7	73.3	81.1	67.3	58.8	71.9
16:00	52.2	55.1	51.6	73.0	82.3	66.9	56.9	62.6
17:00	50.8	55.6	46.8	72.4	80.0	67.0	51.4	62.6
18:00	55.3	51.4	47.7	73.4	77.5	68.8	46.4	61.9
19:00	56.8	46.2	64.0	63.6	74.7	60.3	47.3	57.7
20:00	48.2	49.0	52.2	44.1	66.9	48.5	47.3	50.3
21:00	46.3	46.9	45.0	46.5	58.8	49.4	48.0	48.7
22:00	42.5**	46.6	43.2**	46.5	51.3	48.9	43.4**	46.4
23:00	42.5**	42.5**	43.2**	43.8	58.9	44.1	43.4**	43.5
00:00	42.5**	42.5**	43.2**	44.0	58.5	43.6	43.4**	46.5
01:00	42.5**	42.5**	43.2**	43.9	47.4	43.5	45.0	44.4
02:00	42.5**	43.4	43.2**	44.1	44.7	51.7	43.5	43.6
03:00	42.5**	51.7	43.2**	43.7	43.4	43.5	44.0	50.0
04:00	42.5**	43.1	45.6	43.7	43.6	43.6	43.4**	44.9
05:00	42.5**	49.4	51.1	51.9	47.8	48.2	50.1	45.3
06:00	48.4	48.7	52.4	48.3	58.5	52.5	51.9	45.4

* This was an unusual day due to an increase of approximately 20 sorties performed by Fighter Wing and Training Wing.

** Lower limit of detection of the noise dosimeter

Note: Values shown do not include the 10 dB added to Lavgs between 2200-0700 to compute Ldn.

Table B.4. Hourly Lavg (dB(A)) Measured by Metrosonics Noise Dosimeter to Determine Ldn

SITE 6: La Luz NM

DATE:	4/11-12	4/13-14	4/21-22	4/25-26	4/27-28	4/29-30
START TIME:	19:00	16:00	14:00	13:00	13:00	16:00
Ldn:	62.4	67.1	73.3*	61.2	58.4	63.1
TIME:						
07:00	60.1	55.5	55.7	56.1	51.5	45.2
08:00	48.7	57.5	57.6	50.7	50.9	44.4
09:00	48.2	55.5	64.7	52.4	57.2	44.5
10:00	49.2	61.8	68.6	52.2	60.6	52.4
11:00	51.7	64.6	72.7	50.3	61.9	54.6
12:00	48.3	69.6	72.1	50.1	55.4	54.8
13:00	47.5	66.6	73.0	54.1	45.6	58.5
14:00	49.7	60.2	76.4	52.3	49.6	61.1
15:00	48.1	54.9	80.4	49.5	52.9	62.7
16:00	51.5	52.6	81.0	52.4	49.0	54.8
17:00	51.9	52.6	80.9	54.3	46.4	54.3
18:00	55.9	49.5	72.7	56.3	45.4	57.4
19:00	74.5**	52.4	70.4	50.6	47.4	57.9
20:00	54.9	55.0	57.1	55.3	55.8	48.2
21:00	55.9	56.4	51.5	56.3	48.6	55.8
22:00	45.4	47.2	52.4	51.8	58.8	60.4
23:00	44.4	65.2	48.7	55.5	44.4	56.6
00:00	46.3	60.8	49.5	47.7	44.4	57.4
01:00	43.2	61.9	46.4	58.1	52.2	53.7
02:00	47.6	58.2	46.2	44.2	45.1	52.4
03:00	45.5	64.7	48.2	45.0	45.4	58.5
04:00	46.0	48.8	48.7	61.7	45.5	56.9
05:00	45.1	48.7	49.0	45.1	44.2	56.5
06:00	58.5	53.2	54.6	47.3	49.0	49.4

* This was an unusual day due to an increase of approximately 20 sorties performed by Fighter Wing and Training Wing.

** High level caused by mounting on pole after turn-on time.

Note: Values shown do not include the 10 dB added to Lavgs between 2200-0700 to compute Ldn.

Table B.5. Background, Ln(90), as Determined by Metrosonics Noise Dosimeter for Four Sites in April 1988 at Holloman AFB

Date	Sites 1	2	3	6
4/11-12	**	43*	42*	42*
4/13-14	42	43*	42*	43*
4/14-15	43*	43*	43*	**
4/20-21	44	43*	43*	**
4/21-22	42*	43*	43*	43*
4/25-26	42*	43*	43*	43*
/27-28	42*	43*	43*	43*
4/29-30	**	43*	43*	43*

* Lower limit of detection of noise dosimeter
** No available data

Table B.6. Median, Ln(50), as Determined by Metrosonics Noise Dosimeter for Four Sites in April 1988 at Holloman AFB

Date	Sites 1	2	3	6
4/11-12	**	44	42*	44
4/13-14	59	47	42*	50
4/14-15	43*	43*	43*	**
4/20-21	58	49	44	**
4/21-22	64	54	62	54
4/25-26	49	48	43*	45
4/27-28	51	44	43*	44
4/29-30	**	43*	43*	48

* Lower limit of detection of noise dosimeter
** No available data

Table B.7. Intrusive, Ln(10), as Determined by Metrosonics Noise Dosimeter for Four Sites in April 1988 at Holloman AFB

	Sites			
Date	1	2	3	6
4/11-12	**	53	42	58
4/13-14	75	59	54	64
4/14-15	61	54	46	**
4/20-21	72	61	70	**
4/21-22	90	76	79	75
4/25-26	77	61	61	57
4/27-28	69	57	62	56
4/29-30	**	57	62	60

** No available data

Table B.8. Peak, Ln(01), as Determined by Metrosonics Noise Dosimeter for Four Sites in April 1988 at Holloman AFB

	Sites			
Date	1	2	3	6
4/11-12	**	64	58	74
4/13-14	85	71	68	72
4/14-15	75	67	57	**
4/20-21	79	70	81	**
4/21-22	102	84	85	85
4/25-26	83	70	74	63
4/27-28	79	67	75	65
4/29-30	**	66	74	66

** No available data

APPENDIX C

Impulse Data From Sonic Boom

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TABLE C.1: A LISTING OF PEAKS AND SELS FROM 13 APRIL 88 SONIC BOOM

USAFOEHL Data

Site 1, 13 APRIL 88

PEAK SOUND PRESSURE =	148.5 dB	(530 Pascals)
PEAK TO PEAK SOUND PRESSURE LEVEL =	152.5 dB	(843.4 Pa)
SEL =	89.0 dB	
CSEL =	103.0 dB	

Site 3, 13 April 88

PEAK SOUND PRESSURE =	138.2 dB	(163.1 Pa) *
PEAK TO PEAK SOUND PRESSURE LEVEL =	144.2 dB	(324.7 Pa) *
SEL =	65.0 dB	
CSEL =	90.0 dB	

LEGEND

* POSSIBLE CLIPPING

AFWL/NTESG Data (5)

Site 1, 13 APRIL 88

PEAK SOUND PRESSURE =	145.1 dB	(359 Pascals)
PEAK TO PEAK SOUND PRESSURE LEVEL =	152.3 dB	(845 Pa)

Site 3, 13 April 88

PEAK SOUND PRESSURE =	140.3 dB	(207 Pa)
PEAK TO PEAK SOUND PRESSURE LEVEL =	145.8 dB	(391 Pa)

Estimated Values at Property Line of Missile Range East of Test Track

PEAK SOUND PRESSURE =	145.0 dB	(355 Pascals)
PEAK TO PEAK SOUND PRESSURE LEVEL =	148.0 dB	(502 Pa)
SEL =	92.0 dB	
CSEL =	106.0 dB	

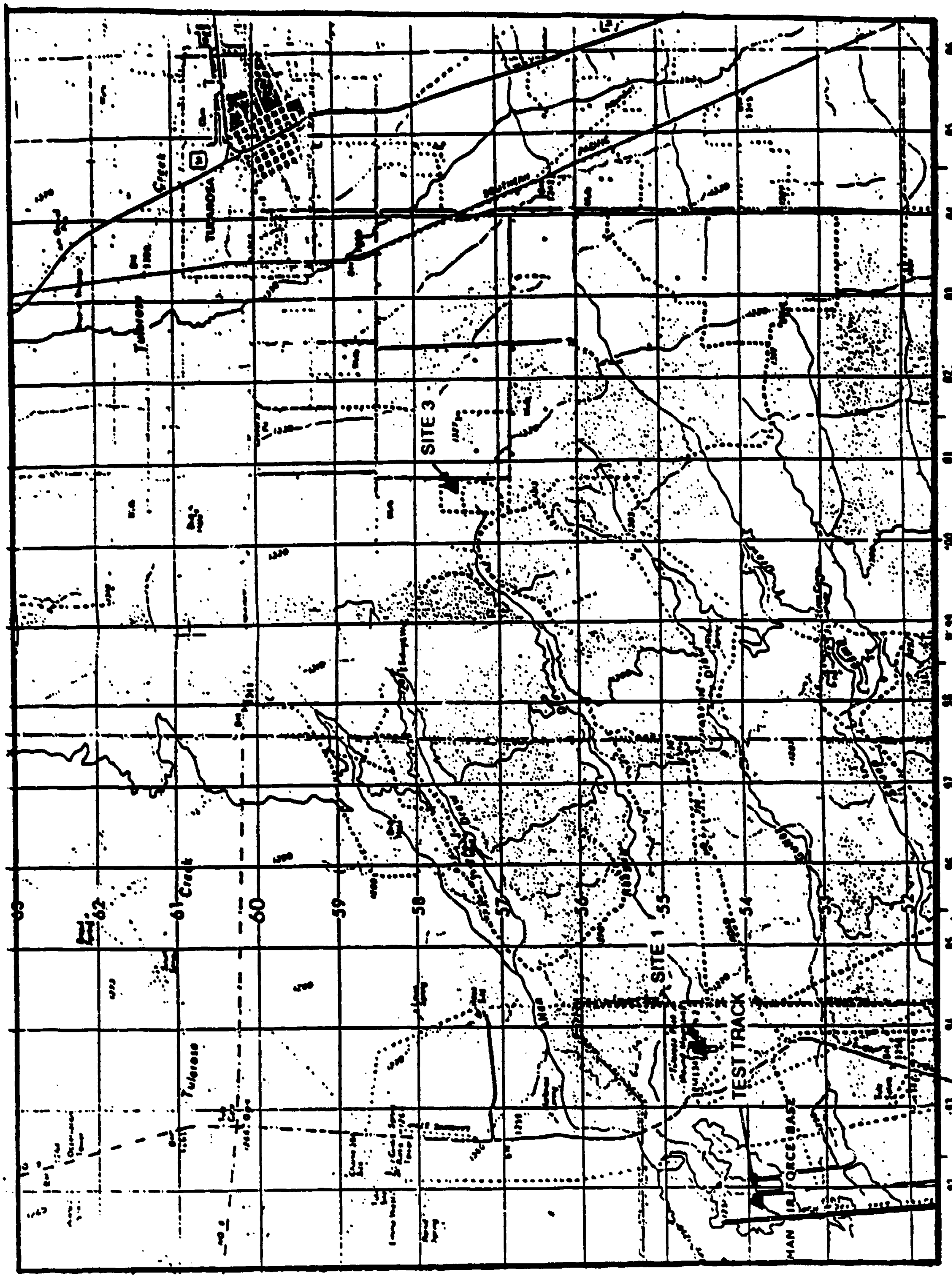

FIG C.1. RECORDING LOCATIONS FOR SITES 1 AND 3

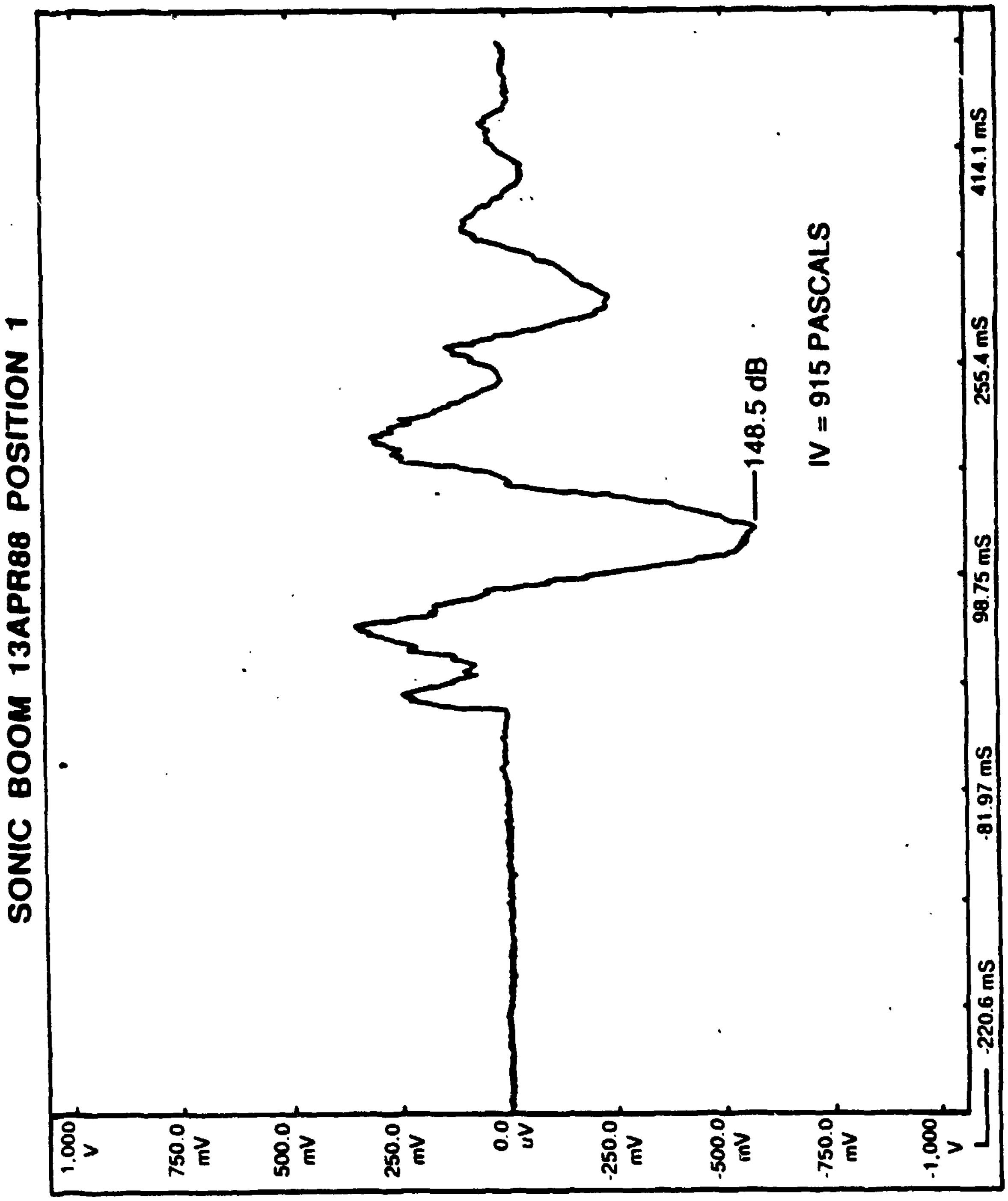

FIGURE C.2. IMPULSE MEASUREMENT AT SITE 1

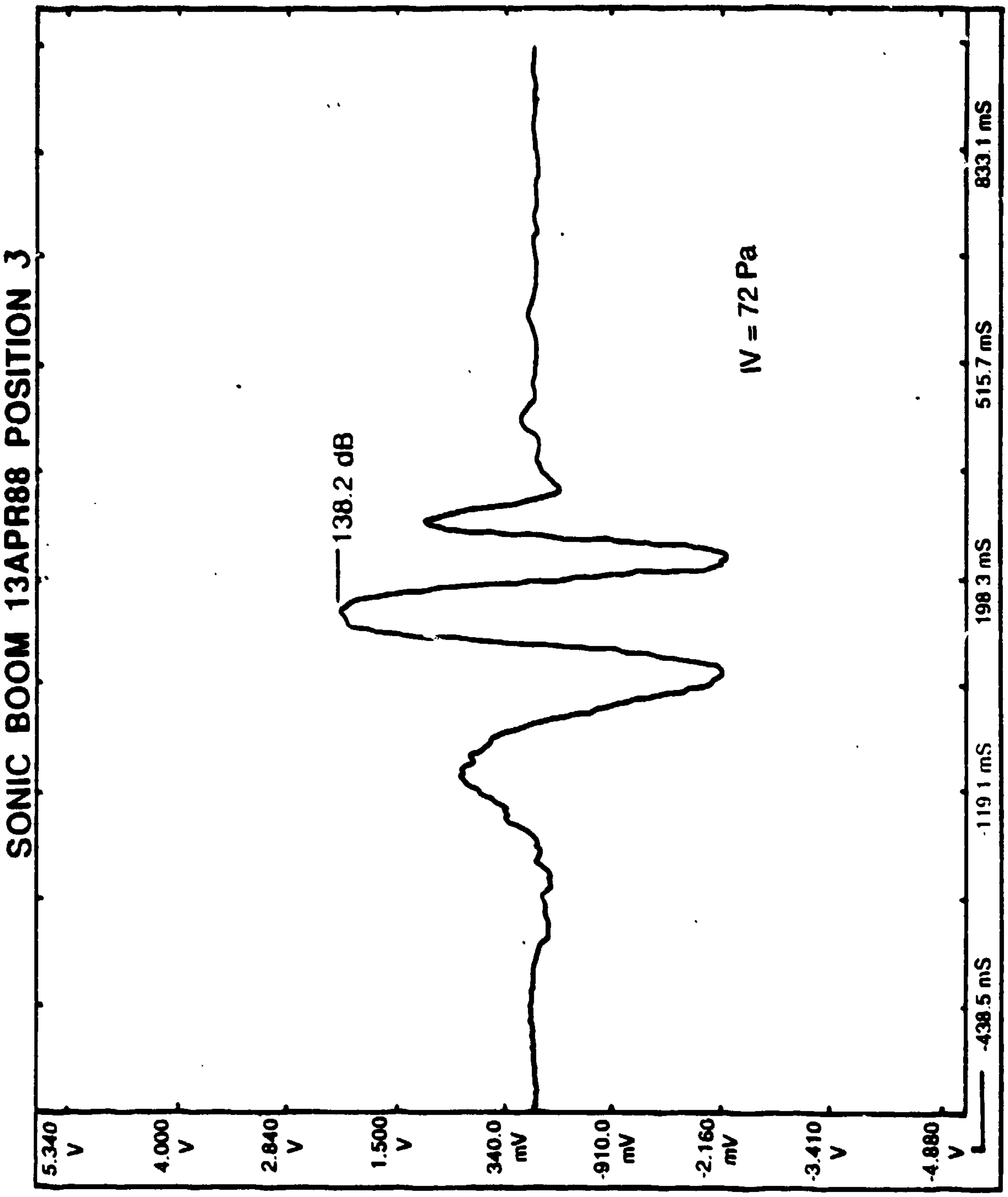

FIG. C.3. IMPULSE MEASUREMENT AT SITE 3

Table C.2: A-weighted Ldns Measured by Metrosonics Noise Dosimeter for Four of the Sites on Several Days in April 1988

	Sites			
Date	1	2	3	6
4/11-12	**	59.2	53.2	62.4
4/13-14	75.5	60.9	58.5	67.1
4/14-15	67.4	59.1	55.7	**
4/20-21	70.6	61.9	68.9	**
4/21-22	89.4	72.6	74.8	73.3
4/25-26	74.2	62.2	62.0	61.2
4/27-28	72.9	61.4	62.9	58.4
4/29-30	**	58.1	62.3	63.1
Median:	73.6	61.2	63.0	63.0
CSEL	103		90	
Composite LDN	73.8		63.1	

** No available data

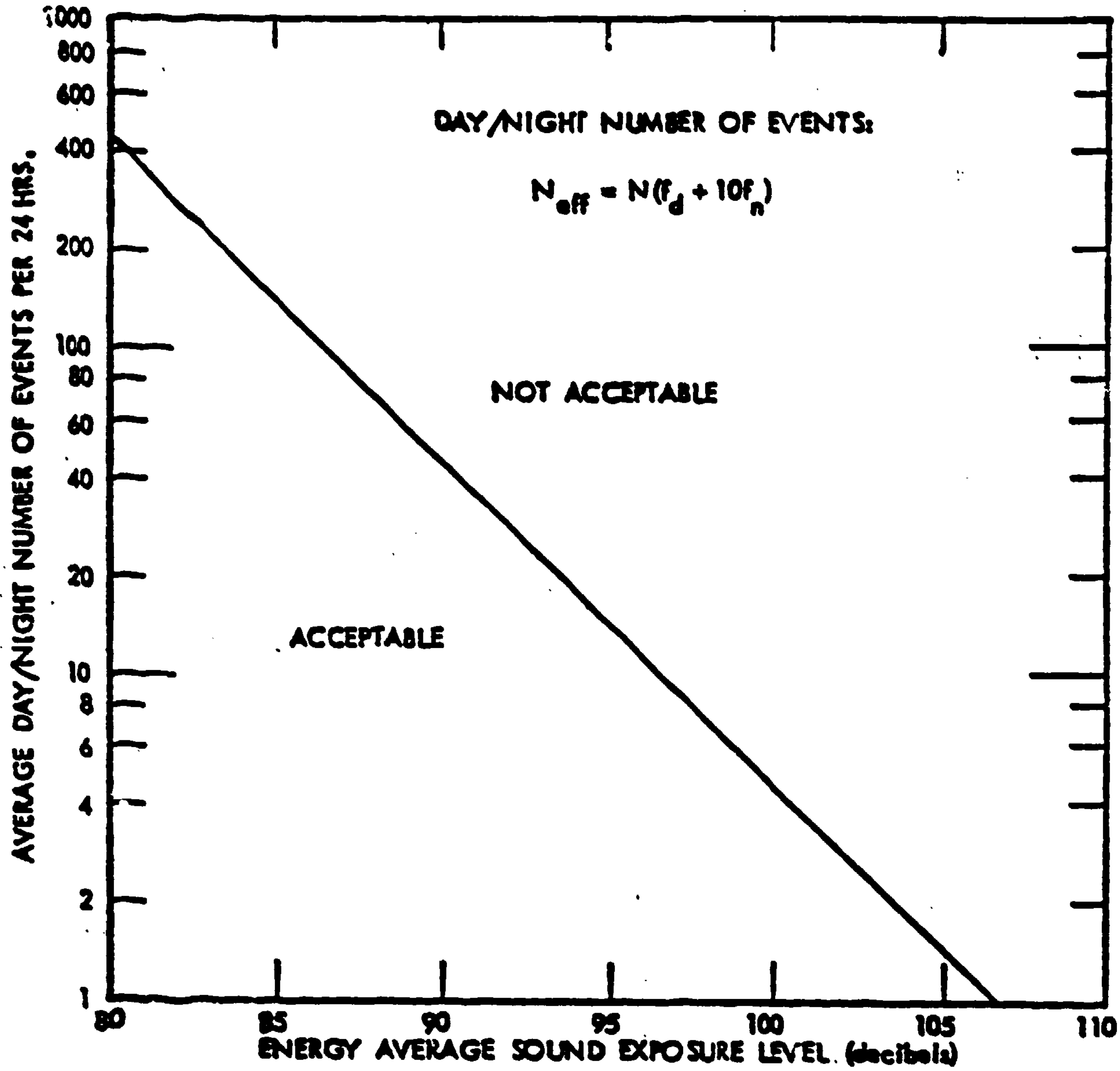

FIGURE C.4. CRITERION FOR LOUD IMPULSIVE SOUNDS

APPENDIX D

Information on Sonic Booms

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Information on Sonic Booms

The following excerpts from the cited references are provided as a summary of the key information provided in the literature which was used to assess rocket sled operations.

A. Sonic Booms:

"An intensive survey was conducted at White Sands, New Mexico, where structures of various design and construction were instrumented and then exposed to more than 1500 sonic booms with overpressures as high as 20 psf. Except for glass, no damage was detected for overpressures up to 5 psf, nor was there any cumulative damage effects after a series of 860 successive flights at about 5 psf. The only evidence of damage at the conclusion of the tests, other than glass breakage, was three bricks that had loosened beneath a window ledge."(3)

"The results of the three large-scale sonic boom structural tests and several other tests were analyzed by NASA. In their conclusion, they make the following statement:

The extensive series of overflight tests have provided valuable data on the order of magnitude of responses to be expected. These tests show that building structures in good repair should not be damaged at boom overpressures less than about 11 psf. However, it is recognized that considerable loading variability occurs, owing to atmospheric effects, and that the residual strength of structures varies according to usage and natural causes. Thus, there is a small probability that some damage will be produced by the intensities expected to be produced by supersonic aircraft.

One additional investigation is worthy of mention. In 1977, an adobe house in southern Arizona was instrumented and evaluated while supersonic training was taking place overhead. The conclusion of the evaluation was that the adobe structure reacted similar to a conventional style structure. Based on this analysis, there should be no difference in the probability of damage to an adobe structure as compared to a conventional structure."(3)

B. Glass Breakage:

"By far, The largest percentage of sonic boom claims stem from broken or cracked glass. All of the tests conducted in the United States have confirmed that glass damage is the most prevalent caused by sonic booms. Because the microstructure of glass is amorphous rather than crystalline, the practical design strength of the glass is dependent on the surface scratch condition. Glass that has been sandblasted, scratched, or nicked will not exhibit the same strength as a properly installed relatively new pane of glass.

In addition to the variation due to surface scratch condition, there are also variations with loading geometry, loading rate, atmospheric moisture content, and composition.

Glass also exhibits a property known as "static fatigue" in that it is weaker for loads for longer duration. Thus for sonic boom loading, which has a duration of the order of 0.1 SEC, the strength of glass will be roughly twice that obtained in typical laboratory assessments."

"By using a data base of unpublished static results provide by Libbey-Owens-Ford Company, a statistical analysis was performed to determine the probability of glass breakage for various overpressures. The following probabilities of breakage for good glass at various nominal overpressures is based on an aircraft approaching from a head-on or perpendicular direction to the window. Even though this information uses aircraft sonic booms, it is a good approximation for the test track."(3)

Overpressures	Probability of Breakage
1 psf = 47.88 Pa = 128 dB	.000023
2 psf	.000075
3 psf = 143.64 Pa = 137 dB	.000300
4 psf = 191.52 Pa = 140 dB	.001200*
5 psf	.002300
6 psf = 287.28 Pa = 143 dB	.004000

* 1 pane in 833 panes

Estimation of the number of window panes to be broken by sonic booms based on the following formula.

G = 3.85 x 10 exp -7 x [N(P)2.78]
P = the boom overpressure in psf
N = number of exposed panes

NOTE: All these quotes were taken from reference 3 and they were worthy of repeating.

APPENDIX E

Glossary

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GLOSSARY OF TERMS

Average Day-night Sound Level [Ldn]: Sound level used to determine community noise. A 24 hour A-weighted equivalent sound level, with a 10 dB penalty applied to the nighttime levels from 2200 to 0700.

** LDN = DNL = Ldn: Ldn is used in the equation.

Ldn Formula:

$$Ldn = 10 \log 1/24 \left[15X10^{(Ld/10)} + 9X10^{(Ln+10/10)} \right]$$

Ld: Daytime equivalent A-weighted sound level between the hours of 0700 and 2200.

Ln: Nighttime equivalent A-weighted sound level between the hours of 2200 and 0700.

A-Weighted Sound Level [dB(A)]: The ear does not respond equally to sounds of all frequencies. The ear is less efficient at low and high frequencies than it is at mid-range or speech range frequencies. In order to obtain a single number representing the sound pressure level of a noise containing a wide range of frequencies in a manner approximating the response of the ear, it is necessary to reduce or weight, the effects of the low and high frequencies relative to the mid-range frequencies. Therefore, the low and high frequencies are de-emphasized with A-weighting.

C-Weighted Sound Exposure Level [CSEL]: The C-weighted SEL is the SEL (see definition below) based on the C-weighted level rather than the A-weighted level.

C-Weighted Sound Level [dB(C)]: The C-weighting scale weights the audible spectrum with more emphasis on the low frequencies than the A-weighting scale.

Composite Average Day-night Level [CLdn]: The CSEL for the event is logarithmically added to the Ldn for each number of events.

*Exceedance Levels [Ln(x.x%)]: The noise levels equaled or exceeded x.x% of the time.

Ln(1.0%): Peak noise level - Noise levels exceeded 1% of the time.

Ln(10.0%): Intrusive noise level - Noise levels exceeded 10% of the time.

Ln(50.0%): Median noise level - Noise levels exceeded 50% of the time.

Ln(90.0%): Background ambient noise level - Noise levels exceeded 90% of the time.

Sound Exposure Level (SEL): The A-weighted sound level measurement of a single noise event integrated over the duration of the noise event (referred to a reference time of one second). In other words, the event is equivalent to a level of a signal of one second duration.

* Definitions for Metrosonics db-310 Sound Analyzers

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APPENDIX F

Sonic Boom Measurement Equipment

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Sonic Boom Measurement Equipment

The Boom Event Analyzer Recorder (BEAR) is a 16 bit microprocessor based instrument that continuously samples the noise then captures and stores the digital waveform of any loud impulse noise. The recorder can discern a sonic boom from the normal background noise and capture it in permanent solid state random access memory (RAM) storage for later analysis. The RAM modules can then be interfaced with a Data Retrieval Unit (DRU) and the information on the DRU transferred to a Zenith Z-100 microcomputer. The microcomputer displays each recorded event, time of occurrence and summary information for all the data stored.

The BEAR digitizes the noise environment at 8 kHz and analyzes it during the downtime between the sampling intervals giving it real time screening for sonic boom events. The BEAR examines the event level, duration and risetime to determine if it should be stored as a boom event These three parameters are selectable via the input keypad to make the BEAR a very flexible instrument with which to capture a wide variety of impulsive events. Along with setting the boom evaluation criteria, the keypad allows input of data, time, test number, location and serial number of the unit. This information is stored in the same RAM modules as data every time any parameter is changed. The operator can also select three other modes from this keypad: calibration, clear memory or data save. In the calibration mode the BEAR simply displays the root-mean-square level of two seconds of the input signal to the microphone for checking against a standard 124 dB sound pressure level pistonphone calibrator. No data is saved to the RAM modules in this mode. The clear memory mode asks the operator to input a special code and, when entered, simply erases the RAM modules and runs the BEAR unit through the internal self-test routines that verify all the hardware components are working properly. The third mode allows the operator to collect one and one-half seconds of data with no screening. This allows the operator to collect and store background noise on the calibrator signal or anything that is desired. The BEAR has a frequency response of 0.5 Hz to 2,500 Hz for producing a sonic boom time history adequate for environmental impact analysis. The maximum overpressure the BEAR is designed for is 155 dB (23.4 pounds per square foot or 1120 pascal) with a 90 dB dynamic range. The RAM modules on a single unit have 512K of memory allowing the BEAR to store over 100 "normal" sonic booms. The BEAR is designed to operate with a PCB Piezo resistive microphone that is totally sealed and extremely rugged making the BEAR able to operate in the enviromental extremes of temperature present in the Southwest U.S. (0-65 degrees C).

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