research report

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TECHNICAL MEMORANDUM 68-11

ANALYSIS OF POTENTIAL COMMUNITY RESPONSE TO TEST OPERATIONS OF ROCKETDYNE/SANTA SUSANA FACILITY

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1.0 INTRODUCTION

The potential community response to noise generated by test operations at the Rocketdyne Santa Susana Facility has been estimated for a 2700 acre tract of land on the southern border of the facility. The essential background data and prediction methods are presented in this report along with the estimated boundaries for various degrees of community reaction. The latter are shown in Figure 1 which summarizes the essential results of this study.

2.0 BACKGROUND

The general location of the Rocketdyne Santa Susana Test Facility and adjacent property and residential property is shown in Figure 2. The nearest densely populated areas to the existing test stands are 8000-10,000 ft away. Rocketdyne has experienced a decreasing trend of complaints from their test operations over the last 10 years. However, the R. A. Watt property lying immediately to the south of the facility has, until now, been essentially unoccupied. While it is not known where the previous complaints have originated from, it may be reasonably assumed that they have originated primarily from the outer edge of the Canoga Park and Santa Susana residential zones. When boundaries for a community reaction corresponding to "sporadic complaints" are drawn on Figure 2, they indeed suggest that these two residential zones just fall within a reaction zone corresponding to a relatively low level of reaction such as "sporadic complaints."

Clearly, however, the close proximity of the R. A. Watt property to the Rocketdyne test stands indicates that much more vigorous community reaction would be expected if this land were populated.

3.0 ROCKETDYNE SANTA SUSANA/NASA FACILITIES

The basic test facilities employed by Rocketdyne at Santa Susana in support of NASA programs are summarized in Table 1. The most important test areas, from a noise generation standpoint, appear to be the four engine test facilities (Coca, Delta, Bowl and Canyon) listed in the first part of Table 1. Approximate locations of the test stands used for NASA systems are identified along with estimated thrust and propellant flow rates. Test durations shown are estimated maximum values. One additional parameter is required for evaluation of community reaction - the actual frequency of firings. At present, it appears that J-2 engine tests are conducted daily but that S-II stage and H-1 engine tests are sporadic. Thus, the J-2 tests will tend to be more significant from a community noise standpoint, all other things being equal.

4.0 ESTIMATED SOUND LEVELS IN COMMUNITY

Contours of overall sound levels and octave band spectra were available for the three principal noise sources (i.e., S-II stage, J-2 and H-1 engines) out to an overall sound level of 100 dB. These estimates were obtained, through Mr. L. D. Saint, Code P&VE-SVR, Marshall Space Flight Center, from Test Laboratory, MSFC. Estimates were provided for nominal propagation conditions (see Figure 3), as well as "favorable" (Figure 4) and "unfavorable" propagation conditions. Favorable propagation conditions were considered in detail and correspond to limiting firings to a time of day when the sound velocity versus altitude has a negative or decreasing gradient as altitude increases. This condition corresponds to the usual atmospheric condition of a decreasing ambient temperature with altitude or to an upwind sound propagation. As indicated in the lower left corner of Figure 3, the most common wind direction in the area is from the southeast which would tend to result in upwind or favorable propagation conditions from the J-2 Delta 2 test stand. According to Reference 1, favorable propagation conditions occur at the Santa Susana site about 60 percent of the time. However, it should be recognized that the firing frequency of current J-2 engine tests at the Delta-2 test stand suggests that some consideration be given to nominal or average weather conditions. This corresponds to an essentially constant sound velocity with altitude (zero gradient).

Octave band spectra provided by MSFC are shown in Figures 5 and 6; these are to be used with the 100 dB and 120 dB contours of overall sound level such as in Figure 3 or 4.

In order to predict community response reaction zones out to a reaction level of "sporadic complaints," it was necessary to extrapolate the data in Figures 3-6 to include overall levels as low as 85 dB. This was carried out by a procedure defined in detail in Appendix A. The extrapolation procedure consisted essentially of correcting the MSFC 100 dB sound levels by the following factors at distances beyond the range of the 100 dB contours.

- Inverse Square Spreading Loss
- Fixed Excess Attenuation Loss Due to a Negative Sound Velocity Gradient (Increases with Frequency)
- Excess Attenuation Loss Due to Atmospheric Absorption (Increases with Distance and Frequency)

No attempt has been made in this study to account for attenuation loss due to shielding by the terrain. A simplified contour map of the area is shown in Figure 7. The test stands lie generally in the 1800-2000 ft altitude range which is indicated by the shaded areas in Figure 7.

5.0 ACOUSTIC ENVIRONMENT CRITERIA AND COMMUNITY REACTION ZONES

Three general criteria were used to evaluate the potential impact of the acoustic environment generated by the Santa Susana operations. These are:

- Subjective Criteria for Physical Discomfort or Hearing Loss
- Structural Damage Criteria
- Criteria for Community Reaction in Terms of Weighted Sound Levels (Composite Noise Rating in PNdB)

The first two criteria can be defined in terms of octave band spectra as shown in Figures 8 and 9. They are obtained from Chapter 10 of Reference 4).

Subjective Criteria

Comparison of the subjective criteria with the expected environment indicate that the levels that may result in physical discomfort lie between the contours for 110 dB and 120 dB overall sound level for all engines. These contours fall within the boundaries of the "vigorous community reaction" zones to be defined later. This only serves to substantiate the general validity of the boundaries of this extreme reaction zone by indicating that physical discomfort may actually contribute to the stimulus which results in such an extreme community response.

No evidence is found for any risk of hearing damage. Thus, in general, there is no indication of physical damage to humans located on the R. A. Watt property.

Structural Criteria

The criteria for damage to residential structure, defined in Figure 9, were used to establish a zone of potential damage by carrying out the following steps.

- The level of the 120 dB octave band spectra was adjusted until there was a 10 dB margin between the damage criteria and the adjusted octave band level.
- The new overall sound level corresponding to this adjusted octave band level defined the overall level for a contour of structural damage.
- This contour was drawn in using the following overall sound levels:

S-II Stage	120 dB
J-2 Engine	127 dB
H-1 Engine	127 dB

The higher overall level for the J-2 and H-1 engines reflects the higher peak frequency and hence lower damaging sound levels at low frequencies.

This procedure amounts to providing a 10 dB margin of safety for the structural criteria defined in Figure 9. When this same procedure is applied to a typical Saturn S-IC octave band spectrum, a damage zone corresponding to an overall level of 115 dB is predicted. This is in line with actual experience by MSFC and tends to verify the damage zones predicted for Santa Susana.

It was found that, in all cases, the boundaries for damage to residential structure fell within the Rocketdyne property line.

Community Reaction

After extrapolating the sound level contours out to about 85 dB for all three major sources, following the steps given in Section 4, the boundaries for various community reaction zones were computed as follows.

- The octave band levels were used to compute a Perceived Noise Level in PNdB following the standard procedure outlined in Chapter 10 of Reference 4. This process amounts to computing a weighted sound level where the weighting accounts for the relative subjective "noisiness" of each octave band.

- The Perceived Noise Levels were corrected in the standard fashion as follows: (Ref. 4)

  S-II, J-2, H-1 – Add +5 dB to account for noise intrusion into an otherwise quiet neighborhood

  J-2 Only – Add +5 dB to account for long duration and high frequency of firing. This correction was applied to J-2 contours from both the Delta and Bowl test stands.

- The resulting corrected Perceived Noise Levels defined the Composite Noise Rating (CNR) in PNdB.

- Curves of overall sound level in dB and CNR in PNdB were constructed as a function of distance for each engine and at 3 directions from the test stand. A typical curve is illustrated in Figure 10.

- The correlation between CNR and <u>average</u> degree of community reaction, illustrated in Figure 11, was used to define boundary values for the CNR in PNdB for each degree of community reaction. These boundary values were converted to distances from the curves plotted in the previous step.

Outer boundaries for the various community reaction zones, constructed as outlined above, were shown in Figure 1 for the case of a negative sound velocity gradient. This assumes that the majority of test firings are conducted under controlled conditions to achieve "favorable" acoustical propagation conditions.

For comparison, boundaries for each engine for the maximum community reaction level are shown in Figure 12 for nominal or average propagation conditions. This involves only the usual inverse square law loss plus atmospheric absorption loss.

Both Figure 1 and 12 also contain the boundaries for residential structural damage defined earlier.

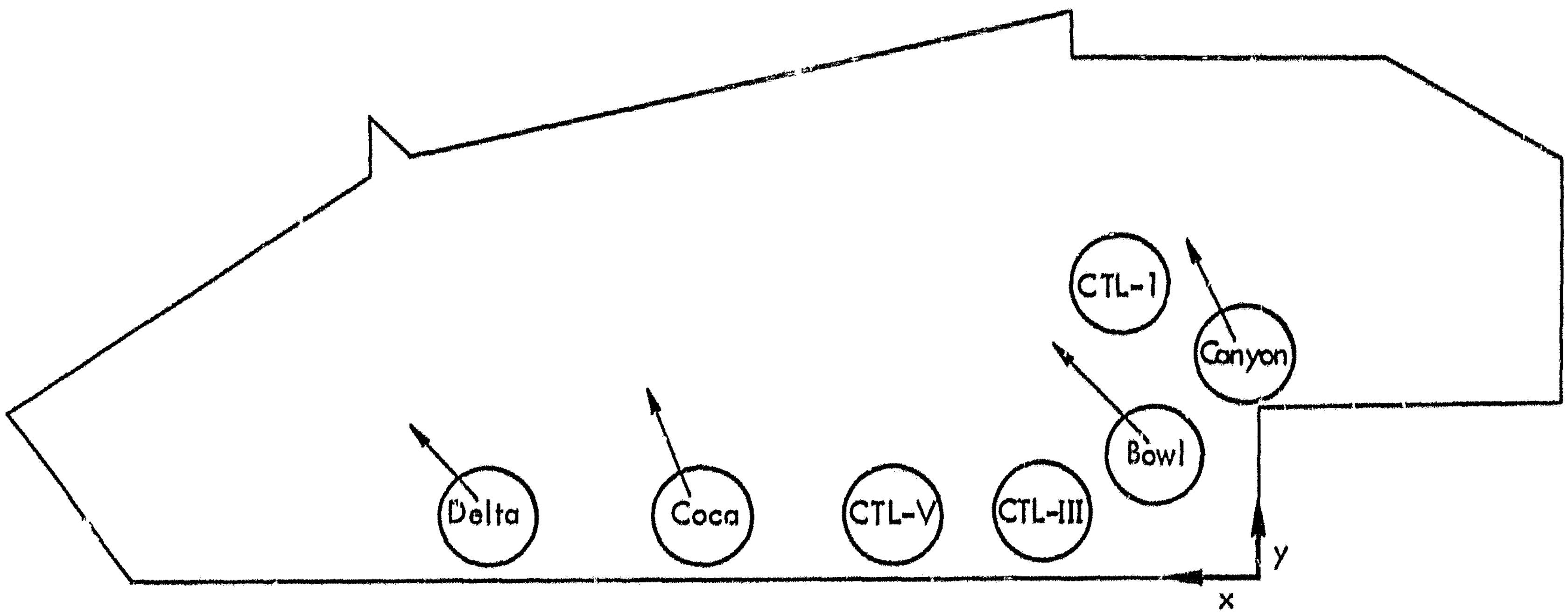
6.0 CONCLUSIONS

An analysis was carried out on the anticipated impact of noise levels generated by rocket engine tests at the Rocketdyne Santa Susana facility on potential inhabitants of the R. A. Watt property. The following conclusions were reached:

- No structural damage to residences is expected.
- Significant portions of the subject property lie in reaction zones ranging from threats of community action to actual vigorous community reaction (i.e., suits, injunctions, etc.).
- Predicted responses are based on extrapolation of data from static firings conducted at locations where the terrain is reasonably flat. Actual measurements at the site are recommended to account for any terrain losses associated with the hilly country at Santa Susana.

TABLE 1

SANTA SUSANA/NASA FACILITIES



	System Tested	Thrust 10^3 lbs	Fuel/ Oxidizer Quantity(1)	Test Duration(1) (sec)	Rocketdyne Designation		Approx. Coord.	
					Test Stand	Bldg. No.	x ft	y ft
Engine Tests	S-II Battleship	750	1880 lb/sec	500	Coca I	733	6200	720
	J-2 Engine	150	375 lb/sec (LH_2/LO_2)	500	Delta 2	737	7900	525
	J-2 Engine	150	375 lb/sec (LH_2/LO_2)	500	Bowl (VTS-2)	722	1210	1660
	J-2 Engine	150	375 lb/sec (LH_2/LO_2)	500	Bowl (VTS-3)	720	1400	1400
	H-1 Engine	185	833 lb/sec (LOX/RP1)	150	Canyon I Canyon II Canyon III	717 718 719	350 244 610	2420 2490 2300
Component Tests	F-1 and J-2 Engines	1500 150			CTL-I CTL-III CTL-V	309 409-411 422		

(1) Estimated

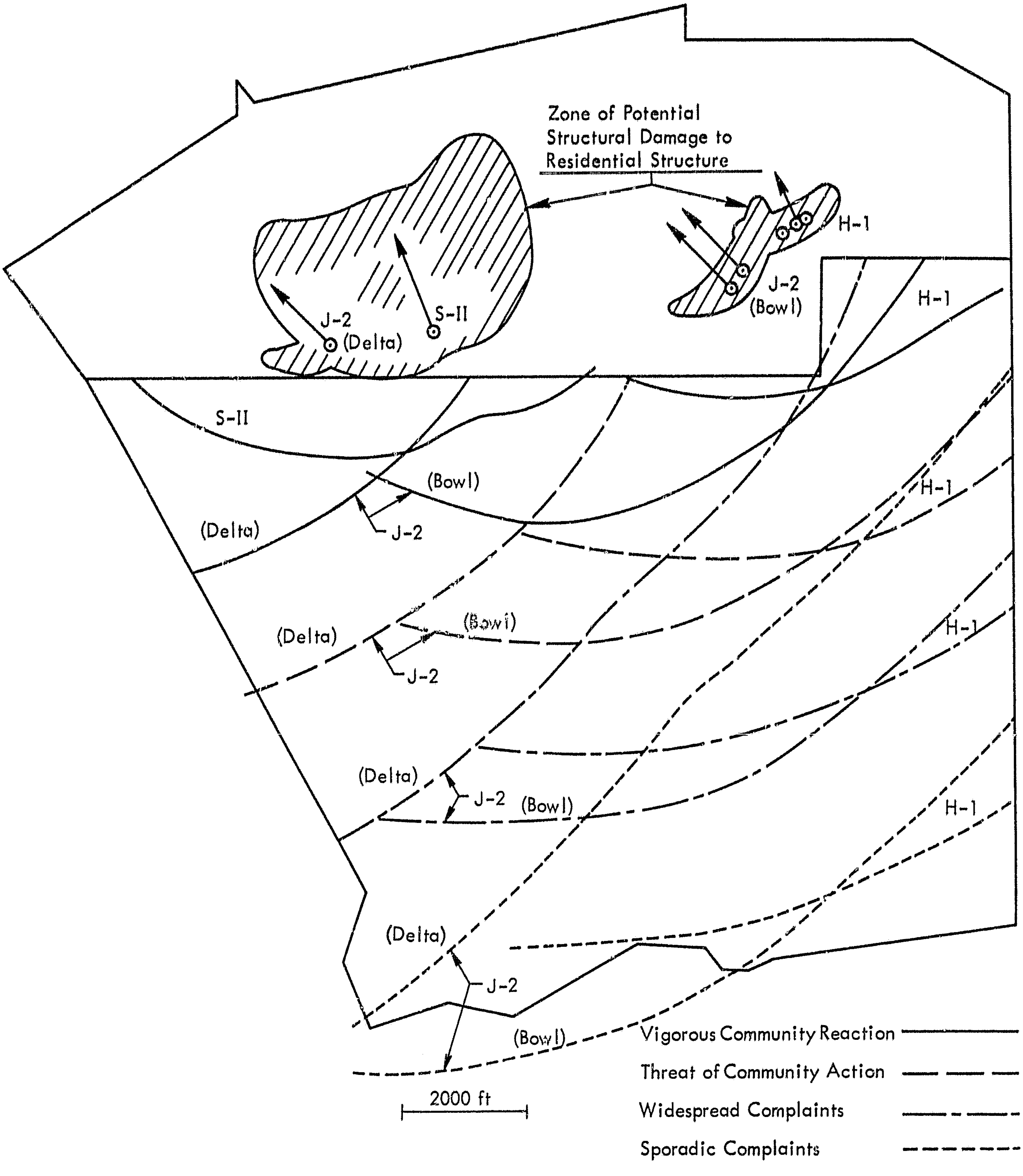


Figure 1. Predicted Community Response for Rocketdyne/Santa Susana Facility Based on Controlled Meteorological Conditions (Negative Velocity Gradient)

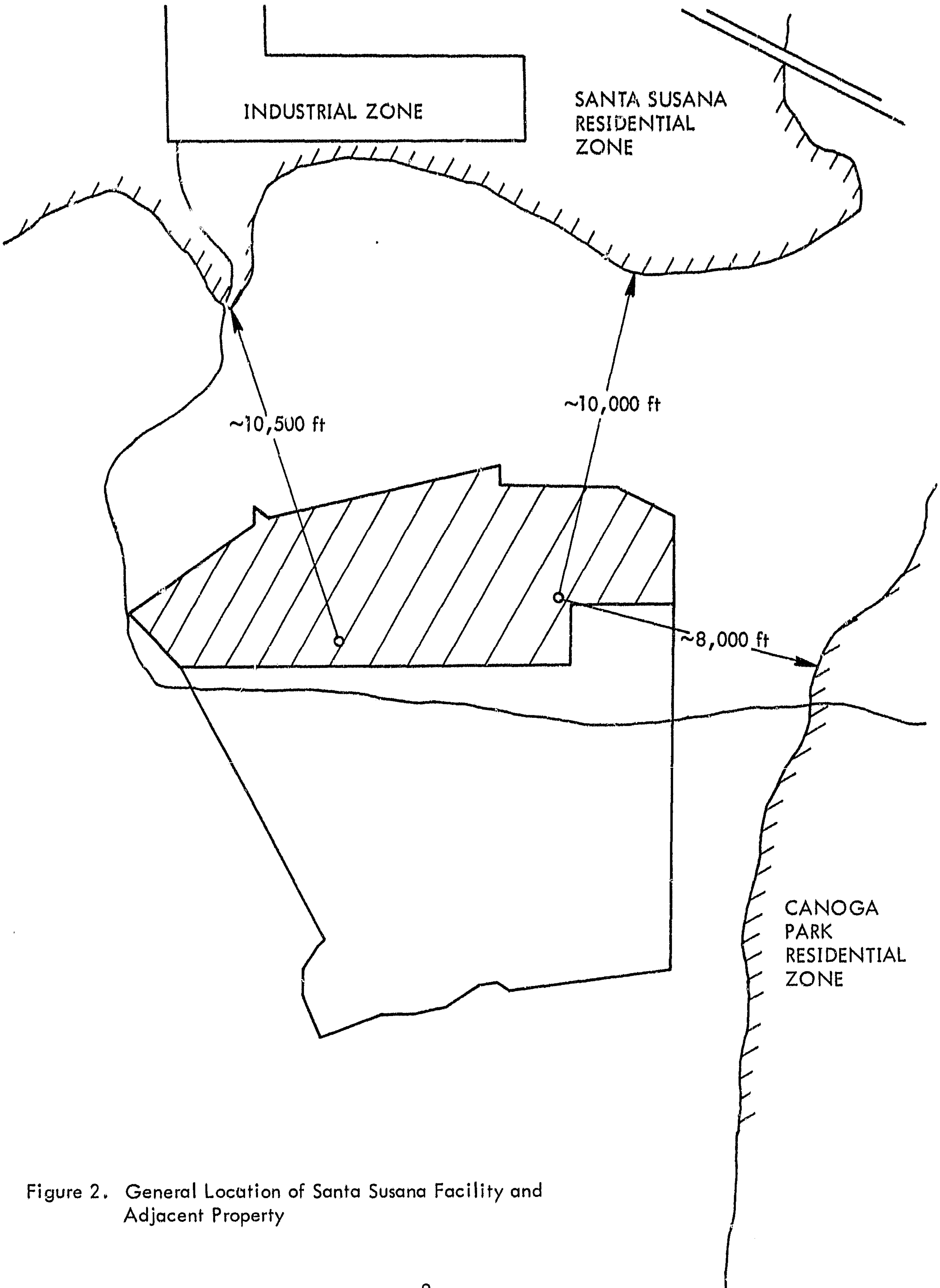


Figure 2. General Location of Santa Susana Facility and Adjacent Property

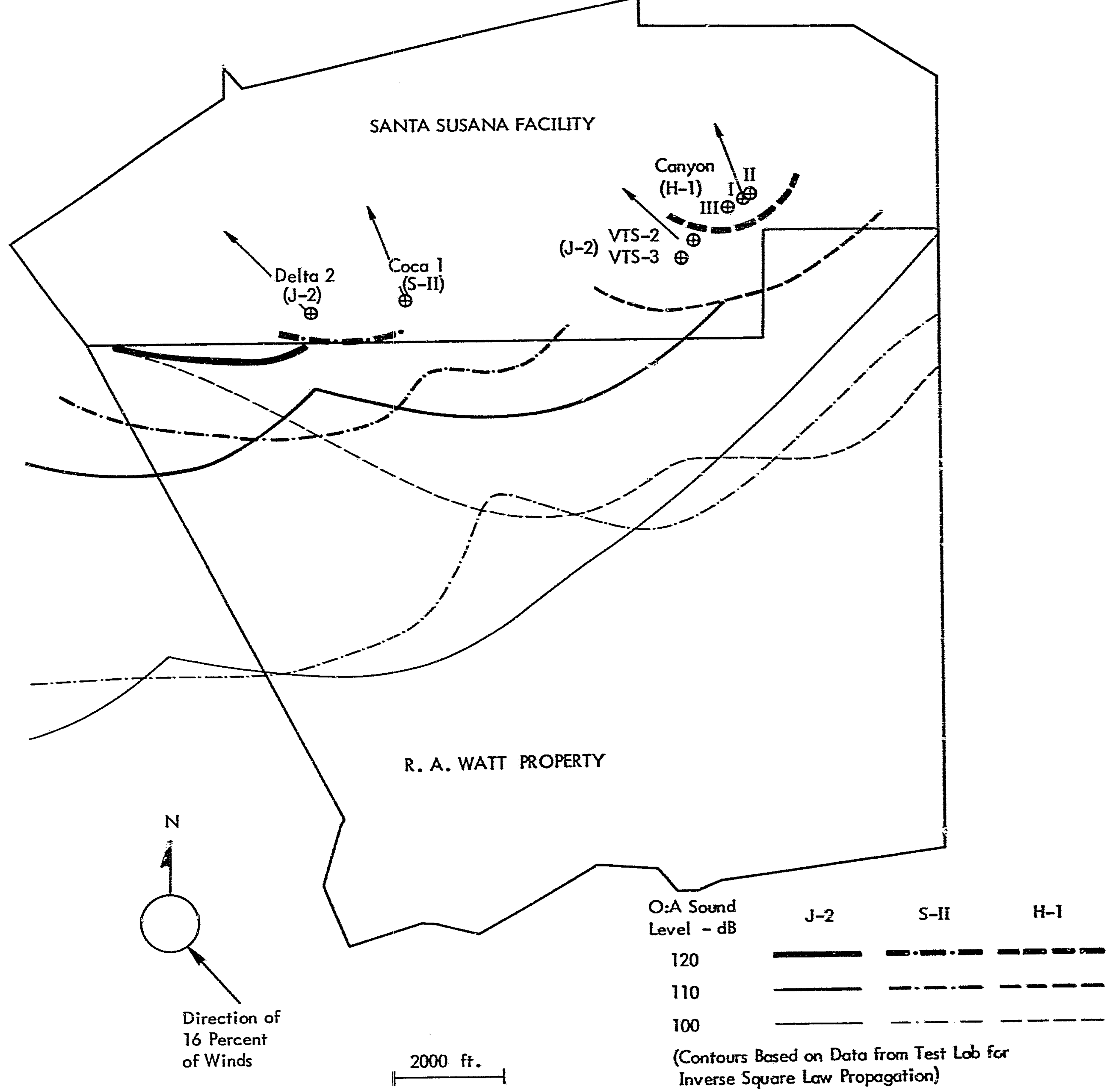


Figure 3. Contours of Overall Sound Level for Nominal Propagation Conditions

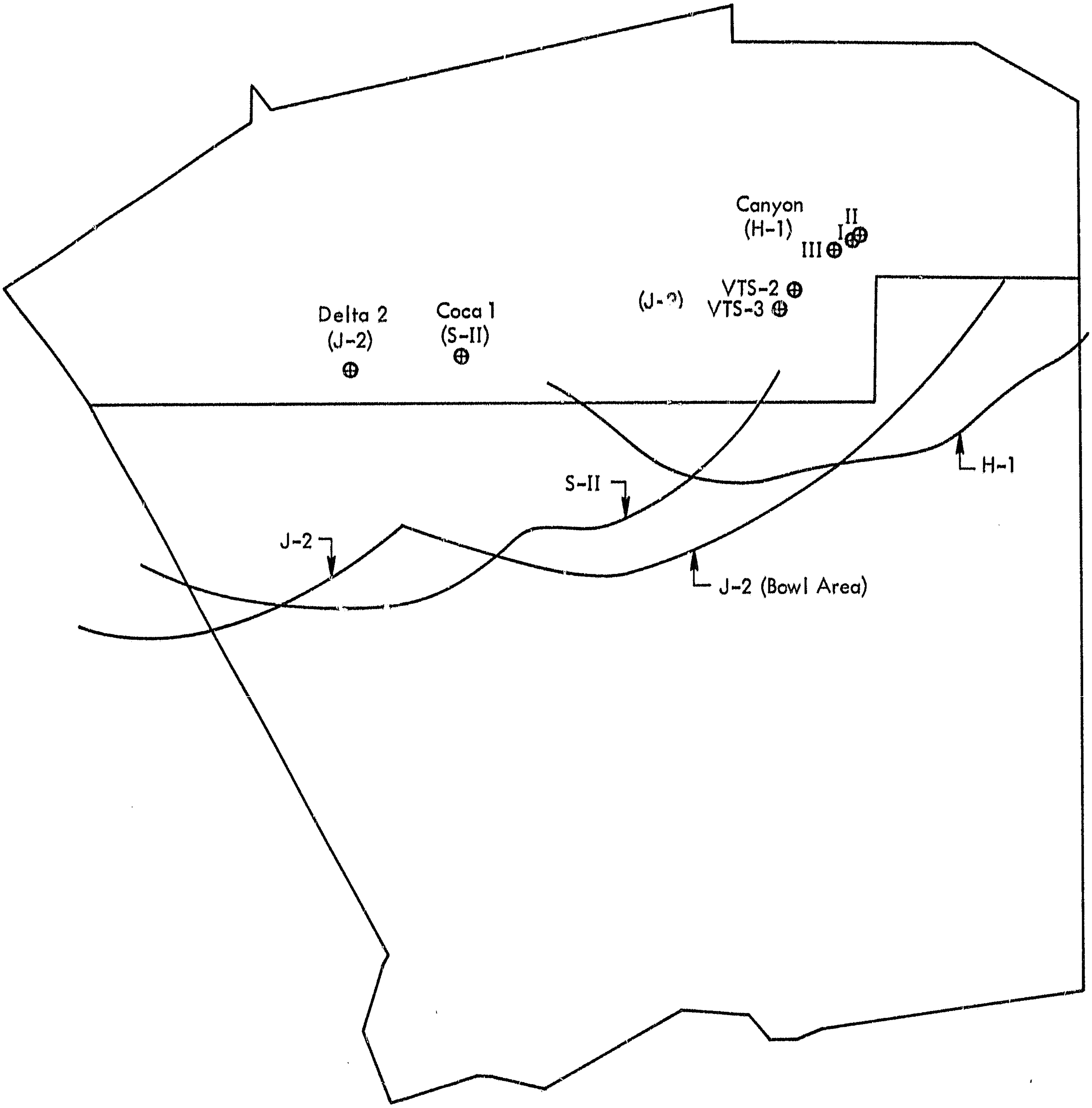


Figure 4. 100 dB Contours for Favorable (Negative) Temperature Gradient

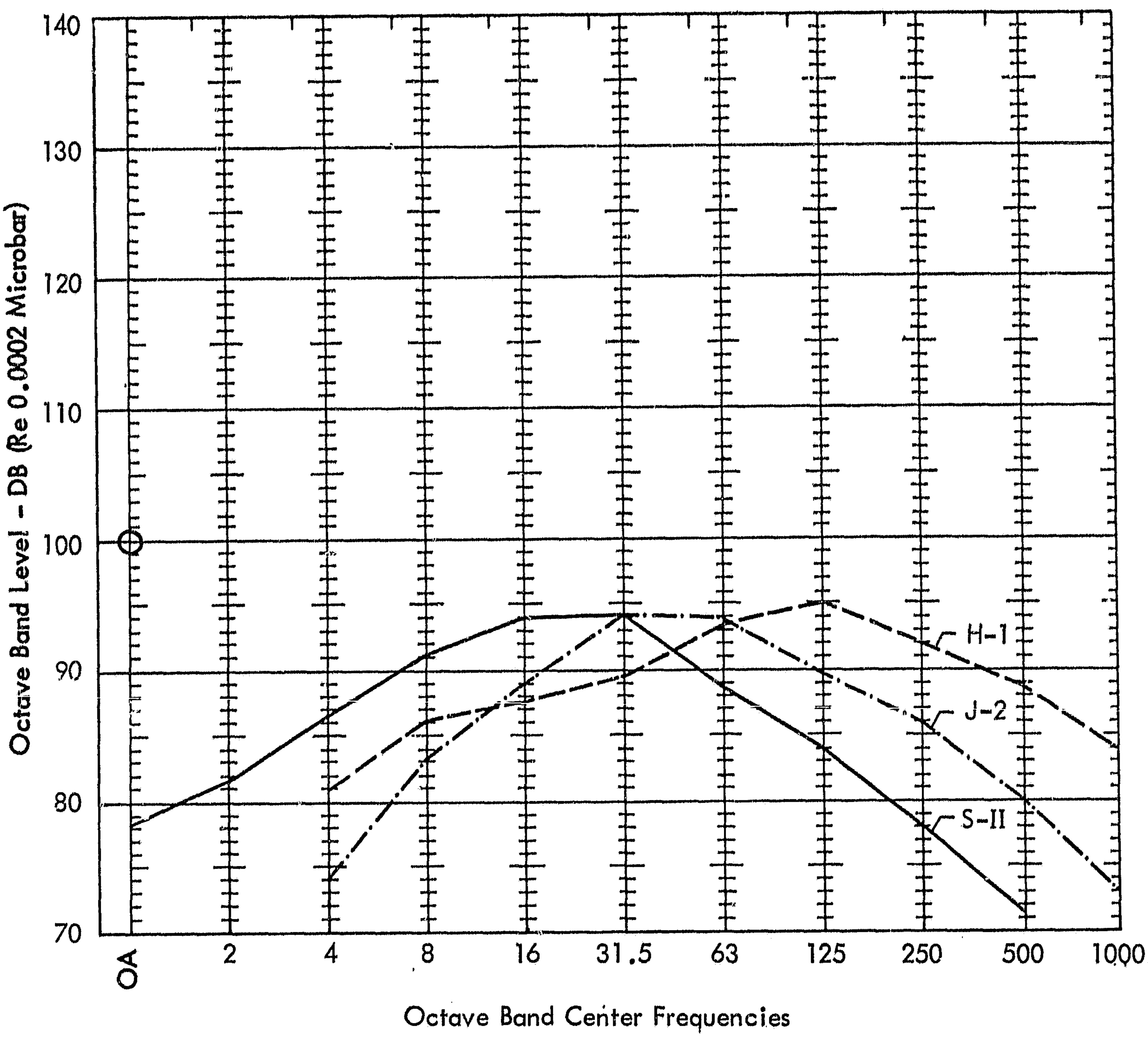


Figure 5. Octave Band Spectra for 100 dB Contours for Santa Susana/NASA Test Operations

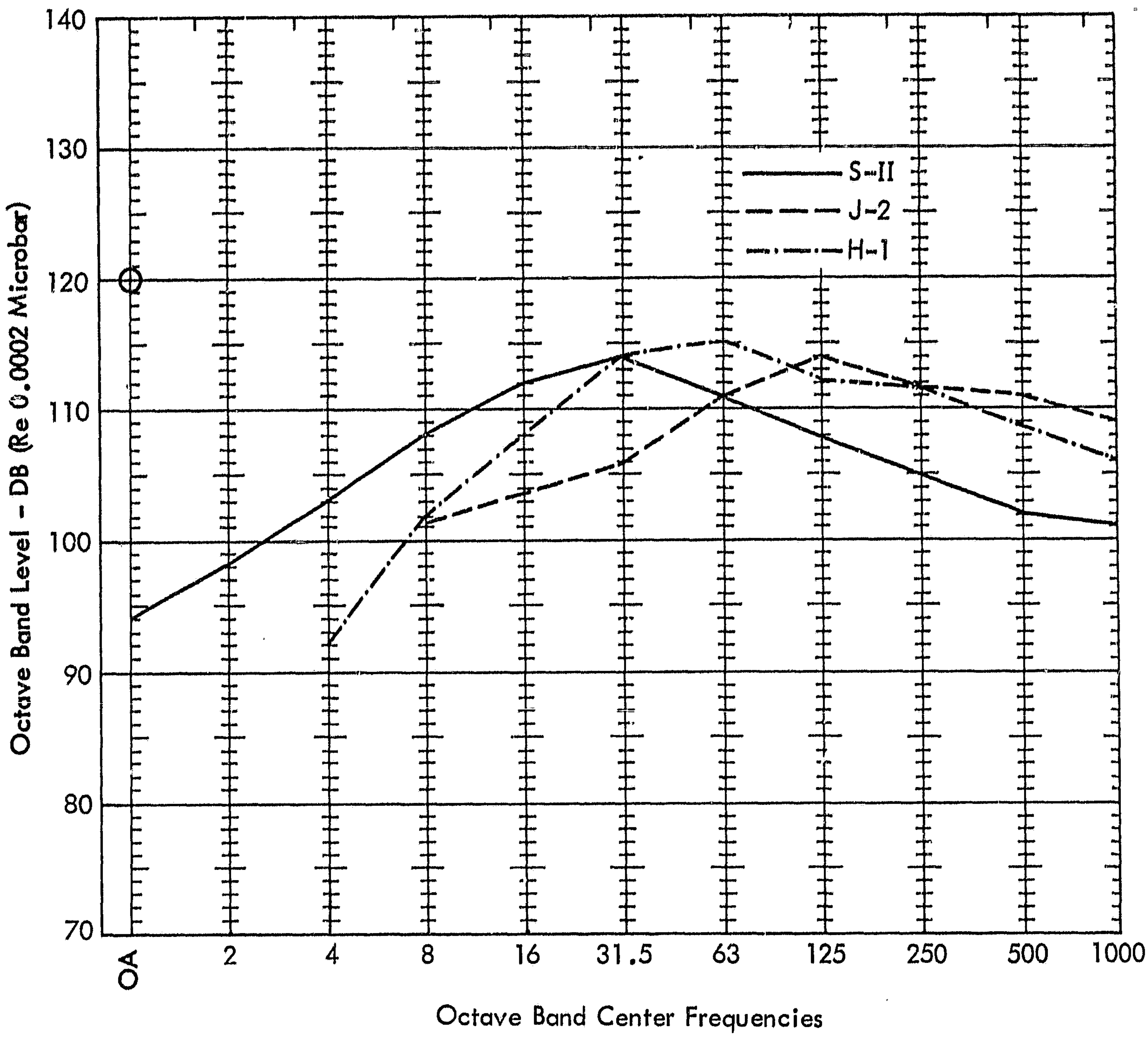


Figure 6. Octave Band Spectra for 120 dB Contours for Santa Susana/NASA Test Operations

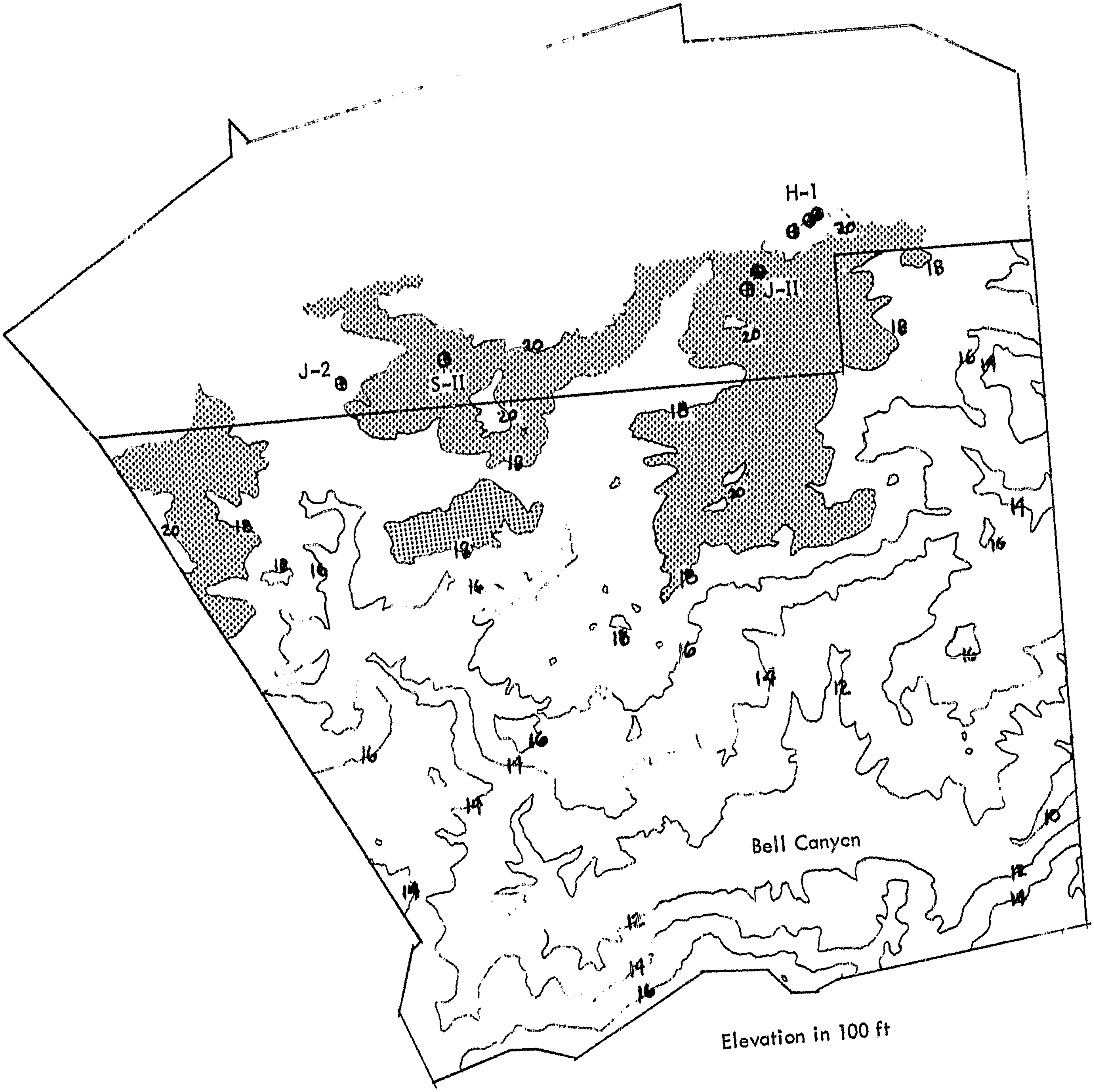


Figure 7. Contour Map of R. A. Watt Property

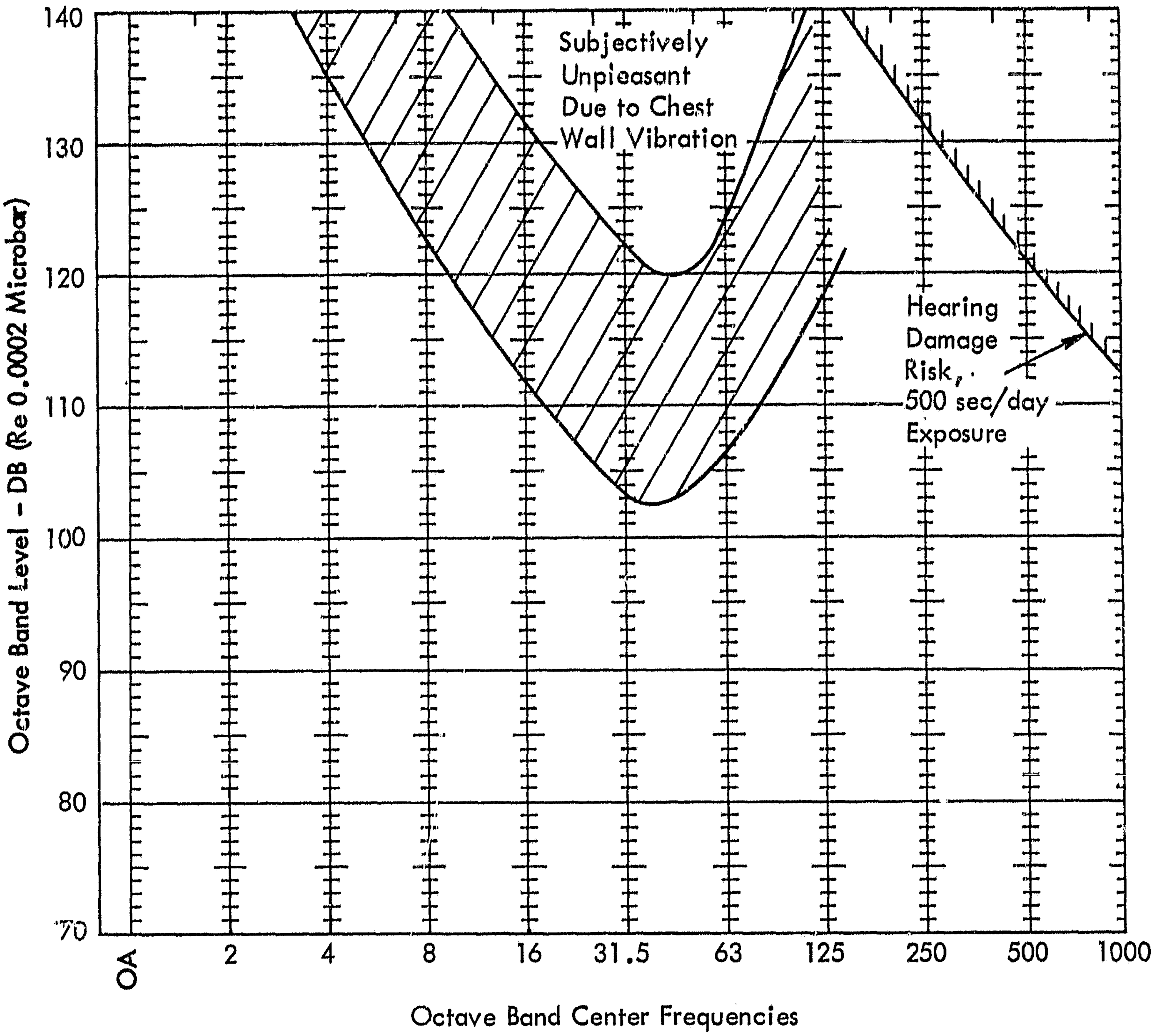


Figure 8. Subjective Criteria for Broad-Band Random Noise

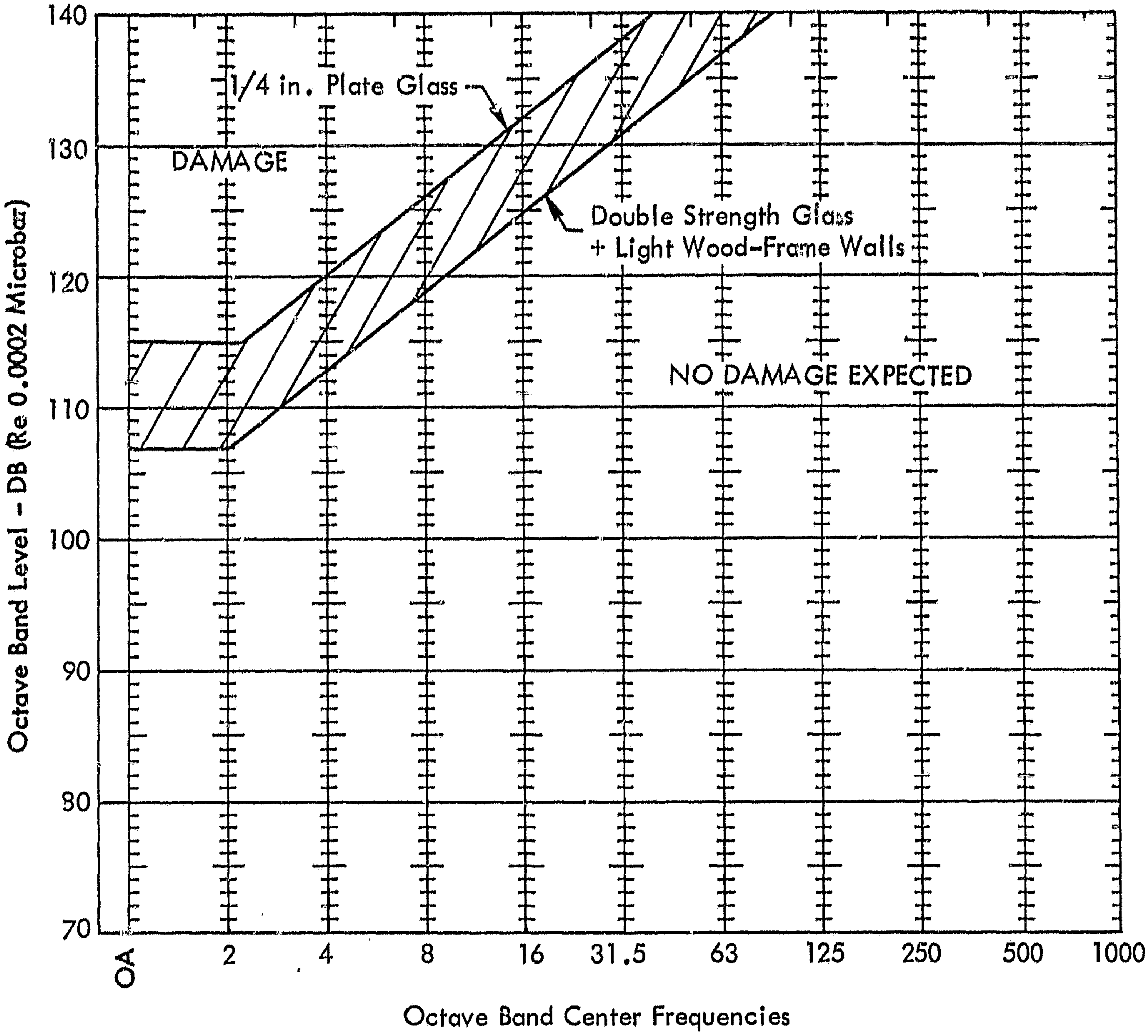


Figure 9. Structural Damage Criteria for Acoustic Excitation of Residential Structure

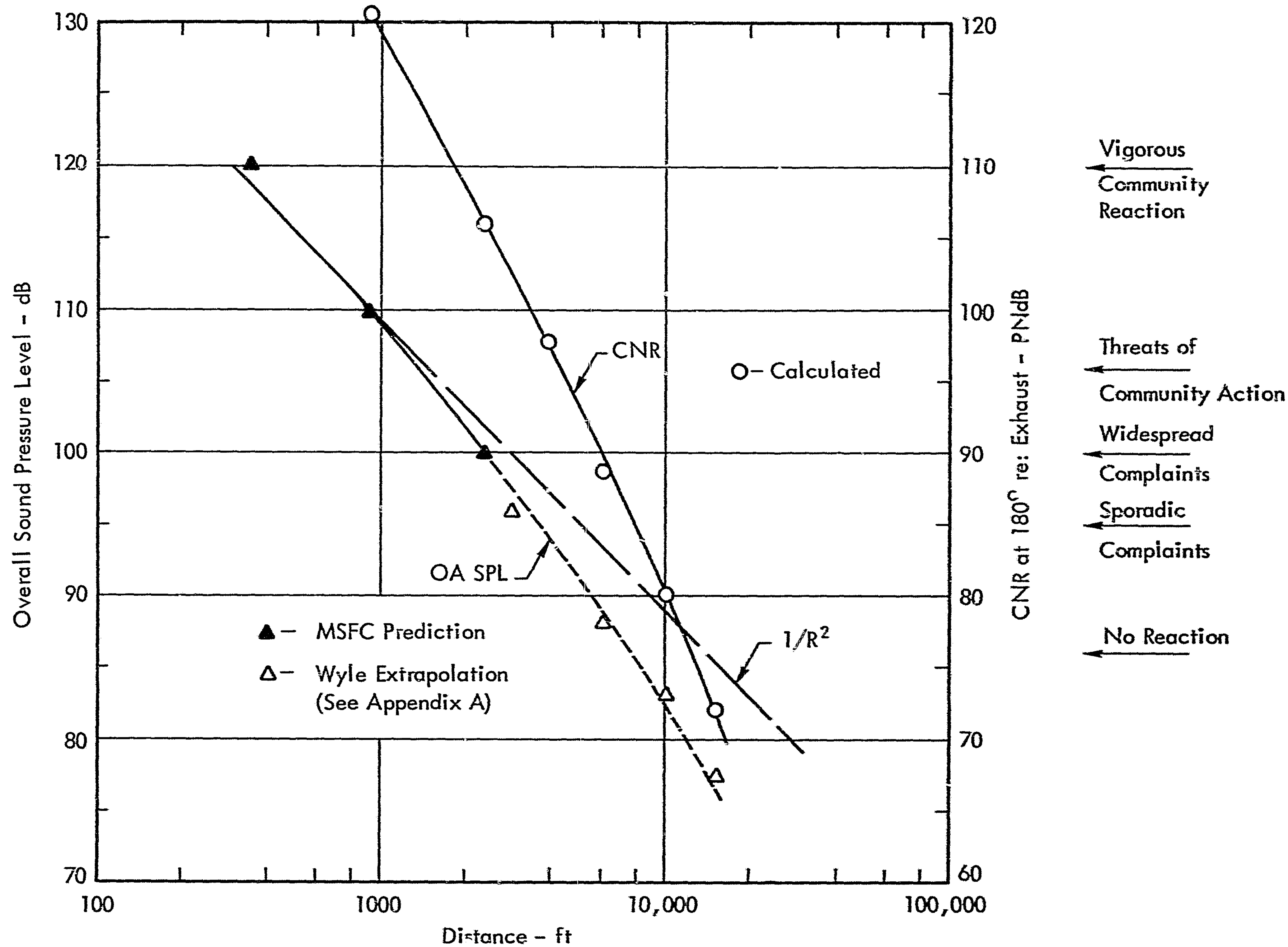


Figure 10. Overall Sound Level and Composite Noise Rating (CNR) Versus Distance at 180° re: Exhaust for J-2 Engine (For Negative Velocity Gradient Propagation Conditions)

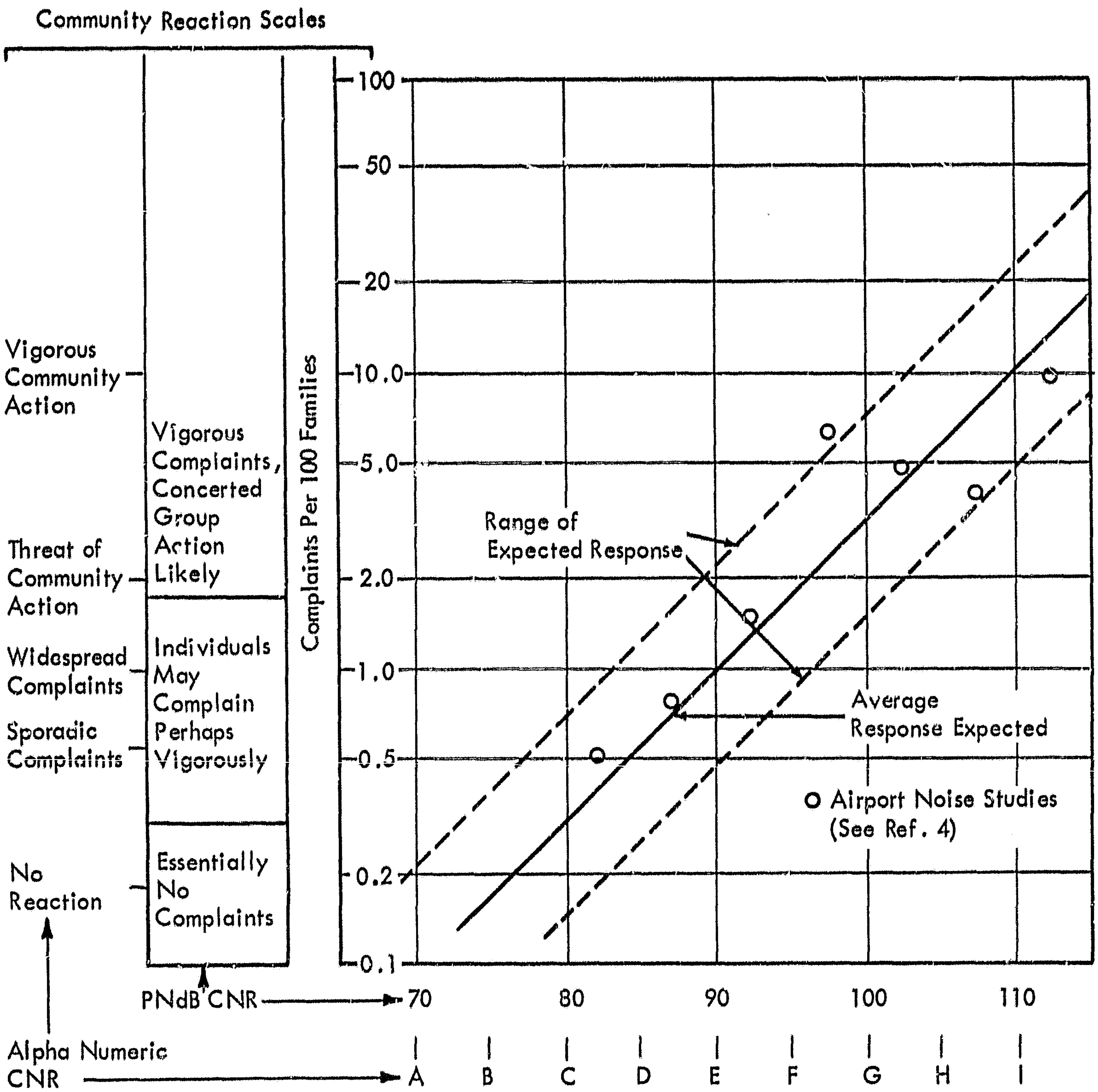


Figure 11. Relationships Between Expected Community Reaction to Noise and Composite Noise Rating

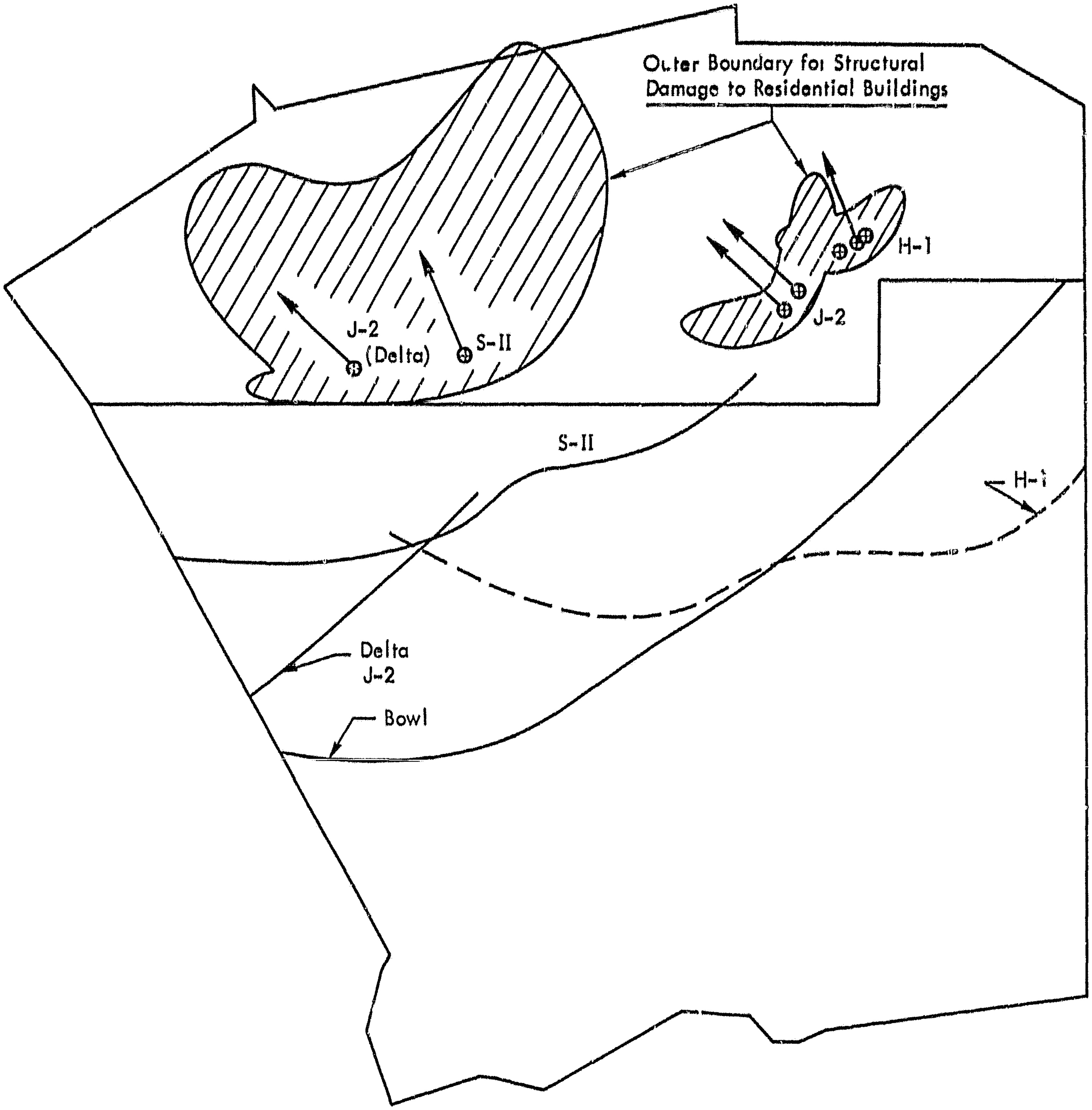


Figure 12. Outer Boundary of Zone for Vigorous Community Reaction, Based on Average Uncontrolled Weather Condition (Nominal Inverse Square Law Propagation)

APPENDIX A

SOUND PROPAGATION FOR NEGATIVE SOUND VELOCITY GRADIENT

The estimation of community noise levels in the vicinity of a rocket test site, based on "controlled meteorological conditions" requires a consistent basis for predicting propagation loss. This basis is defined here.

The term "controlled meteorological conditions" refers, in this case, to test conducted only when the variation in speed of sound with altitude has an approximately constant negative slope. In other words, sound velocity decreases with increasing altitude. This negative sound velocity gradient tends to bend sound rays upward resulting in a so-called shadow zone due to an excess attenuation loss in addition to that provided by geometrical spreading and by atmospheric absorption.

An extensive set of data are reported from field tests of wide band noise propagation for just such conditions of a negative velocity gradient (Refs. 2,3). The data cover two non-overlapping extremes of "high" frequency propagation measured over distances from 0 to 4500 ft (Ref. 3) and low frequency propagation measured over distances of 5000 to 23,000 ft (Ref. 2). Without going into details of the results, the general trend in attenuation loss in excess of geometric spreading and atmospheric absorption loss may be summarized as follows:

Region 1 — Up to a distance of 200 to 400 feet, the excess attenuation loss is essentially zero. This is called Region 1 (Ref. 2).

Region 2 — When the negative sound velocity gradient is due, in part, to ground winds, the excess loss beyond region 1, decreases rapidly to a fixed value in a distance (Region 2) typically equal to 400 to 1600 ft.

Region 3 — Beyond this transition region, the excess remains roughly constant. The maximum value of this excess attenuation varies from 10 to 30 dB for frequencies of 300-4800 Hz over distances up to 4500 ft. The higher attenuation occurs for a source-receiver path which lies close to the direction from which a ground wind is blowing. The more intense a ground wind, and the closer the propagation path to being directly upwind, the higher the fixed attenuation in Region 3. An average value for this fixed loss of about 15 dB at 1000 Hz appears reasonable for engineering purposes.

At low frequencies, around 100 Hz, and over distances in excess of 4500 ft, the fixed attenuation observed from Reference 2 over a wide range of conditions was about 5-6 dB.

Only the fixed attenuation in Region 3 is of concern here and it will be assumed to have the following values at distances beyond 1500 ft for a negative velocity gradient.

Frequency, Hz	1-8	16	32	63	125	250	500	1000	2000	4000
Fixed Excess Loss, dB	2	3	4	5	6.5	8	10	12.5	16	20

These values are based on a theoretical trend line through the data cited above as shown in Figure A-1.

In addition to this fixed loss, and normal inverse square spreading loss, the following attenuation rate was used to account for atmospheric absorption loss (see Chapter 7 of Reference 4).

Frequency (Hz)	Attenuation Rate dB/1000 ft
4	0.06
8	0.07
16	0.135
32	0.27
64	0.5
125	0.5
250	0.5
500	1.0
1000	1.7
2000	3.5
4000	8.0

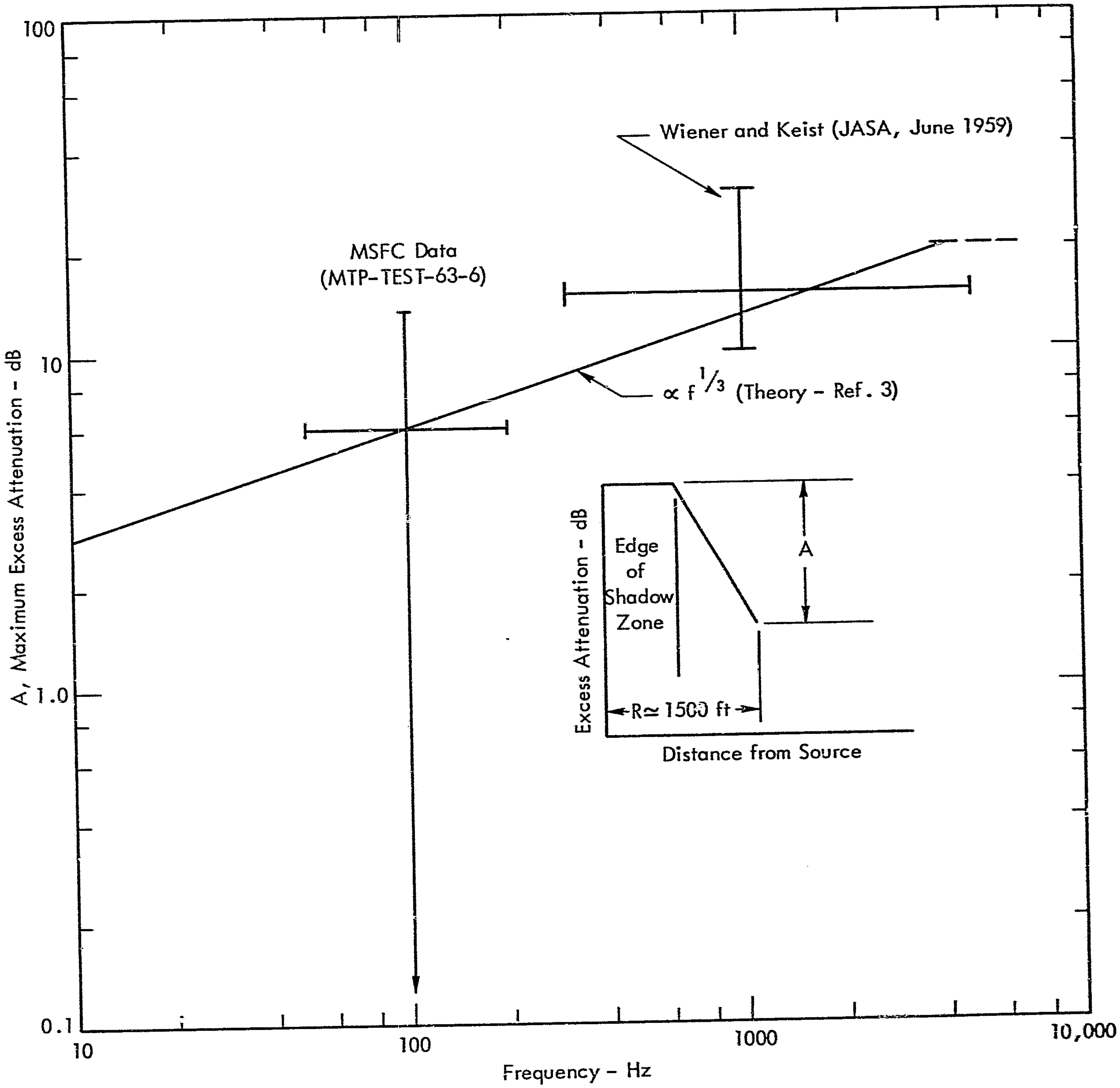


Figure A-1. Tentative Design Chart for Estimating Average Value of Maximum Excess Attenuation in a Shadow Zone Created by Wind and/or Temperature Gradients

REFERENCES

1. S-2 Acoustics Study, Rocketdyne BCI 63-109

2. R. N. Tedrick and R. C. Polly, "A Preliminary Investigation of the Measured Atmospheric Effects Upon Sound Propagation," Marshall Space Flight Center Memorandum MTP-TEST-63-6, May 1963.

3. F. M. Weiner and D. N. Keast, "Experimental Study of the Propagation of Sound Over Ground," J. Acoust. Soc. Am. 31, 724-733, June 1959.

4. L. C. Sutherland, ed., "Sonic and Vibration Environments for Ground Facilities - A Design Manual," Wyle Laboratories Research Staff WR 68-2, March 1968.