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CONCORDE NOISE-INDUCED BUILDING VIBRATIONS

INTERNATIONAL AIRPORT DULLES - FINAL REPORT

Staff-Langley Research Center

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National Aeronautics and
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CONCORDE NOISE-INDUCED BUILDING VIBRATIONS
INTERNATIONAL AIRPORT DULLES - FINAL REPORT

By Staff-Langley Research Center*

SUMMARY

The National Aeronautics and Space Administration (NASA) conducted a series of studies to assess the noise-induced building vibrations associated with Concorde operations. The vibration levels of windows, walls, and floors were measured along with the associated noise levels of Concorde, subsonic aircraft and some nonaircraft events. Test sites included Sully Plantation which is adjacent to International Airport Dulles (IAD) and three residential homes located in Montgomery County, Maryland. The measured vibration response levels due to Concorde operations were:

- o higher than the levels due to other aircraft
- o less than the levels due to certain household events which involve direct impulsive loading such as door and window closing
- o less than criteria levels for building damage
- o comparable to levels which are perceptible to people

INTRODUCTION

Measurements of Concorde noise-induced building vibrations were conducted by the National Aeronautics and Space Administration (NASA) for the DOT/FAA as part of the Concorde assessment program. Measurement sites

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for the vibration assessment are shown in figure 1 which locates the buildings relative to departure paths at IAD. The first study was carried out at Sully Plantation, Chantilly, Virginia, and included both arrival and departure operations during the period of May 20 through May 28, 1976. The results were reported in NASA TM X-73919. A second study was conducted at Sully Plantation from June 14 to June 17, 1976, to expand the noise and vibration data base on departure operations which had levels that greatly exceeded those due to arrival operations. The results were reported in NASA TM X-73926. Sully Plantation was chosen for the first series of tests because of its proximity to the airport (approximately 5.6 kilometers (3.0 nmi) from brake release) and because of the public interest in this recently restored historical landmark. A third series of tests was conducted to monitor noise and vibration response in more typical residential type homes located at various distances from the airport. Three homes in Montgomery County, Maryland, ranging from 21 to 31 kilometers (11 to 17 nmi) were identified by the FAA as potential test sites. In each case, concern about building vibrations had been expressed by the occupants who were willing to offer their homes as test sites. The results from this third study were reported in NASA TM X-73947.

The approach followed in the assessment of Concorde noise-induced building vibrations involved: the development of functional relationships ("signatures") between the vibration response of building elements and the outdoor and/or indoor noise levels for events of interest and the comparison of Concorde-induced responses with the responses associated with other aircraft as well as common domestic events and/or criteria. A summary of recorded events is listed in Table I.

Detailed information on building locations, structural details, test procedures, instrumentation, and data acquisition is given in the cited NASA reports which are available upon request.

RESULTS AND DISCUSSION

Noise-Induced Vibration

The building vibration characteristics associated with Concorde and other noise events were studied by examining the "response signatures." As previously indicated, the signature is simply the relationship between the vibratory response and the sound pressure level and provides a comparison of the relative effectiveness of each noise for generating vibration over a range of noise levels. Representative signatures measured on a north window at Sully Plantation are shown in figure 2 for the Concorde and subsonic aircraft departures. Several data points were obtained for each aircraft departure. The solid line represents a least squares fit of the composite Concorde data points (5 flights) and the dashed curve represents the collective response signatures for the subsonic aircraft (39 flights). These and other data collected at Sully Plantation and Montgomery County suggest that the vibration response to aircraft noise can be approximated by a linear relationship between the acceleration level and the overall sound pressure level. Furthermore, the differences in response signatures between the various aircraft were relatively small at Sully Plantation and such differences, if they exist, could not be detected in the Montgomery County data. On an absolute basis, however, the maximum or peak Concorde noise and induced vibration levels exceed those of the subsonic aircraft in all cases.

The similarity in the response signatures for Concorde and the subsonic aircraft may be explained by examining the spectral characteristics of the noise. The frequency content of the Concorde noise relative to the noise from the other aircraft is shown in figures 3(a) and 3(b). The spectra have been normalized to the overall noise level to enable a direct comparison between aircraft at both locations. As can be seen, the low-frequency characteristics of the Concorde and the subsonic aircraft are similar. This would suggest that the vibration response due to Concorde and the subsonic aircraft would be similar for a given overall sound pressure level.

The maximum noise and vibration levels recorded at Sully Plantation and the test sites in Montgomery County are summarized in figure 4 for aircraft events. As previously noted, the noise levels and, hence, the vibration levels resulting from Concorde operations exceeded those of the subsonic aircraft. Furthermore, the relative differences in maximum levels were found to be greater in Montgomery County than at Sully Plantation. With respect to the vibration resulting from nonaircraft events, Table II includes a summary of the maximum vibration levels associated with several common household events as well as aircraft events. As noted, various (nonacoustical) direct impulsive type loadings which occur on a building due to the closing of doors and windows, dropping of a book, etc., can generate vibratory levels equal to or exceeding those due to aircraft noise.

Vibration Effects

A comprehensive review of the effects of low-frequency noise on building structures and people is given in the final Concorde Environmental Impact Statement (EIS). Representative measurements from the present study were selected for analysis in order to determine if the levels of vibration due

to Concorde operations represent potential adverse impacts, either due to structural damage or to human perception and reaction.

Structural response.- For structural damage prediction, the safe structural limit recommended by the Bureau of Mines for blasting vibrations is 2.0 inches per second particle velocity. This limit would prevent plaster cracking, broken windows, masonry cracks, and other damage to buildings. A lower limit of 1.0 inch per second particle velocity is the accepted practice for longer duration exposures such as an aircraft overflight. This limit of 1.0 inch per second is shown in figure 5 in terms of vibration level and vibration frequency. Also shown on this figure are the "worst" case or maximum levels that were measured during the present study for window, wall, and floor at Sully Plantation during Concorde departure operations. The measured levels are about a factor of 20 to 30 less than the damage criteria limit and no damage to such building structures would be expected due to the Concorde levels measured.

Human response.- Numerous studies have been made to establish perception thresholds and degree of annoyance to different types of vibration stimuli. These studies are reviewed in the final Concorde EIS and relevant criteria are reproduced in figure 6. Also shown on this figure are the "worst" case or maximum wall vibration levels that were measured during Concorde departure operations at Sully Plantation (figure 6(a)) and for the three test sites in Montgomery County (figure 6(b)).

Comparison of these measurements with the criteria shows the levels to be comparable to levels which are perceptible to people.

CONCLUDING REMARKS

The following conclusions are based on building vibration response measurements at Sully Plantation which is adjacent to International Airport Dulles and at three residential homes located in Montgomery County, Maryland:

1. The vibration response of building elements consisting of windows, walls, and floors appear to be directly proportional to the sound pressure level of the aircraft noise and virtually independent of aircraft type.

2. Concorde operations resulted in higher noise levels and, consequently, higher vibration levels than subsonic jet aircraft.

3. Certain household events which involve direct impulsive loading such as door and window closing resulted in response levels equal to or higher than those associated with Concorde operations.

4. Comparison of the response levels with structural damage criteria shows the measured responses to be less than those expected to cause damage such as cracked plaster or broken windows.

5. All measurements were below the International Standard Organization's threshold of perception.

6. Most measurements were close to or below the International Standard Organization's proposed "minimum complaint level."

TABLE I. SUMMARY OF RECORDED EVENTS

Location	Subsonic Aircraft	Concorde	Special Events	Total
Sully Plantation	121	7	21	149
Montgomery County, Md.	36	14	42	92
TOTAL	157	21	63	241

TABLE II.- MAXIMUM VALUES OF VIBRATION

Location	Activity	Acceleration, g_{rms} Window	Wall	Floor
Sully Plantation	Concorde	0.432	0.048	0.166
	Other Aircraft	0.229	0.023	0.046
	Road Traffic	<0.013	<0.013	<0.013
	Tour Group	<0.013	<0.013	0.068
	Vacuum Cleaner	0.105	0.025	0.065
	*Book Drop	----	0.18	3.8
	*Step From Chair	----	<0.04	1.0
Montgomery County	Concorde	0.12	0.034	-----
	Other Aircraft	0.02	<0.005	-----
	*Door Closing	0.7	0.9	-----
	*Window Closing	>1.0	0.2	-----
	*Window Washing	0.168	0.012	-----

*Acceleration Peak Values
<Less Than
>Greater Than
-----Not Measured

TABLE III.- LEGENDS FOR FIGURES 6(a) AND 6(b)

Criteria for Vibration Environmental - Horizontal Motion

Curve	Description
A	ISO "Reduced - Comfort" Boundary 16 Min/Day Exposure
B	ISO "Reduced - Comfort" Boundary Continuous Exposure
C	Upper Bound of Band of "Perceptible Vibration Levels," NASA Design Manual
D	ISO "Threshold of Perception"
E	Lower Bound of Band of "Perceptible Vibration Levels," NASA Design Manual
F	ISO Draft Proposal (minimum complaint level) Residential Daytime
G	ISO Draft Proposal (minimum complaint level) Residential Nighttime

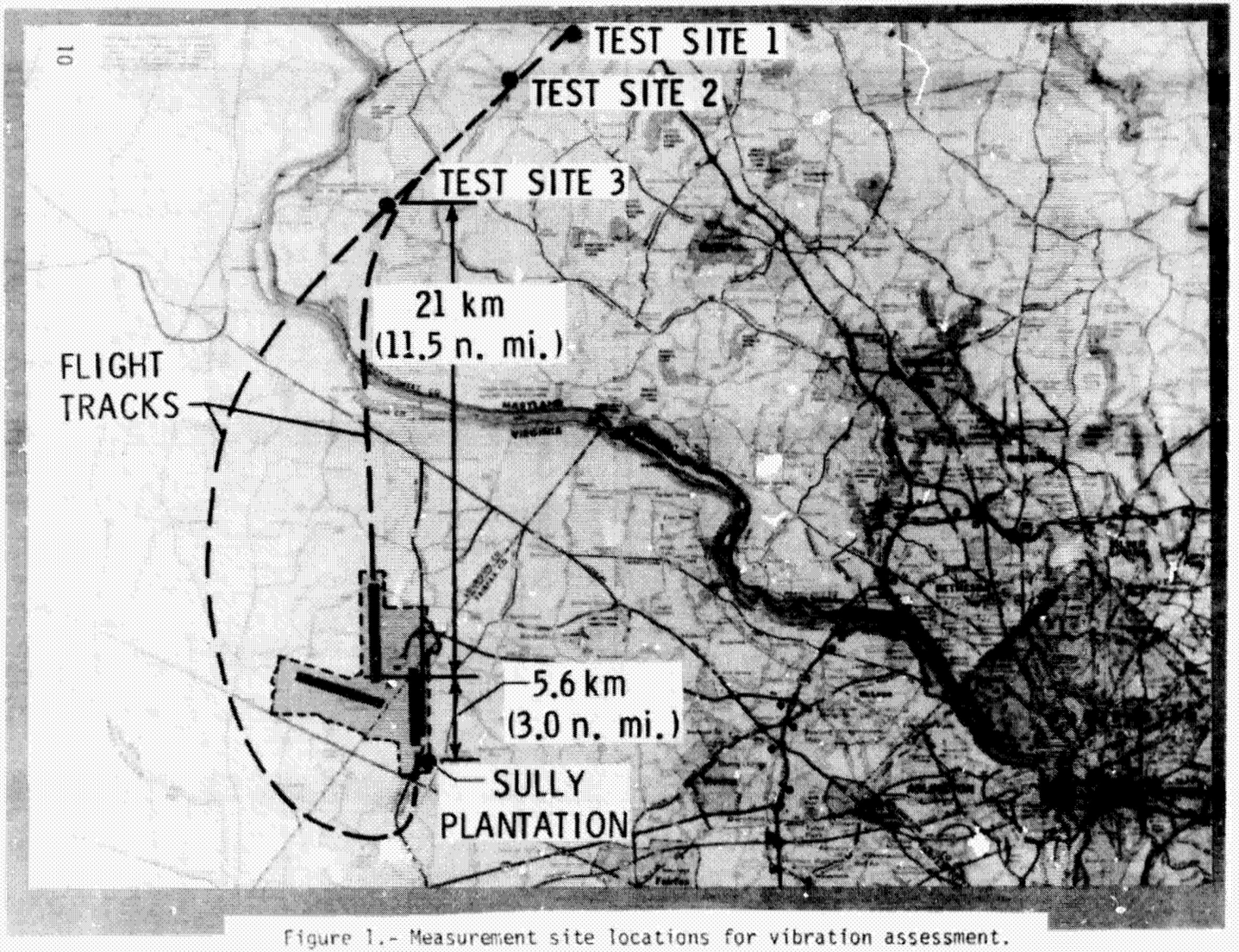

Figure 1.- Measurement site locations for vibration assessment.

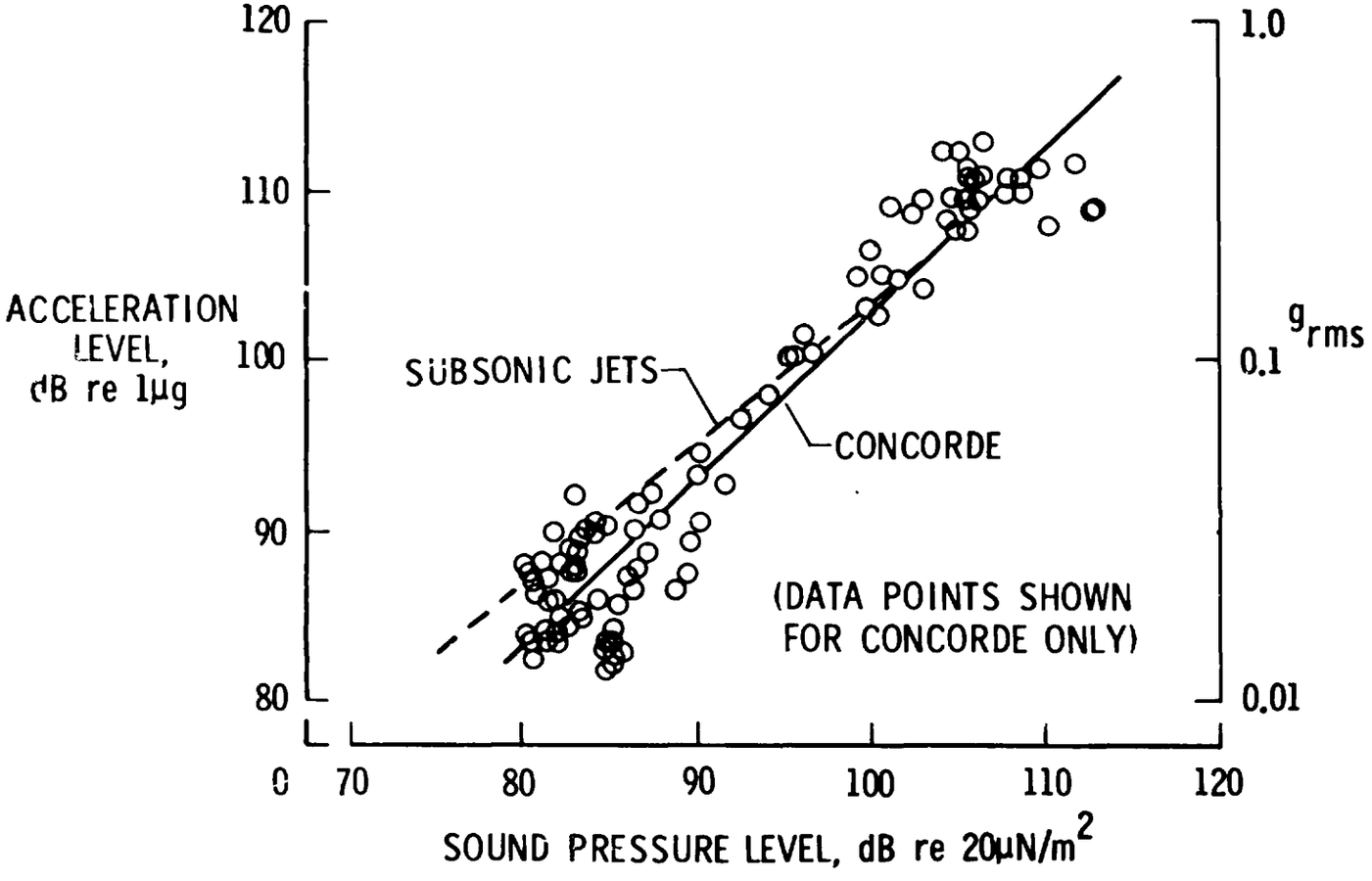

Figure 2.- North window vibration response for departures. Sully Plantation.

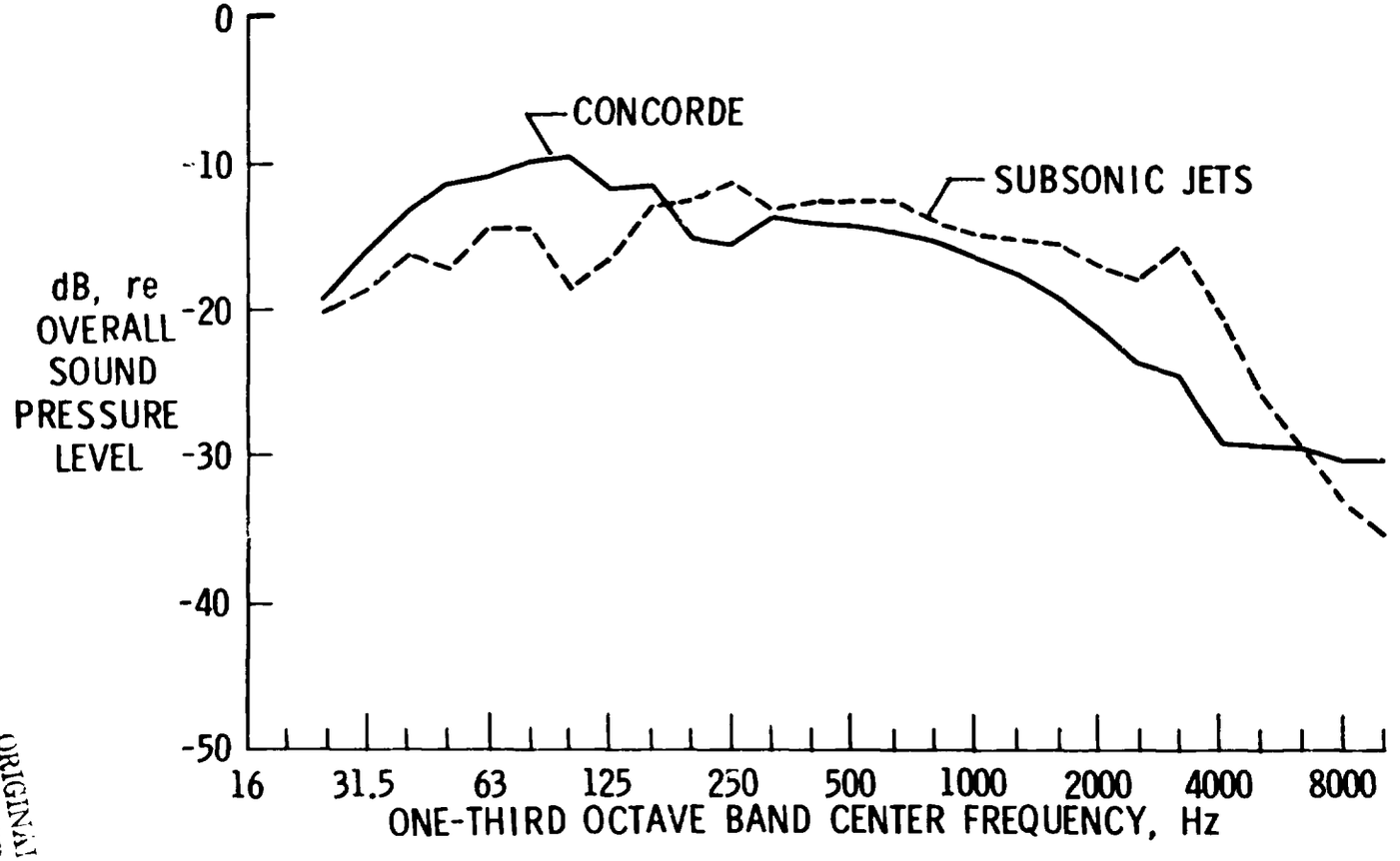

Figure 3(a).- Normalized noise spectra for departure. Sully Plantation.

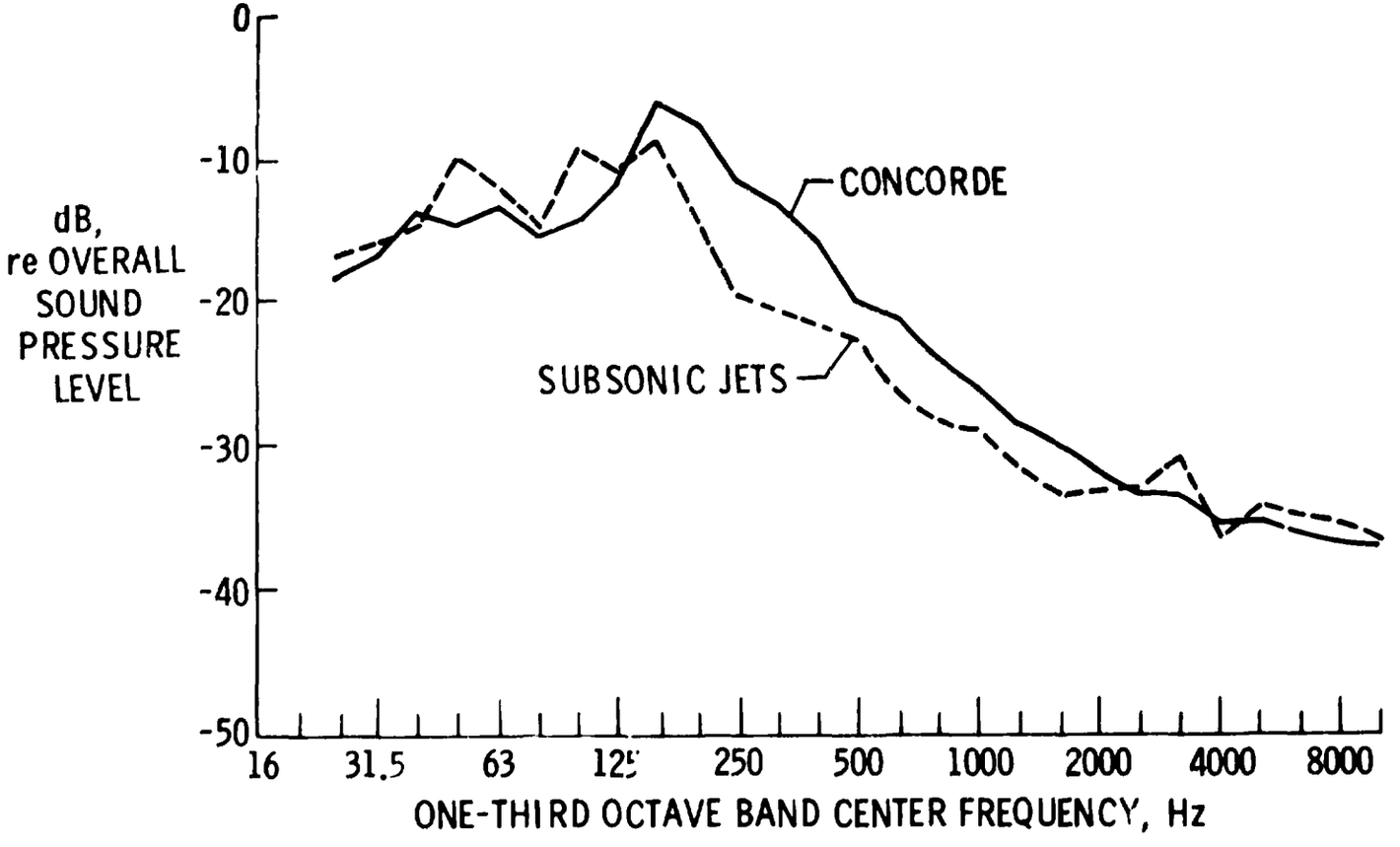

Figure 3(b).- Normalized noise spectra for departures. Montgomery County, Maryland.

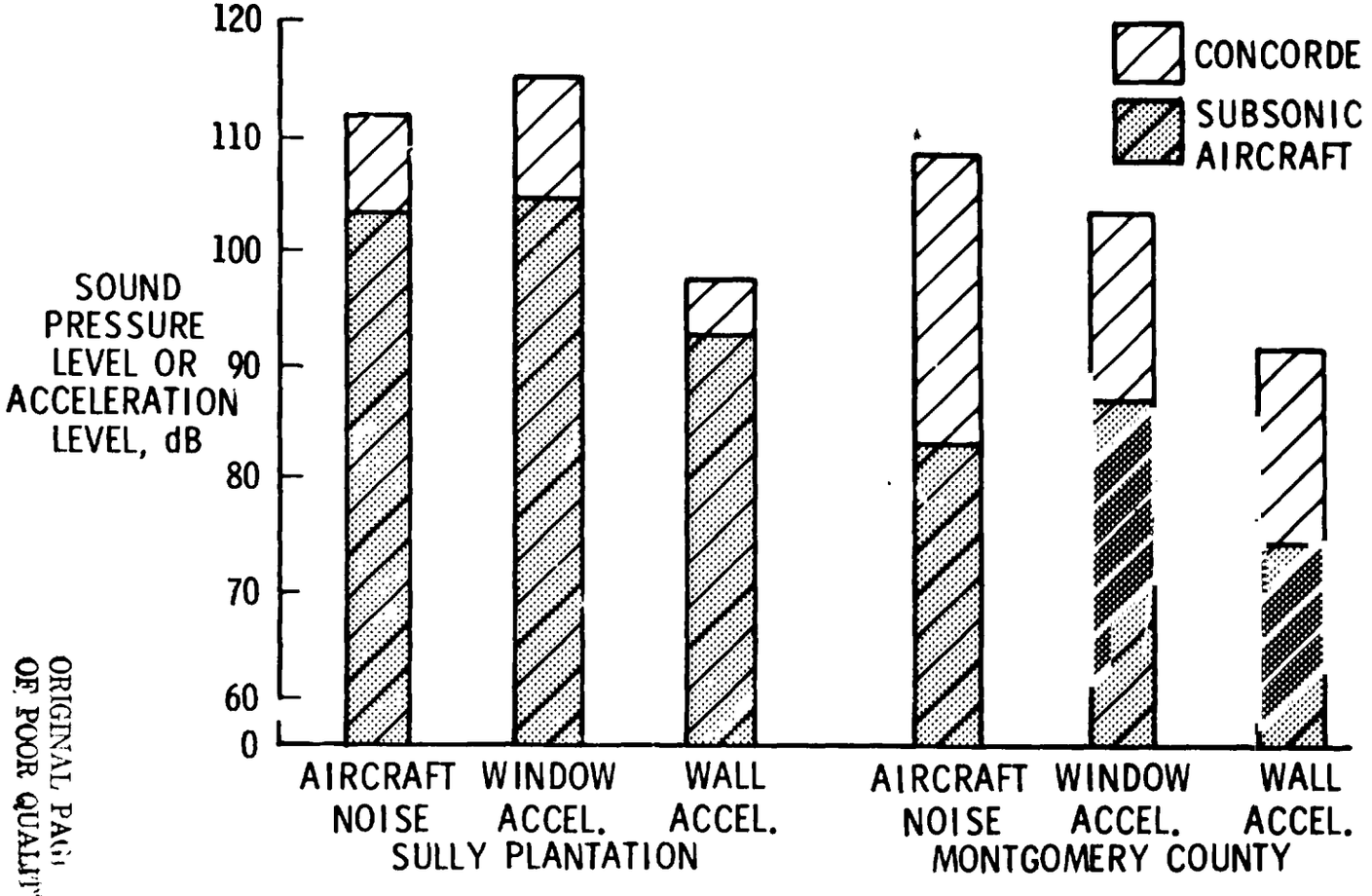

Figure 4.- Maximum observed noise and vibration levels.

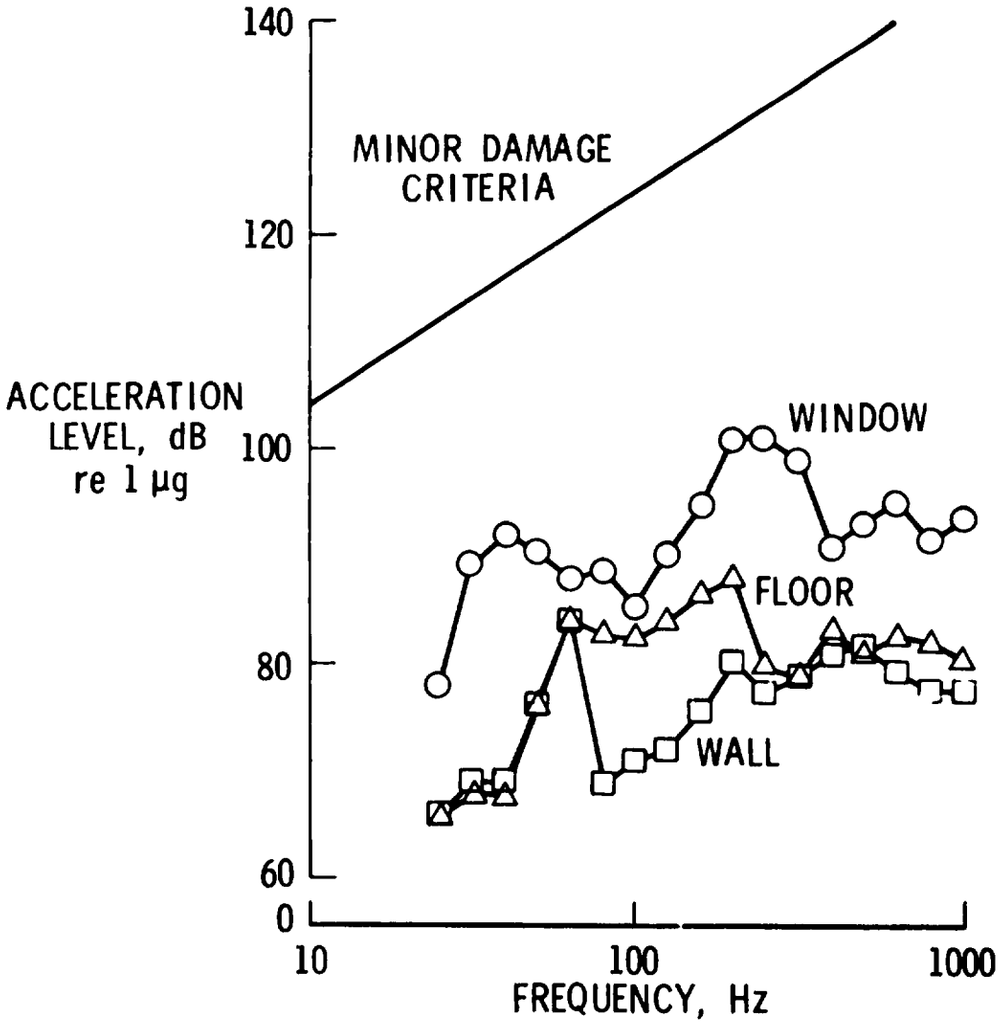

Figure 5.- Comparison of maximum response with criteria for building structure damage.

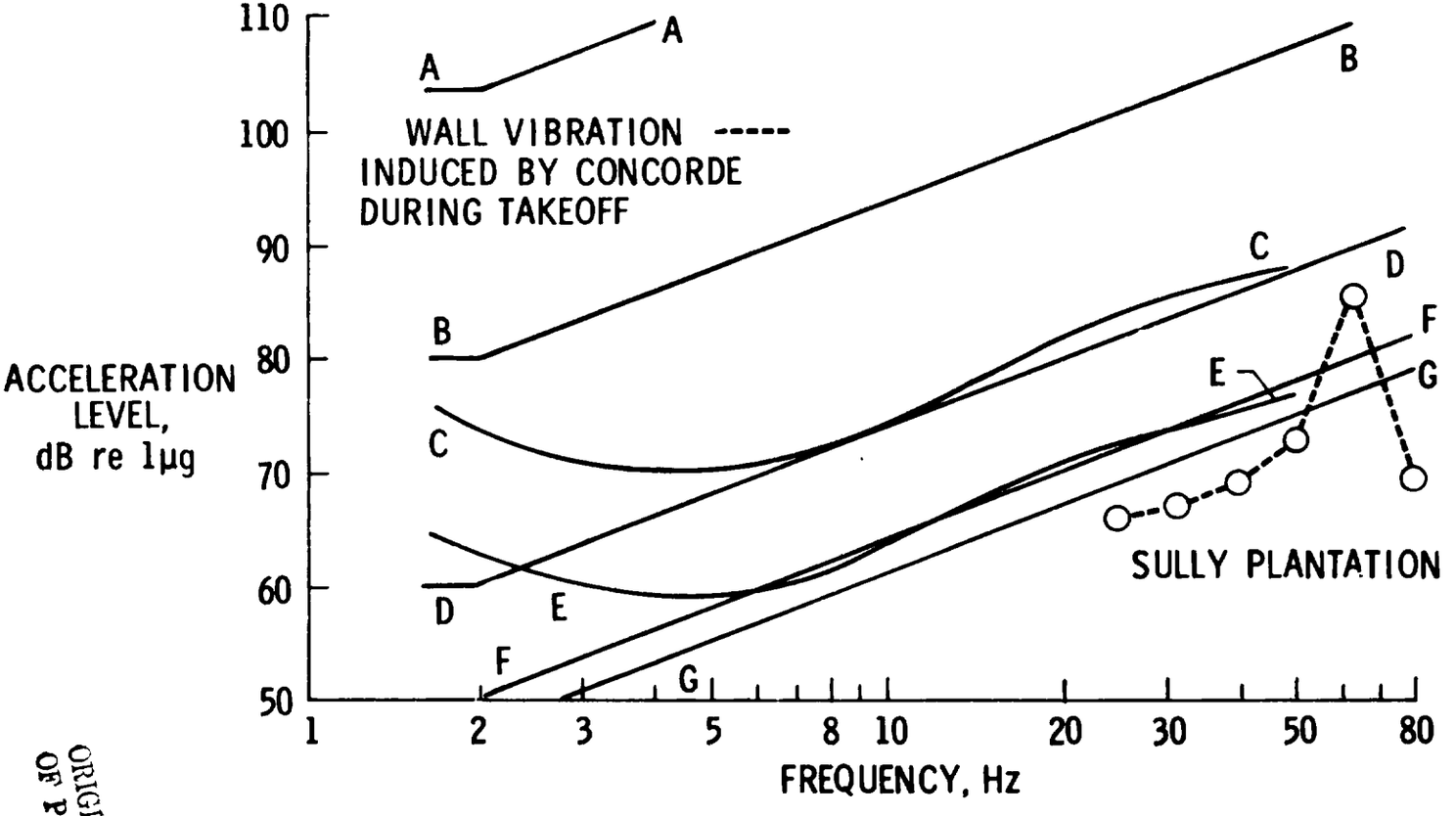

Figure 6(a).- Comparison of maximum response with criteria for human comfort. (Note. See Table III for description of curves.)

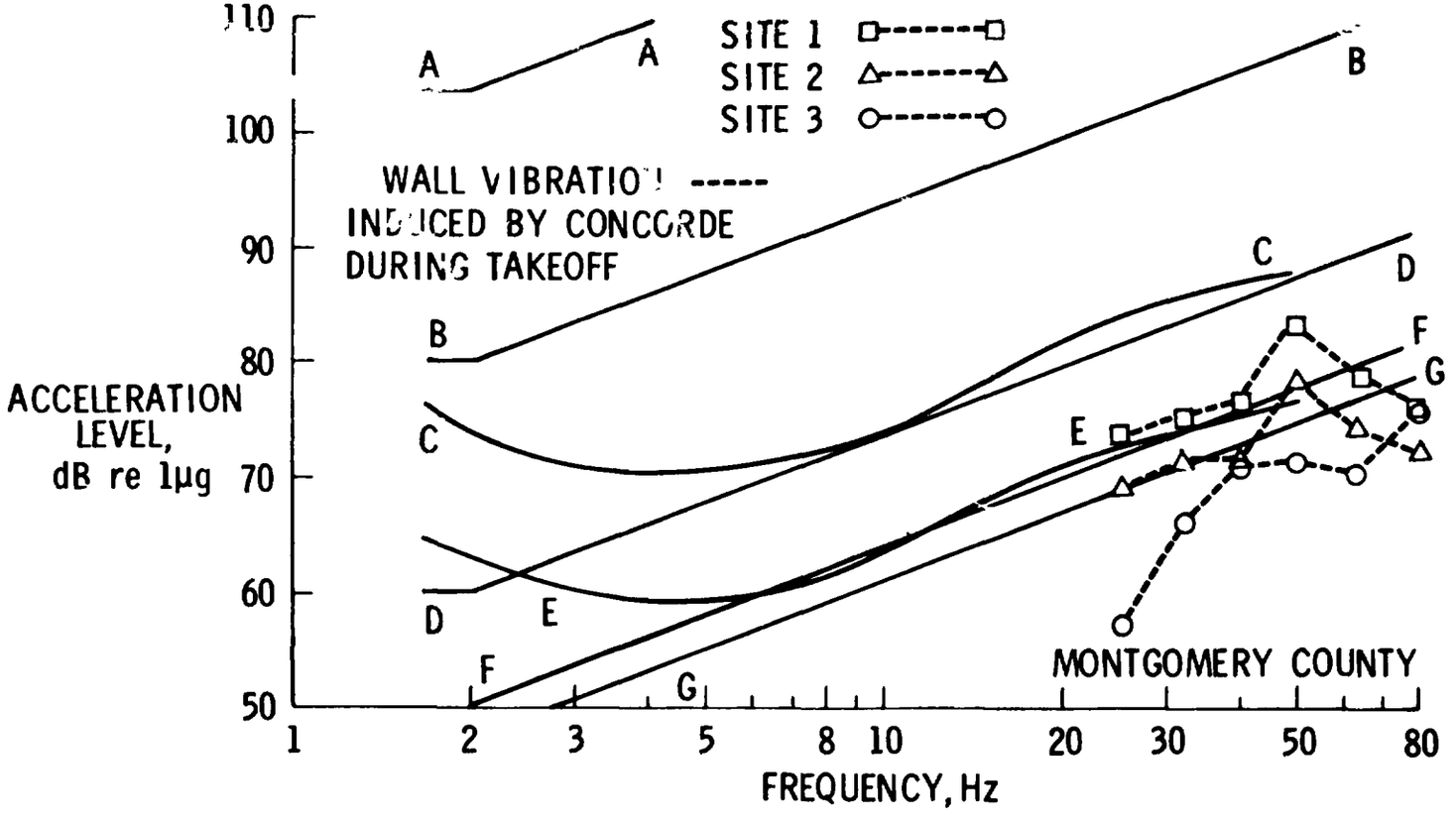

Figure 6(b).- Comparison of maximum response with criteria for human comfort. (Note: See Table III for description of curves.)

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15. Supplementary Notes

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16 Abstract

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