NASA CONTRACTOR REPORT

NASA CR-12

c.1

NASA CR-1227

A METHOD FOR PREDICTING LAUNCH VEHICLE VIBRATION LEVELS IN THE REGION OF THE SPACECRAFT ADAPTOR

by A. G. Piersol and W. F. Van Der Laan

Prepared by
MEASUREMENT ANALYSIS CORPORATION
Los Angeles, Calif.
for Langley Research Center

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • JANUARY 1969

NASA CR-1227

A METHOD FOR PREDICTING LAUNCH VEHICLE VIBRATION LEVELS IN THE REGION OF THE SPACECRAFT ADAPTOR

By A. G. Piersol and W. F. Van Der Laan

Issued by Originator as Report No. MAC 709-10

Prepared under Contract No. NAS 1-7490 by
MEASUREMENT ANALYSIS CORPORATION
Los Angeles, Calif.

for Langley Research Center

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

For sale by the Clearinghouse for Federal Scientific and Technical Information
Springfield, Virginia 22151 – CFSTI price $3.00

ABSTRACT

This report derives and presents a set of prediction curves for launch vehicle vibration levels in the region of the spacecraft adaptor structure. The prediction curves are arrived at through a regression analysis of previous data collected for various different launch vehicle configurations, and are based upon six rudimentary parameters describing the launch vehicle flight and propulsion conditions. The intent is to provide a basis for making preliminary vibration predictions early in the conceptual design of a new launch vehicle configuration so that test specifications and design criteria can be established for the procurement of long lead time equipment items. The predictions are presented in terms of average power spectral densities in octave band frequency intervals for liftoff, transonic flight, and maximum dynamic pressure flight. All data used to arrive at the prediction curves are presented, and the efficiency of the curves is fully evaluated.

CONTENTS

CONTENTS (continued)

1. INTRODUCTION

Aerospace engineers are continually seeking simpler and more accurate techniques for predicting launch vehicle vibration environments. Of particular interest are predictions for the vibration levels which occur in the upper structural regions on or near the spacecraft adapter. Such predictions are needed as a basis for design criteria and test specifications for the overall spacecraft assembly.

The various procedures currently used to predict launch vehicle vibration environments may be broadly divided into two categories; analytical procedures, and empirical procedures. Analytical procedures refer to those techniques where the response of some derived structural model is calculated using an assumed excitation function. Empirical procedures include those techniques which are based upon extrapolations from data collected for previous launch vehicle designs. Summaries of currently used analytical and empirical prediction procedures are available from [1, 2].

Analytical procedures offer the greatest potential accuracy, since they permit a more thorough description of the excitation properties and structural design of interest. However, they also require more information concerning the details of the excitation and structure. This fact presents a serious restriction on their use for arriving at vibration predictions early in the conceptual design phase for a new vehicle before the detailed design has been formulated. It is at this point in the design sequence (early in the conceptual phase) when vibration predictions are desired to establish detailed design criteria and test specifications for the procurement of long lead time components.

Empirical procedures do not present the above noted problem because their implementation does not require detailed information concerning the excitation properties and structural design of interest. Hence, they can be readily applied to predict vibration environments for anticipated launch vehicle configurations early in the conceptual design phase. On the other hand, their indifference to details clearly restricts their potential accuracy. In spite of this limited potential accuracy, empirical prediction procedures of one form or another are currently in wide use.

Empirical prediction procedures are generally based upon broad correlations between average vibration response characteristics for a general class of structures and some property of the vibration excitation for the vehicle of interest. From [2], most of the current procedures for predicting launch vehicle vibration environments are based upon observed correlations between average structural response and acoustic noise. Although correction factors for approximating the aerodynamic noise induced vibration are sometimes suggested, such procedures are fully useful only for predicting the vibration environment during liftoff. Furthermore, they require predictions for acoustic noise as an intermediate step to arrive at vibration predictions. A more general procedure which would provide predictions for the vibration environment during all significant launch phase events based upon basic flight and engine parameters is clearly desirable.

The development of a more general prediction procedure was recently investigated and outlined for applications to aircraft vibration environments, as detailed in [3]. It appears that the basic approach suggested in [3] should be applicable to launch vehicles as well. The principal requirement to execute the development is the availability of a large store of past launch vehicle vibration data in the form of power spectra (or some other measure of frequency composition). The NASA Langley Research Center has such a store of vibration data which were collected through contracts with various aerospace manufacturers. The purpose of the studies reported herein is to apply the suggested techniques in [3] to selected portions of this available launch vehicle vibration data. The objective is to develop a more general and flexible empirical procedure for predicting the launch vehicle vibration environment in the region of the spacecraft adapter structure. Note that the intent is to arrive at a prediction procedure which can be applied to a new vehicle configuration early in the conceptual design phase. Once a specific configuration design has been formulated or actually manufactured, other vibration prediction techniques outlined in [1, 2] would probably yield more accurate estimates for the vibration environment of interest.

2. GENERAL APPROACH

The general approach to be used centers around a regression study of available launch vehicle vibration data collected from previous measurement programs. To illustrate the approach, consider the case of a launch vehicle which has completed liftoff and passed through Mach 1. Assume the vibration at some point on the spacecraft adaptor structure is measured at different dynamic pressures. The results might be as shown in Figure 1.

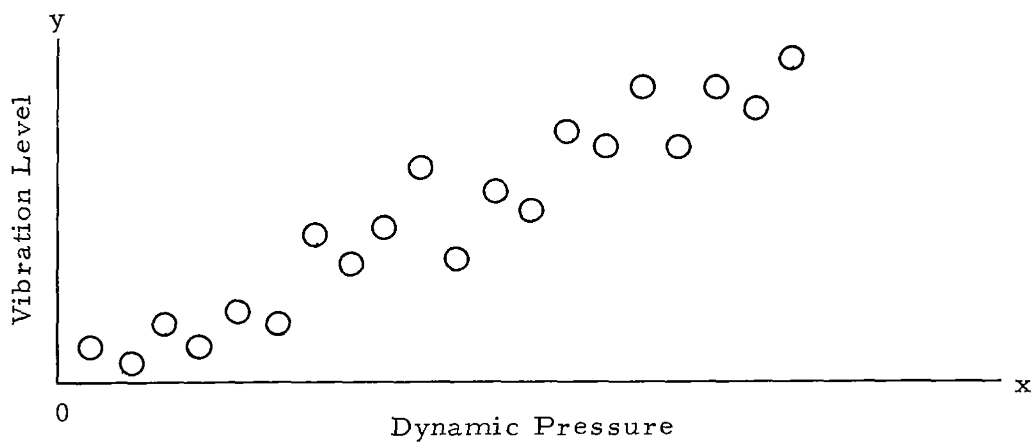

Figure 1. Vibration Level Versus Dynamic Pressure

The data in Figure 1 indicate there is some correlation between dynamic pressure and vibration level. Specifically, the vibration seems to increase with increasing dynamic pressure. A regression study will establish this relationship in a statistical manner by making a least squares linear fit to the data to obtain an equation of the form

$$\hat{y} = \hat{A}_0 + \hat{A}_1 x \qquad (1)$$

A regression program will produce the required estimates for the coefficients A_0 and A_1 (the hat, $\wedge$, denotes an estimate), which in turn, leads to the equation which estimates the dependent variable y (vibration level) as a function of the independent variable x (dynamic pressure).

The above example is based upon a one dimensional prediction model. The procedure can be readily extended to include as many dimensions as desired. That is, one may assume a model for vibration at some point on the adaptor structure as a function of many different variables, resulting in the following equation:

$$\hat{y} = \hat{A}_0 + \hat{A}_1 x_1 + \hat{A}_2 x_2 \ldots + \hat{A}_N x_N \qquad (2)$$

The independent variables x_i (i = 1, 2, 3, ..., N) would ideally include all factors which might influence the vibration response of the launch vehicle structure; for example, dynamic pressure, structural weight density, engine exhaust gas velocity, etc. In practice, it will not be feasible to include all factors which influence the vibration. This is particularly true of those factors which describe the dynamic properties of the structure. This failure to achieve an ideal model will be reflected by a variance for the regression coefficient estimates, which in turn will result in a variance for the final estimate of y for any given set of values for x_i (i = 1, 2, 3, ..., N). However, this overall variance can be estimated as part of the regression analysis, and serve as a basis for selecting conservative prediction limits for the vibration.

To help clarify this point, assume the vibration levels could be measured at each and every point on the spacecraft adaptor structure for all launch vehicle configurations to be covered by the prediction model. Further assume the data have been normalized so that the measurements represent the vibration levels for a common set of independent variables. The resulting vibration levels would undoubtedly be somewhat different due to the absence of various factors in the regression model which in reality influence the vibration environment. Now assume a probability density function for these vibration levels could be developed, as illustrated in Figure 2.

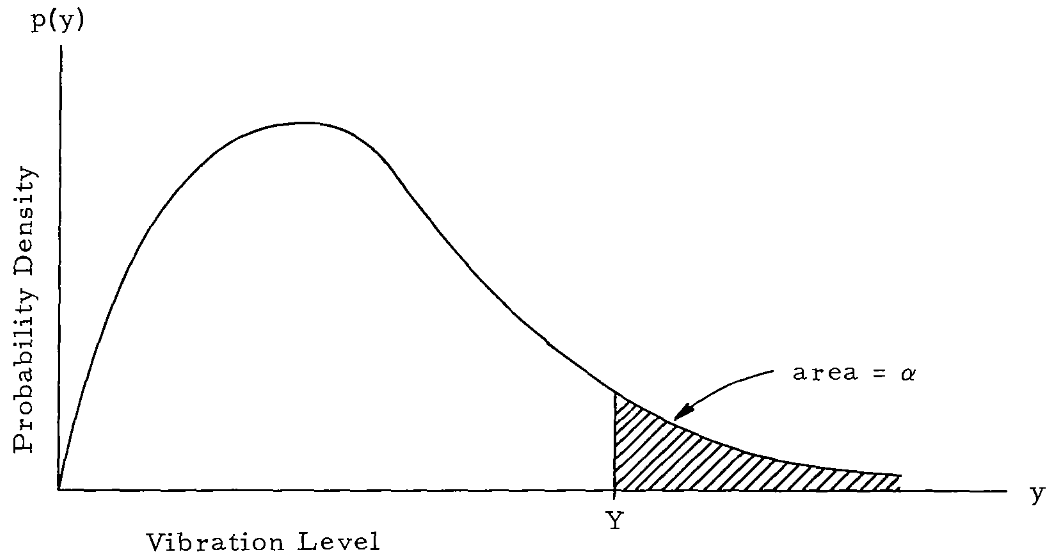

Figure 2. Probability Density Function for Vibration Levels

The selection of a conservative design criterion or test level reduces to the selection of a desired percentage point of the density function, indicated by Y in Figure 2. The percentage point used to select the level Y will determine the degree of conservatism in the resulting criterion or test. Specifically, if the α percentage point is used for the selection, then for any point on the spacecraft adaptor structure of a future launch vehicle configuration, the probability that the vibration level will exceed Y is equal to α. Of course, in practice, where only a finite sample of data is available, the exact probability density function for the anticipated vibration levels cannot be determined. Hence, the statistical procedures for selecting a conservative level are somewhat more involved than indicated in this simple illustration. Nevertheless, the procedures are well defined and straightforward from a computational viewpoint [4, 5].

3. DETAILED APPROACH

There are four primary steps required to develop a general prediction model for the launch vehicle vibration environment in the region of the spacecraft adaptor structure, as follows.

a. Selection of independent variables
b. Formulation of regression model
c. Selection of a probability density function for the predictions
d. Performance of a regression analysis on suitable data

Each of these four steps will now be discussed. Note that the manner in which each step is accomplished involves various possible options. The specific options selected to develop the prediction curves which conclude this report are detailed. However, different options might be exercised to develop somewhat different prediction curves if so desired.

3.1 SELECTION OF INDEPENDENT VARIABLES

There are three primary requirements for the independent variables selected for use in the regression model. First, there should be either theoretical or empirical evidence to support the conclusion that the variables indeed have a significant influence on the resulting vibration environment. Second, the variables should involve only those flight and engine parameters whose values can be predicted with reasonable accuracy early in the conceptual design phase of a new launch vehicle configuration. Third, the variables must be related to the resulting vibration environment in a linear manner. This does not mean that each individual parameter in the variable must be linearly related to the resulting vibration. It does mean, however, that all nonlinear relationships must be anticipated and properly included in the definition of the independent variable.

Based upon the studies summarized in [3], it is believed that the mean square value for the acceleration response of the adaptor structure can be described as a first order of approximation by two independent variables, as follows.

$$x_1 = \rho A V_e^8 / c^5 w^2 \tag{3a}$$

$$x_2 = q^2 / w^2 \tag{3b}$$

where

ρ = air density

A = rocket nozzle exit area

V_e = rocket exhaust gas velocity

c = ambient speed of sound

q = free stream dynamic pressure ($\rho V^2/2$)

w = structural surface weight density

Note that the two variables include six individual flight and engine parameters combined in a manner which hopefully will eliminate anticipated nonlinear relationships, as developed in [3]. The x_1

variable is designed to describe the contribution of acoustic noise to the vibration environment while the x_2 variable is designed to account for the aerodynamic noise contribution.

3.2 FORMULATION OF REGRESSION MODEL

At first glance, it might appear that an appropriate regression model would be of the form $G(f) = A_0(f) + A_1(f)\, x_1 + A_2(f)\, x_2$, where x_1 and x_2 are as defined in Eq. (3), $G(f)$ is the power spectrum for the acceleration response, and $A_i(f)$, $i = 0, 1, 2$, are the regression coefficients as a function of frequency. However, three problems arise which rule out this direct approach. First, the expression for x_1, as given by Eq. (3a), is applicable only for zero airspeed conditions. Second, although the mean square values for the structural response to acoustic noise and aerodynamic noise are believed to be proportional to x_1 and x_2, respectively, the power spectrum for the response at a specific frequency may not be proportional. In other words, the power spectrum for the structural response to both acoustic noise and aerodynamic noise changes in relative spectral shape as well as total area as x_1 and x_2 vary. Third, the shock wave-boundary layer interactions during transonic flight induce vibration levels which may deviate strongly from the q dependent relationship suggested in Eq. (3b).

The first problem can be overcome by exploiting certain practical aspects of the launch phase vibration environment. Specifically, there are three events during the launch phase where the vibration environment tends to peak. These three events are liftoff, transonic flight, and maximum dynamic pressure flight. Since design criteria and test specifications are generally based upon the maximum anticipated vibration environment, it is reasonable to restrict attention to the vibration during these three noted events. This permits the regression model to be separated into three separate models. Since the airspeed at liftoff is zero, the liftoff vibration can be modeled simply by $y = A_0 + A_1 x_1$. Similarly, since the acoustic noise contribution is negligible during transonic and maximum dynamic pressure flight (max q usually occurs at supersonic speeds), these two events can be described by models of the form $y = A_0 + A_2 x_2$.

The second problem may be dealt with by considering the data in terms of a dimensionless frequency. For the case of acoustic noise induced vibration data, it is suggested in [3] that a common relative spectral shape will be obtained if the regression model is written in the form

$$G(\Omega) = A_0(\Omega) + A_1(\Omega)\, x_1 \tag{4}$$

where

$\Omega = f d c_e / V_e c$

d = rocket nozzle exit diameter

c_e = local speed of sound

c = ambient speed of sound

V_e = rocket exhaust gas velocity

f = cyclical frequency

The predictions produced by the regression model may be readily converted to cyclical frequency in cps (f) by using the definition for the dimensionless frequency (Ω). The same procedure could be applied to the model for aerodynamic noise induced vibration by using a dimensionless frequency parameter appropriate for that type of data. Such an approach, however, is not suggested for this case. As discussed in [3], the spectrum for aerodynamic noise is relatively uniform over a wide frequency range. Hence, shifts in the spectrum shape should not seriously hamper the development of a model in terms of cyclical frequency.

The third problem is particularly difficult because the transonic excitation is heavily dependent upon the detailed geometry of the launch vehicle-spacecraft configuration in the region of the adaptor. It is not considered feasible to include a geometry dependent factor as an independent variable in the regression model. Hence, the transonic vibration will be considered a function of the variable x_2, but with different regression coefficients than those which apply to the maximum dynamic pressure induced vibration.

In conclusion, the regression equations used for the prediction models in this report are as follows

Liftoff	$G_1(\Omega) = A_{01}(\Omega) + A_{11}(\Omega)\, x_1$	(5a)
Transonic Flight	$G_2(f) = A_{02}(f) + A_{12}(f)\, x_2$	(5b)
Max q Flight	$G_3(f) = A_{03}(f) + A_{13}(f)\, x_2$	(5c)

where x_1 and x_2 are as defined in Eq. (3), and the A terms are the regression coefficients. Note that the A_1 terms define the contributions of the independent variables to the vil ation environment while the A_0 terms define the residual vibration due to other sources.

3.3 SELECTION OF PROBABILITY DENSITY FUNCTION

The form of the probability density function for the resulting power spectra predictions is unknown. In past studies of this type, various forms have been assumed including the lognormal distribution [6], the Rayleigh distribution [7], the normal distribution [3], and special empirical distributions [8]. The validity of each of these various assumed distribution forms is open to question. For the prediction curves developed in this report, the normal distribution is assumed for two reasons. First, the normal distribution assumption is convenient for the computational procedures to be used. Second, the normal distribution is believed to be more appropriate than a highly skewed distribution (such as the lognormal distribution) for the case of vibration in a narrowly restricted structural zone, as is of interest here.

3.4 PERFORMANCE OF REGRESSION ANALYSIS

The estimation of the coefficients in Eq. (5) is accomplished using conventional regression analysis procedures, as presented in [4, 5] and illustrated for aircraft data in [3]. The analysis is performed using data reduced in the form of average power spectral density in octave bands. For any given octave band, let $y = G(f)$, $a_0 = A_0(f)$, and $a = A_1(f)$. Further, let y_k denote the kth power spectrum measurement and x_k denote the value of the independent variable for the kth measurement. Assuming n number of measurements are available, the required calculations are as follows.

$$a = \frac{\sum_{k=1}^{n} (x_k - \bar{x})(y_k - \bar{y})}{\sum_{k=1}^{n} (x_k - \bar{x})^2} \tag{6a}$$

$$a_0 = \bar{y} - a\bar{x} \tag{6b}$$

$$\Phi = \frac{a^2 \sum_{k=1}^{n} (x_k - \bar{x})^2 (n - 1)}{\sum_{k=1}^{n} (y_k - ax_k)^2} \tag{6c}$$

$$\gamma = a \frac{s_x}{s_y} \tag{6d}$$

where

$$s_x = \left[\sum_{k=1}^{n} (x_k - \bar{x})^2 / (n - 1) \right]^{1/2}$$

$$s_y = \left[\sum_{k=1}^{n} (y_k - \bar{y})^2 / (n - 1) \right]^{1/2}$$

$$Z = 0.5 \left[n - 3 \right]^{1/2} \log_e \left(\frac{1 + \gamma}{1 - \gamma} \right) \tag{6e}$$

$$L_{a;\alpha} = a \pm t_{n-2;\alpha/2}\, s_{y\cdot x} \left[\sum_{k=1}^{n} (x_k - \bar{x})^2 \right]^{-1/2} \qquad (6f)$$

where

$t_{n-2;\alpha/2}$ = the $\alpha/2$ percentage point of a student's "t" distribution with n - 1 degrees-of-freedom

$$s_{y\cdot x} = \left[\sum_{k=1}^{n} (y_k - a x_k)^2 / (n - 2) \right]^{1/2}$$

$$E\left[y_u \right] = a_0 + a x_u \quad ; \quad u = 1, 2, 3, \ldots, m \qquad (6g)$$

where

x_u = fixed value of x

$$Y_{u;\alpha} = E\left[y_u \right] + t_{n-2;\alpha}\, s_{y\cdot x} \left[1 + \frac{1}{n} + \frac{(x_u - \bar{x})^2}{\sum_{k=1}^{n} (x_k - \bar{x})^2} \right]^{1/2} \qquad (6h)$$

The regression coefficients a_0 and a are given by Eqs. (6a) and (6b), respectively. The other calculations are used to evaluate the model and select prediction limits, as follows.

3.4.1 Evaluation of Model Linearity

It is initially assumed that the relationship between x and y is linear. The validity of the assumption should be checked. This may be done using the value of Φ given by Eq. (6c). If the model is nonlinear, the value of Φ will be distributed like the variable F with degrees-of-freedom given by $df_1 = 1$ and $df_2 = n - 1$ [9]. Hence, a hypothesis of nonlinearity may be tested by comparing the value of Φ with the tabulated value for $F_{1, n-1; \alpha}$ at any desired level of significance α. If $\Phi < F_{1, n-1; \alpha}$, the model is nonlinear. If $\Phi > F_{1, n-1; \alpha}$, there is no reason to question that the model is linear.

3.4.2 Evaluation of Model Efficiency

The efficiency of the model may be evaluated in terms of the correlation coefficient γ given by Eq. (6d). The quantity $(1 - \gamma^2)$ is a measure of the power contributed to y by variables other than x. If the model provided a perfect description for y given x, γ would equal unity. On the other hand, if there were no relationship between y and x, γ would equal zero. It is clearly desirable to establish if γ is significantly different from zero. This is accomplished using the Fisher "Z" transformation given by Eq. (6e). If $\gamma = 0$, the value of Z will be normally distributed with a mean of zero and a variance of unity. Hence, a hypothesis of significant correlation may be tested by comparing the value of Z with the tabulated value of the standardized normal distribution at any desired percentage point α. If $Z < z_\alpha$, the correlation coefficient is not significantly different from zero. If $Z > z_\alpha$, the correlation coefficient is significantly different from zero.

The efficiency of the model can also be evaluated in terms of the $(1 - \alpha)$ confidence interval for a, as given by Eq. (6f). If the lower confidence limit is less than zero, the interpretation is the same as for the case where the correlation coefficient is not significantly different from zero.

3.4.3 Selection of Prediction Limits

The final prediction limit is selected at any desired percentage point using Eqs. (6g) and (6h). The term $Y_{u;\alpha}$ provides a $(1 - \alpha)$ prediction limit for each value of y_u for a given value, x_u, of the independent variable.

4. DATA SELECTION

The source of vibration data for the required regression analysis was a collection of contractor data compilations provided by the NASA Langley Research Center. The criteria for the selection of specific data to be analyzed were as follows.

a. The data must represent measurement locations on basic structure in the upper region of the launch vehicle on or near the spacecraft adaptor.

b. The data must represent the actual launch environment (no static firing data are used).

c. The data must be in a form which can be translated into average power spectra in octave bands for individual measurements.

d. The data must appear to be of reasonable quality and otherwise representative of the vibration environment.

With the four above noted restrictions, only a small portion of the available data was found to be usable for the studies. Specifically, after careful editing, a total of 94 separate measurements at 19 different locations on nine different vehicle configurations were used for the analyses. A summary of the measurement locations and vehicles is presented in Table 1. Also included in Table 1 are the values for the various vehicle parameters needed to calculate the independent variables for the regression model.

The most difficult parameter to arrive at in Table 1 was the surface weight density (w) for the structural location of each measurement.

Table 1. Measurement Locations and Other Pertinent Information

Code No.	Vehicle	Measurement	Location	V_e (ft/sec)	d (ft)	A (ft^2)	w (lb/ft^2)	c_e (ft/sec)	q at Mach 1 (lbs/ft^2)	max q (lbs/ft^2)
1	Thor DSV-2G	Sta: -204 long.	Interface between asset and adapter	8060	3.81	11.4	39.	2142	669	880
2	Thor DSV-2J	Sta: 132 long.&rad.	On ring	8060	3.81	11.4	0.61	2142	669	750
3	Thor Agena D	A452 long.	Shear web, internal	8060	3.81	11.4	1.7	2142	669	700
4	Atlas D/ Agena B	RA 005 long.&rad.	On ring Sta: 232.5	7800	5.5	23.7	6.7	2152	640	900
5	Atlas D/ Agena D	P1 long.&rad.	On ring Sta: 247	7800	5.5	23.7	1.9	2152	640	900
6	Titan I	878 long.&rad.	On skin 1" aft of R/V interface. Sta: 79.088	8100	5.09	20.3	0.58	2142	610	735
7	Titan I	980 long.&rad.	R/V interface ring Sta: 79.088	8100	5.09	20.3	3.5	2142	610	735
8	Titan I	24 long.&rad.	BTL Transmitter Guidance Bay. Sta: A-51	8100	5.09	20.3	1.3	2142	610	735
9	Titan I	552 long.	IMU mounting point to truss	8100	5.09	20.3	7.2	2142	610	735
10	Titan I	641 long.&rad.	BTL Receiver mounting Sta: B-0	8100	5.09	20.3	5.6	2142	610	735

Table 1 (Continued)

Code No.	Vehicle	Measure-ment	Location	V_e (ft/sec)	d (ft)	A (ft^2)	w (lb/ft^2)	c_e (ft/sec)	q at Mach 1 (lbs/ft^2)	max q (lbs/ft^2)
11	Titan I	1039 long.	Digital Computer mounting leg	8100	5.09	20.3	9.2	2142	610.	735
12	Titan II	744 long.&rad.	Martin/G.E. R/V Inter-face Flange. Sta: 269.516	8370	5.09	20.3	2.2	3028	550	660
13	Titan IIIA	2653 long.&rad.	Compartment 3A Struc-ture. Sta: 130	8370	5.09	20.3	4.0	3028	590	710
14	Titan IIIA	2555 long.	Compartment 3A Guidance Truss	8370	5.09	20.3	17.	3028	590	710
15	Titan IIIA	2640 long.&rad.	Compartment 3A Guidance Truss	8370	5.09	20.3	12.5	3028	590	710
16	Titan IIIC	2551 long.	Compartment 3A Structure Sta: 130	7580	13.4	141.0	3.8	2470	685	845
17	Titan IIIC	2558 long.	Compartment 3A Equipment Truss	7580	13.4	141.0	13.	2470	685	845
18	Titan IIIC	2591 long.&rad.	Compartment 3A Instrumentation Truss	7580	13.4	141.0	32.	2470	685	845
19	Titan IIIC	2637 long.&rad.	Compartment 3A Truss, Autopilot mount	7580	13.4	141.0	17.	2470	685	845

V_e = rocket engine exhaust gas velocity

d = rocket engine nozzle exit diameter

A = rocket engine nozzle exit area

m = surface mass density of structural location

c_e = local speed of sound in rocket engine exhaust area

q at Mach 1 = dynamic pressure at Mach 1

max q = maximum dynamic pressure during launch

In those cases where the measurement location structure was relatively clean, the surface weight density was estimated in a straightforward manner by computing the weight of the overall structure (including equipment) in a square foot area centered on the measurement location. In other cases where the measurement location structure was complex or poorly defined, considerable personal judgment was required. However, these matters should not be of particular concern to those who use the prediction curves concluding this report. Vibration predictions are usually desired for a structural region rather than a specific point. The surface weight density to be used for such predictions may be estimated by calculating the total weight of the region and dividing by the projected area of the region, in a manner similar to that detailed in [10].

5. DATA SUMMARY

Vibration data in the longitudinal and radial directions for each of the locations noted in Table 1 were reduced to average power spectral densities in octave bands for each of the three launch phase events of interest (liftoff, transonic flight, and max q flight). The results are presented in Tables 2 through 9 along with the appropriate values for the independent variables, x_1 and x_2, as defined in Eq. (3). Note that data is omitted in those octave bands where the measurement noise appeared to be unacceptably high or the data quality was otherwise questionable.

Referring to Tables 2 through 5, it is seen that two sets of data are presented for the liftoff vibration measurements. The first set is presented in terms of cyclical frequency (unshifted) octave bands. The second set is presented in terms of dimensionless frequency (shifted) octave bands, where the dimensionless frequency Ω is as defined in Eq. (4). The theory leading to the model in Eq. (4) indicates that liftoff vibration data should be predicted in terms of dimensionless frequency. However, it would be more convenient in practice if the predictions could be made in terms of cyclical frequency. Hence, both cases are studied to determine if the use of dimensionless frequency is necessary.

Table 2. Summary of Unshifted Longitudinal Vibration Data for Liftoff

Measurement Code No.	x_1 $\times 10^{14}$	Average Power Spectral Densities in g^2/cps for Octave Bands in cps						
		0-37.5	37.5-75.0	75.0-150	150-300	300-600	600-1200	1200-2400
1	.058	-	.00017	.00015	.000035	.0000012	.0000024	-
2	239.2	-	.0074	.006	.009	.04	.145	-
3	29.7	-	.0045	.001	.001	.001	.016	.002
4	3.17	-	.0002	.0001	.0001	.0002	.001	.0008
5A	38.4	-	.001	.001	.001	.005	.025	.002
5B	38.4	-	.0005	.0005	.001	.004	.024	.004
6	493.0	.023	.004	.0026	.016	.73	.040	.0088
7	13.53	.014	.0037	.0008	.0009	.0017	.0017	.0013
8	98.25	-	-	.0087	.008	.09	.038	.01
9A	2.3	-	.00017	.00017	.00009	.0007	.0016	.0013
9B	2.3	-	.0003	.00012	.000032	.00036	.0008	.00018
10	5.2	-	.00065	.00022	.00045	.014	.0021	.0012
11	1.9	-	.0008	.00083	.00021	.00036	.00065	.00014
12	44.4	-	-	-	.0064	.004	.0016	.0023
13A	13.4	-	.00028	.00023	.0032	.002	.0072	.0014
13B	13.4	-	.00036	.00036	.0011	.0036	.004	.0028
14	0.77	-	.00009	.000032	.00013	.0005	.0002	.0001
15A	1.38	-	.00022	.00014	.00063	.001	.0004	.00018
15B	1.38	-	.000071	.000032	.00028	.00089	.00032	.000089
16	46.9	-	.0016	.0011	.0045	.0025	.0013	.0028
17	4.2	-	.00028	.00018	.00028	.001	.001	.001
18	.68	-	.00032	.00021	.00013	.00041	.00011	.00009
19	2.37	-	.00036	.000067	.00013	.00023	.00029	.0001

$$x_1 = \frac{\rho A V_e^8}{c^5 w^2} \text{ ft}^6/\text{lbs-sec}^3$$

Table 3. Summary of Shifted Longitudinal Vibration Data for Liftoff

Measurement Code No.	x_1 $\times 10^{14}$	Average Power Spectral Densities in g^2/cps for Octave Bands in Dimensionless Frequency ($fdc_e/V_e c$)						
		0-.0375	.0375-.0750	.0750-.150	.150-.300	.300-.600	.600-1.200	1.200-2.400
1	.058	-	.00017	.00015	.000035	.0000012	.0000024	-
2	239.2	-	.0074	.006	.009	.04	.145	-
3	29.7	-	.0045	.001	.001	.001	.016	.002
4	3.17	-	.0002	.0001	.0001	.0002	.0010	.0008
5A	38.4	-	.001	.001	.001	.005	.025	.002
5B	38.4	-	.0005	.0005	.001	.004	.024	.004
6	493.0	.023	.004	.0026	.016	.73	.040	.0088
7	13.53	.014	.0037	.0008	.0009	.0017	.0017	.0013
8	98.25	-	-	.0087	.008	.09	.038	.01
9A	2.3	-	.00017	.00017	.00009	.0007	.0016	.0013
9B	2.3	-	.0003	.00012	.000032	.00036	.0008	.00018
10	5.2	-	.00065	.00022	.00045	.014	.0021	.0012
11	1.9	-	.0008	.00083	.00021	.00036	.00065	.00014
12	44.4	-	-	-	-	.0064	.004	.0016
13A	13.4	-	-	.00028	.00023	.0032	.002	.0072
13B	13.4	-	-	.00036	.00036	.0011	.0036	.004
14	0.77	-	-	.00009	.000032	.00013	.0005	.0002
15A	1.38	-	-	.00022	.00014	.00063	.001	.0004
15B	1.38	-	-	.000071	.000032	.00028	.00089	.00032
16	46.9	-	-	-	-	.0016	.0011	.0045
17	4.2	-	-	-	-	.00028	.00018	.00028
18	0.68	-	-	-	-	.00032	.00021	.00013
19	2.37	-	-	-	-	.00036	.000067	.00013

$$x_1 = \frac{\rho A V_e^8}{c^5 w^2} \quad ft^6/lbs\text{-}sec^3$$

Table 4. Summary of Unshifted Radial Vibration Data for Liftoff

Meas. Code No.	x_1 $\times 10^{14}$	Frequency (cps) 0-37.5	37.5-75.0	75.0-150	150-300	300-600	600-1200	1200-2400
2A	240.	-	.0071	.008	.018	.069	.082	-
2B	240.	-	.005	.006	.015	.08	.22	-
4A	3.2	-	.0002	.0002	.0001	.0006	.0038	.0017
4B	3.2	-	-	-	-	.002	.006	.0025
5	38.	-	.001	.001	.0025	.007	.046	.001
6	490.	.0324	.0042	.0047	.049	.29	.031	.007
7	13.	.026	.0041	.0020	.0042	.029	.059	.011
8	98.	.03	.006	.0017	.0022	.0028	.0042	.0022
10	5.2	-	.0096	.00076	.009	.09	.016	.010
12	44.	-	-	-	.008	.0056	.0050	.0035
13	13.	-	.0004	.00018	.0010	.0022	.0025	.028
15	1.4	-	.000035	.000032	.00016	.0004	.00016	.00071
18	0.68	-	.0003	.00038	.00025	.0007	.0014	.00022
19A	2.4	.00032	.00009	.00025	.00050	.00017	.00040	.00007
19B	2.4	-	.00012	.00042	.00048	.00048	.00080	.00015

$$x_1 = \frac{\rho A V_e^8}{c^5 w^2} \ ft^6/lbs\text{-}sec^3$$

Table 5. Summary of Shifted Radial Vibration Data for Liftoff

Meas. Code No.	x_1 $\times 10^{14}$	Frequency (cps)						
		0-.0375	.0375 .0750	.0750-.150	.150-.300	.300-.600	.600-1.200	1.200-2.400
2A	240	-	.0071	.008	.018	.069	.082	-
2B	240	-	.005	.006	.015	.08	.22	-
4A	3.2	-	.0002	.0002	.0001	.0006	.0038	.0017
4B	3.2	-	-	-	-	.002	.006	.0025
5	38.	-	.001	.001	.0025	.007	.046	.001
6	490.	.0324	.0042	.0047	.049	.29	.031	.007
7	13.	.026	.0041	.002	.0042	.029	.059	.011
8	98.	.03	.006	.0017	.0022	.0028	.0042	.0022
10	5.2	-	.0096	.00076	.009	.09	.016	.010
12	44.	-	-	-	-	.008	.0056	.005
13	13.	-	-	.0004	.00018	.0010	.0022	.0025
15	1.4	-	-	.000035	.000032	.00016	.0004	.00016
18	0.68	-	-	-	-	.0003	.00038	.00025
19A	2.4	-	-	-	.00032	.00009	.00025	.00050
19B	2.4	-	-	-	-	.00012	.00042	.00048

$$x_1 = \frac{\rho A V_e^8}{c^5 w^2} \ \mathrm{ft}^6/\mathrm{lbs\text{-}sec}^3$$

Table 6. Summary of Longitudinal Vibration Data for Transonic Flight

Measurement Code No.	x_2 $\times 10^5$	Average Power Spectral Densities in g^2/cps for Octave Bands in cps						
		0-37.5	37.5-75.0	75.0-150	150-300	300-600	600-1200	1200-2400
2	12.04	-	.0055	.0045	.0076	.018	.08	-
3	1.5	-	.006	.0015	.0005	.002	.0165	.007
4	.091	-	.0001	.0001	.00015	.0012	.0029	.003
5A	1.1	-	.0004	.0004	.0004	.002	.015	.0075
5B	1.1	-	.0004	.0004	.0004	.0006	.006	.004
6	10.9	-	.0068	.0038	.021	1.15	.032	.011
7	.3	-	.0045	.0029	.0014	.0014	.0026	.0026
8	2.2	-	-	.015	.015	.030	.080	.017
9A	.072	-	.00055	.0006	.00055	.002	.016	.013
9B	.072	-	.00056	.00064	.0010	.0041	.014	.0039
10	.116	-	.005	.0015	.0082	.041	.025	.011
11	.044	-	.00097	.0036	.0016	.0028	.0085	.0028
12	.63	-	-	-	.0035	.0040	.0028	.0071
13A	.218	-	.00071	.0016	.013	.013	.056	.025
13B	.218	-	.00025	.00004	.005	.0035	.035	.016
14	.0124	-	.000071	.00011	.0004	.0014	.0028	.0011
15A	.0223	-	.00014	.0005	.0010	.0018	.004	.0013
15B	.0223	-	.000063	.00032	.00063	.0018	.0025	.0016
16	.33	-	-	.008	.014	.0063	.008	.045
17	.029	-	.00026	.00026	.00045	.0016	.0045	.00093
18	.005	-	.00036	.0004	.00022	.00083	.00066	.0023
19	.016	-	.00028	.00009	.00018	.00093	.00365	.00146

$$x_2 = \frac{g^2}{w^2} \quad \text{(dimensionless)}$$

Table 7. Summary of Radial Vibration Data for Transonic Flight

Meas. Code No.	x_2 x 10^5	Frequency (cps) 0-37.5	37.5-75.0	75.0-150	150-300	300-600	600-1200	1200-2400
2A	12.	-	.012	.022	.060	.057	.070	-
2B	12.	-	.017	.018	.026	.050	.120	-
4A	.091	-	-	-	-	.0045	.009	.0075
4B	.091	-	.0035	.003	.004	.011	.012	.0085
5	1.1	-	.001	.001	.001	.004	.027	.0035
6	11.	.044	.013	.019	.26	.96	.11	.022
7	.30	.045	.0074	.010	.011	.020	.16	.063
8	2.2	.23	.10	.020	.013	.013	.023	.013
10	.12	.05	.011	.0069	.028	.19	.067	.028
12	.63	-	-	-	.0040	.0071	.011	.0089
13	.22	-	.0063	.0056	.008	.018	.04	.08
15	.022	-	.000028	.00025	.0004	.0011	.0020	.016

$$x_2 = \frac{q^2}{w^2} \quad \text{(dimensionless)}$$

Table 8. Summary of Longitudinal Vibration Data for Maximum Dynamic Pressure Flight

Measurement Code No.	x_2 $\times 10^5$	Average Power Spectral Densities in g^2/cps for Octave Bands in cps						
		0-37.5	37.5-75.0	75.0-150	150-300	300-600	600-1200	1200-2400
1	.005	-	.00017	.00015	.000075	.0000018	.0000036	-
6A	16.07	.351	.128	.082	.134	1.418	.083	.022
6B	16.07	.260	.042	.034	.041	1.000	.131	.041
7	.44	.015	.0027	.0008	.0002	.0002	.0013	.0100
8	3.2	-	-	.012	.012	.015	.046	.016
9A	.105	-	.00008	.00009	.00008	.00032	.0018	.0016
9B	.105	-	.00026	.00011	.00045	.00080	.0013	.00025
10	.17	-	.00026	.00007	.00011	.00055	.00024	.00031
11	.064	-	.00025	.00012	.00007	.00019	.0016	.0007
12	.9	-	-	-	-	.0025	.0064	.032
13A	.315	-	.00009	.000057	.00032	.0004	.0032	.0009
13B	.315	-	.00032	.00016	.0016	.00072	.0112	.0072
14	.018	-	.00005	.000028	.000056	.00022	.00045	.00011
15A	.032	-	.00013	.00013	.00013	.00020	.00035	.00018
15B	.032	-	.000022	.000016	.000056	.00022	.00020	.00016
16	.49	-	-	.001	.005	.0028	.0035	.016
17	.044	-	.00011	.000036	.00045	.00018	.0005	.0001
18	.007	-	.00016	.000053	.00005	.000067	.000053	.00010
19	.025	-	.000062	.00004	.000056	.00015	.00082	.00033

$$x_2 = \frac{g^2}{w^2} \quad \text{(dimensionless)}$$

Table 9. Summary of Radial Vibration Data for Maximum Dynamic Pressure Flight

Meas. Code No.	x_2 $\times 10^5$	Frequency (cps)						
		0-37.5	37.5-75.0	75.0-150	150-300	300-600	600-1200	1200-2400
6	16.07	.019	.0044	.0015	.017	.39	.10	.021
7	.44	.018	.0040	.0014	.0008	.0029	.081	.46
8	3.2	.11	.018	.0064	.007	.0041	.0064	.0064
10	.17	.20	.027	.0067	.003	.003	.0004	.0003
12	.9	-	-	-	.0063	.0035	.020	.040
13	.315	-	.00022	.00071	.0013	.008	.045	.025
15	.032	-	.000028	.000009	.00004	.00011	.00014	.0016

$$x_2 = \frac{q^2}{w^2} \quad \text{(dimensionless)}$$

6. REGRESSION ANALYSIS RESULTS

The results of the regression analyses of the data in Tables 2 through 9 are presented in Appendices A through H. Seven specific calculations are presented, as detailed in Section 3.4 and summarized below.

a. Estimates for the $A_0(f)$ weights

b. Estimates for the $A_1(f)$ weights

c. 97.5% confidence intervals for the $A_1(f)$ weights

d. Analysis of Variance Tests for Linearity (Φ)

e. Estimates for the correlation coefficients (γ)

f. Tests of the correlation coefficients for a significant difference from zero (Z)

g. 97.5% upper prediction limits (Y)

The results for (a) through (f) are summarized in Tables 10 through 12. Note that the longitudinal and radial vibration are analyzed separately for each significant launch phase event.

Referring to the results for the longitudinal liftoff vibration data summarized in Table 10 (a) and (b), it is seen that the correlation is relatively good in all frequency bands for the data analyzed in cyclical frequency (unshifted). Furthermore, the model passes a linearity test in all frequency bands except one (75 to 150 cps). For the dimensionless frequency (shifted) case, however, significant correlation and linearity are not obtained in the two lowest frequency bands (below 0.150). It appears that the more convenient cyclical frequency model is not only acceptable, but perhaps superior to the dimensionless frequency model.

Table 10. Summary of Regression Analysis Results for Liftoff Vibration Data

(a) Results for Unshifted Liftoff Vibration Data in Longitudinal Direction

Frequency Interval (cps)	Estimate for Coefficient A_0 x 10^{-4}	Estimate for Coefficient A_1 x 10^{-19}	97.5% Confidence Interv. for A_1 x 10^{-19}		Test for Lin'ty at 1% Level of Significance	Correlation Coefficient γ	Test of γ for Signif. Diff. from Zero at 1% Level of Significance
			Lower Limit	Upper Limit			
37.5-75	7.94	1.08	0.40	1.72	accept	0.64	accept
75-150	6.33	0.96	0.24	1.69	reject	0.50	accept
150-300	7.83	3.34	2.71	3.98	accept	0.92	accept
300-600	-207.40	126.15	102.23	150.07	accept	0.91	accept
600-1200	53.67	17.25	7.94	26.55	accept	0.61	accept
1200-2400	12.72	1.85	0.94	2.77	accept	0.73	accept

(b) Results for Shifted Liftoff Vibration Data in Longitudinal Direction

Dimensionless Frequency Interval	Estimate for Coefficient A_0 x 10^{-4}	Estimate for Coefficient A_1 x 10^{-19}	97.5% Confidence Interv. for A_1 x 10^{-19}		Test for Lin'ty at 1% Level of Significance	Correlation Coefficient $\hat{\gamma}$	Test of γ for Signif. Diff. from Zero at 1% Level of Significance
			Lower Limit	Upper Limit			
0.0375-0.075	12.62	0.95	0.03	1.87	reject	0.60	reject
0.075 -0.150	7.78	0.92	0.10	1.75	reject	0.49	reject
0.150 -0.300	2.63	3.40	2.96	3.84	accept	0.96	accept
0.300 -0.600	-208.43	126.20	102.29	150.11	accept	0.91	accept
0.600 -1.20	52.17	17.31	8.02	26.40	accept	0.61	accept
1.20 -2.40	16.81	1.77	0.60	2.94	accept	0.64	accept

Table 10 (Continued)

(c) Results for Unshifted Liftoff Vibration Data in Radial Direction

Frequency Interval (cps)	Estimate for Coefficient A_0 $\times 10^{-4}$	Estimate for Coefficient A_1 $\times 10^{-19}$	97.5% Confidence Interv. for $A_1 \times 10^{-19}$		Test for Lin'ty at 1% Level of Significance	Correlation Coefficient γ	Test of γ for Signif. Diff. from Zero at 1% Level of Significance
			Lower Limit	Upper Limit			
37.5-75	21.63	0.87	-0.47	2.21	reject	0.40	reject
75-150	7.66	1.36	0.72	2.00	accept	0.78	accept
150-300	4.59	8.70	7.24	10.16	accept	0.95	accept
300-600	-1.91	48.66	36.51	60.81	accept	0.89	accept
600-1200	166.07	19.13	0.11	38.16	reject	0.46	reject
1200-2400	50.59	0.32	-3.72	4.35	reject	0.05	reject

(d) Results for Shifted Liftoff Vibration Data in Radial Direction

Dimension-less Frequency Interval	Estimate for Coefficient A_0 $\times 10^{-4}$	Estimate for Coefficient A_1 $\times 10^{-19}$	97.5% Confidence Interv. for $A_1 \times 10^{-19}$		Test for Lin'ty at 1% Level of Significance	Correlation Coefficient γ	Test of γ for Signif. Diff. from Zero at 1% Level of Significance
			Lower Limit	Upper Limit			
0.0375-0.075	43.50	0.21	-1.95	2.38	reject	0.12	reject
0.075 -0.150	10.03	1.29	0.51	2.07	reject	0.76	accept
0.150 -0.300	-0.54	8.82	7.16	10.47	accept	0.95	accept
0.300 -0.600	-2.06	48.69	36.56	60.82	accept	0.89	accept
0.600 -1.20	165.10	19.17	0.15	38.19	reject	0.46	reject
1.20 -2.40	29.66	0.80	-1.23	2.82	reject	0.29	reject

Table 11. Summary of Regression Analysis Results for Transonic Vibration Data

(a) Results for Transonic Vibration Data in Longitudinal Direction

Frequency Interval (cps)	Estimate for Coefficient A_0 x 10^{-3}	Estimate for Coefficient A_1 x 10^{-8}	97.5% Confidence Interv. for A_1 x 10^{-8}		Test for Lin'ty at 1% Level of Significance	Correlation Coefficient γ	Test of γ for Signif. Diff. from Zero at 1% Level of Significance
			Lower Limit	Upper Limit			
37.5-75	34.45	-4×10^4	-3×10^5	2×10^5	reject	-0.08	reject
75-150	1.77	0.30	-0.18	0.79	reject	0.29	reject
150-300	2.95	1.01	0.26	1.75	reject	0.55	accept
300-600	-8.87	47.86	24.52	71.20	accept	0.65	accept
600-1200	13.03	4.24	1.28	7.20	reject	0.59	accept
1200-2400	8.42	0.41	-2.08	2.90	reject	0.09	reject

(b) Results for Transonic Vibration Data in Radial Direction

Frequency Interval (cps)	Estimate for Coefficient A_0 x 10^{-3}	Estimate for Coefficient A_1 x 10^{-8}	97.5% Confidence Interv. for A_1 x 10^{-8}		Test for Lin'ty at 1% Level of Significance	Correlation Coefficient γ	Test of γ for Signif. Diff. from Zero at 1% Level of Significance
			Lower Limit	Upper Limit			
37.5-75	16.40	0.19	-3.62	3.99	reject	0.03	reject
75-150	5.72	1.24	0.36	2.12	reject	0.80	accept
150-300	5.83	8.86	2.27	15.45	reject	0.61	reject
300-600	32.24	25.48	-0.46	51.42	reject	0.48	reject
600-1200	48.87	4.14	-3.80	12.08	reject	0.37	reject
1200-2400	26.18	-0.72	-8.34	6.90	reject	-0.09	reject

Table 12. Summary of Regression Analysis Results for Maximum Dynamic Pressure Vibration Data

(a) Results for Max. q Vibration Data in Longitudinal Direction

Frequency Interval (cps)	Estimate for Coefficient A_0 $\times 10^{-3}$	Estimate for Coefficient A_1 $\times 10^{-8}$	97.5% Confidence Interv. for $A_1 \times 10^{-8}$		Test for Lin'ty at 1% Level of Significance	Correlation Coefficient γ	Test of γ for Signif. Diff. from Zero at 1% Level of Significance
			Lower Limit	Upper Limit			
37.5-75	-0.30	5.31	3.83	6.78	accept	0.88	accept
75-150	-0.29	3.63	2.87	4.39	accept	0.91	accept
150-300	-0.44	5.44	4.02	6.87	accept	0.87	accept
300-600	-23.85	75.39	67.15	83.64	accept	0.97	accept
600-1200	1.93	6.67	5.75	7.60	accept	0.96	accept
1200-2400	4.50	1.77	0.88	2.66	accept	0.73	accept

(b) Results for Max. q Vibration Data in Radial Direction

Frequency Interval (cps)	Estimate for Coefficient A_0 $\times 10^{-3}$	Estimate for Coefficient A_1 $\times 10^{-8}$	97.5% Confidence Interv. for $A_1 \times 10^{-8}$		Test for Lin'ty at 1% Level of Significance	Correlation Coefficient γ	Test of γ for Signif. Diff. from Zero at 1% Level of Significance
			Lower Limit	Upper Limit			
37.5-75	9.72	-0.23	-2.62	2.16	reject	-0.13	reject
75-150	2.95	-0.05	-0.74	0.64	reject	-0.10	reject
150-300	2.19	0.95	0.49	1.41	accept	0.94	accept
300-600	-15.17	24.51	19.82	29.20	accept	0.98	accept
600-1200	22.47	4.53	-1.31	10.36	reject	0.65	reject
1200-2400	94.85	-5.19	-34.23	23.85	reject	-0.18	reject

Referring now to the results for the radial liftoff vibration data in Table 10(a) and (d), it is seen that relatively good correlation and linearity are achieved in the three frequency bands between 75 and 600 cps for the unshifted data, and 0.075 to 0.600 for the shifted data. The data above and below these frequency ranges fail the test for significant correlation and linearity. The results again indicate that the dimensionless frequency model is no better than the cyclical frequency model.

Next, consider the results for the transonic vibration data presented in Table 11. For the longitudinal data, significant correlation is achieved in the frequency range from 150 to 1200 cps. However, the linearity of the model is accepted only in the 300 to 600 cps frequency band. For the radial data, significant correlation is indicated in only one frequency band (600 to 1200 cps), and the linearity hypothesis is rejected in all bands. Hence, the assumed model does not provide a very efficient description of transonic vibration.

Finally, consider the results for the maximum dynamic pressure vibration data in Table 12. For the longitudinal data, it is seen that excellent results are obtained for model linearity and correlation in all frequency bands. For the radial vibration data, significant correlation and linearity are obtained only in the frequency range from 300 to 600 cps.

In conclusion, the regression model defined in Eq. (5) appears to provide a reasonably efficient description for the longitudinal vibration of launch vehicle structure in the region of the spacecraft adaptor during liftoff and maximum dynamic pressure flight. The model is somewhat less efficient, however, in describing the radial vibration during these launch events, and even less efficient yet in describing the longitudinal or radial vibration during transonic flight. The reason for the inefficiency in describing the transonic vibration is clear. Specifically, transonic vibration is heavily dependent upon factors other than dynamic pressure, as previously summarized in Section 3.2. The reason for the limited efficiency in describing the radial vibration during liftoff and maximum dynamic pressure flight is less obvious. One possible explanation might be as follows. The surface weight density terms used for the regression analysis were established by estimating the surface weights of measurement locations based upon a longitudinal projection. These same weight density terms were then applied to the radial data . It appears likely that a new set of weight densities should have been calculated based upon a radial projection. In any case, it should be emphasized that the noted lack of efficiency does not rule out the use of the assumed model as a vibration prediction tool. It only indicates that the model is far from optimum, and that more accurate predictions could be achieved if a more efficient model were available. Further studies of this type to develop more efficient vibration prediction models are strongly suggested.

7. PREDICTION CURVES

Using the results presented in Appendices A through H, a 97.5 percent upper prediction limit for the longitudinal and radial vibration on the basic structure of a launch vehicle in the region of the spacecraft adaptor can now be established. Such prediction curves for liftoff, transonic flight, and maximum dynamic pressure flight are summarized in Figures 3 through 8. Note that the best spread in the prediction curves for various values of the independent variables is obtained for the maximum dynamic pressure induced longitudinal vibration. This is to be expected because the prediction model is most efficient for this case.

The vibration predictions given by Figures 3 through 8 are in terms of average power spectra in octave bands. The actual power spectrum for a given vibration measurement may have peaks which exceed the octave band averages by a wide margin. Past studies of average power spectra in octave bands versus narrow band power spectra indicate that most spectral peaks will be no more than 7 dB higher than the octave band average. Hence, if predictions for power spectra peaks are desired, Figures 3 through 8 may be applied by adding 7 dB to the predictions at all frequencies.

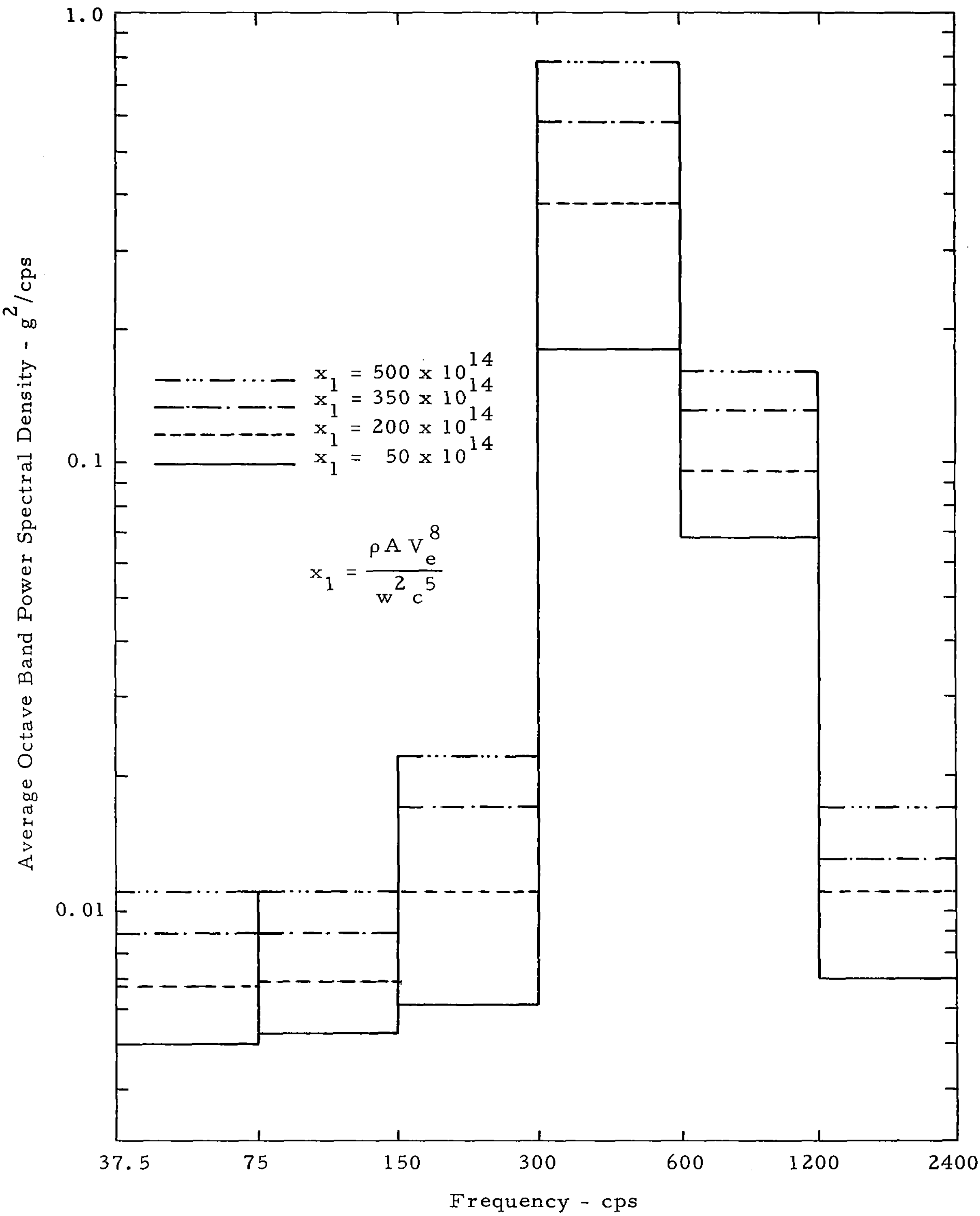

Figure 3. 97.5% Upper Prediction Limit for Liftoff Vibration in the Longitudinal Direction

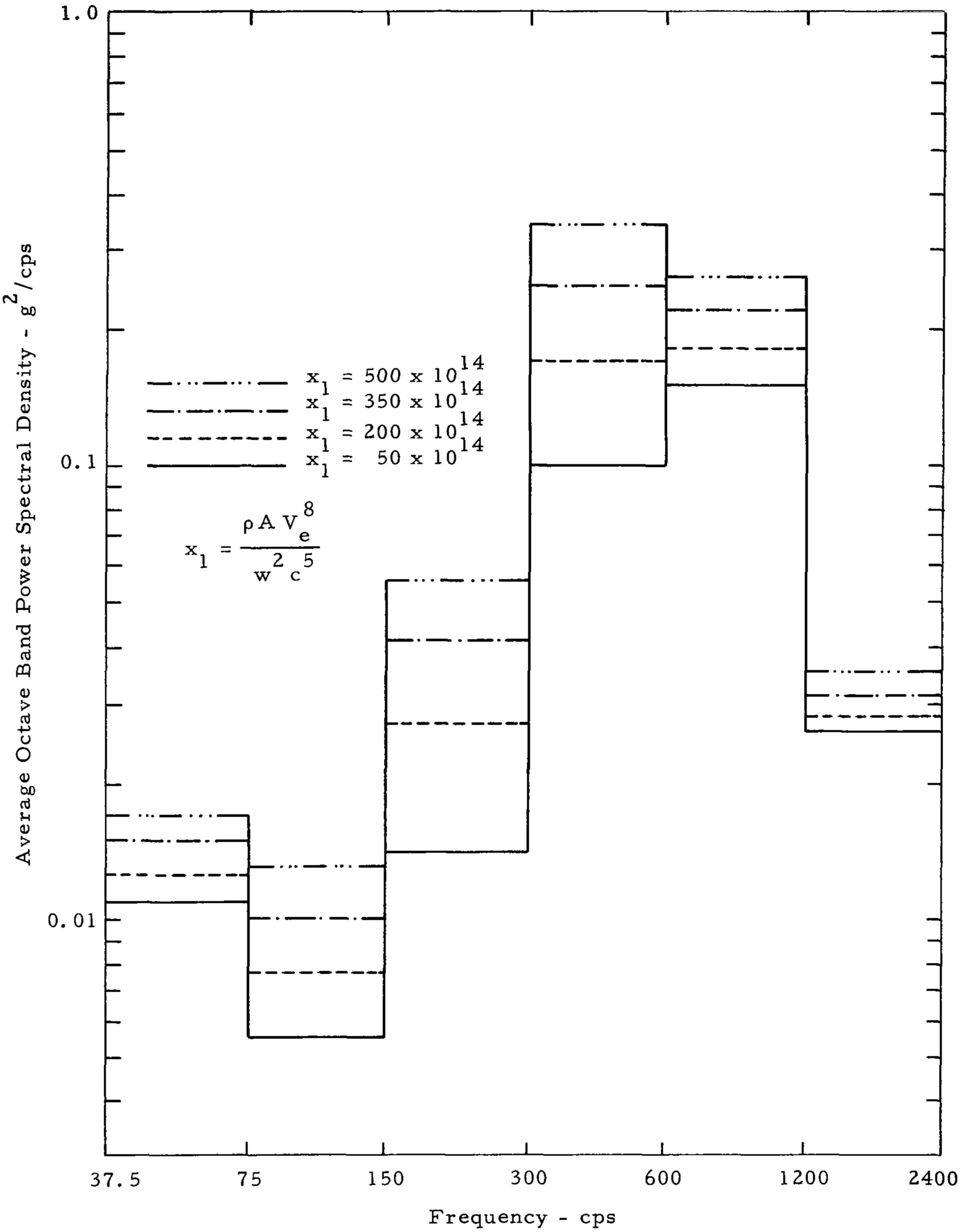

Figure 4. 97.5% Upper Prediction Limit for Liftoff Vibration in the Radial Direction

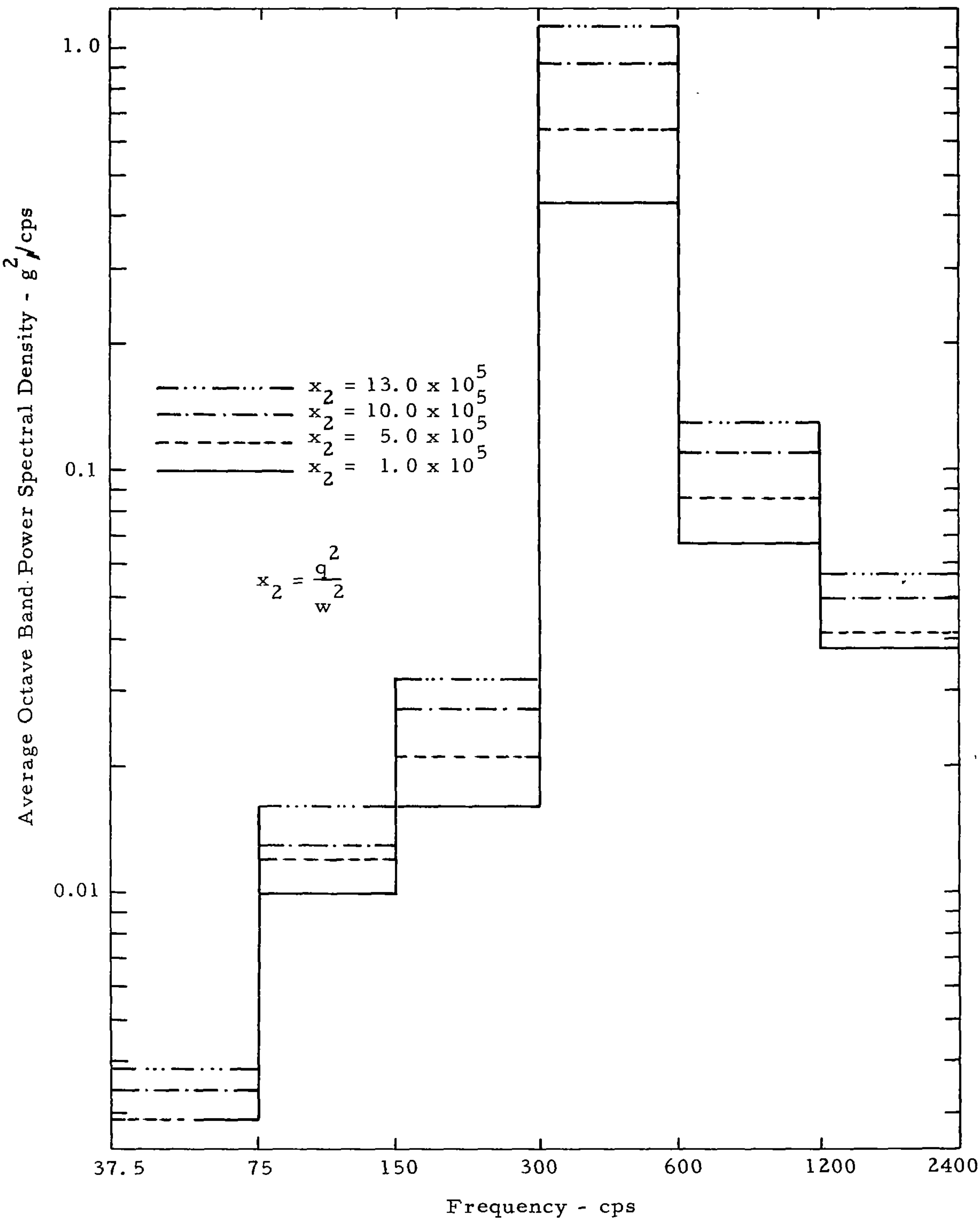

Figure 5. 97.5% Upper Prediction Limit for Transonic Vibration in the Longitudinal Direction

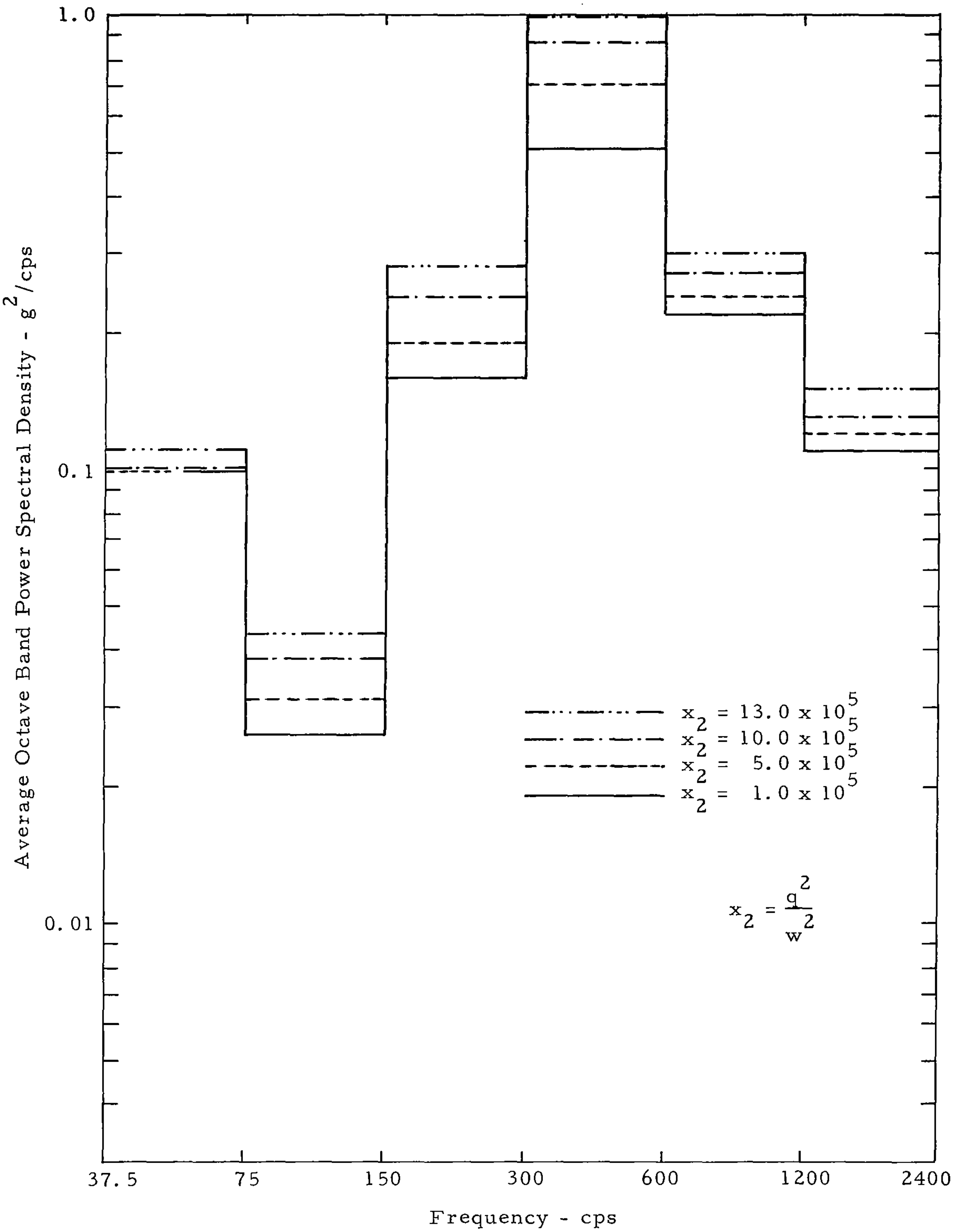

Figure 6. 97.5% Upper Prediction Limit for Transonic Vibration in the Radial Direction

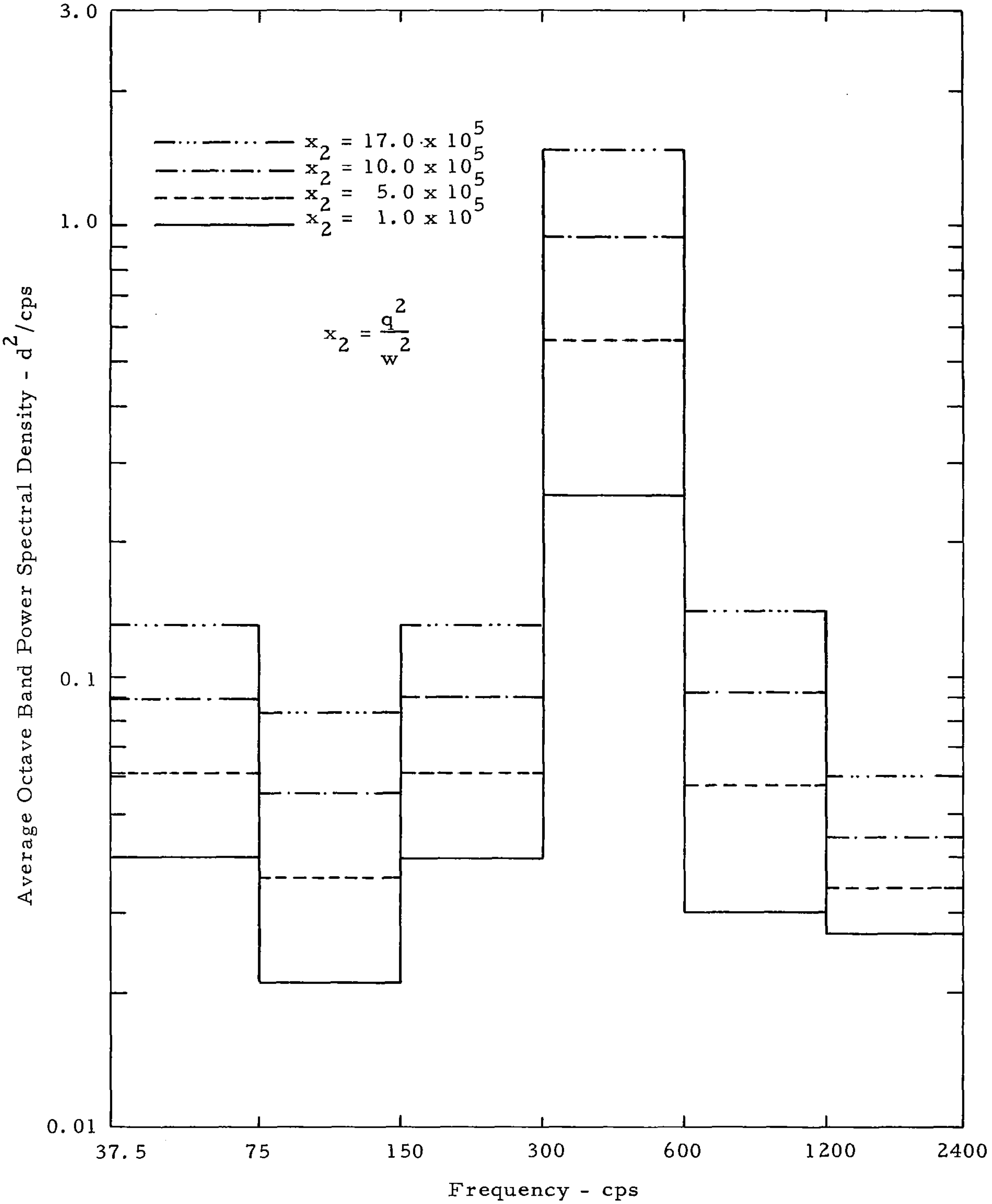

Figure 7. 97.5% Upper Prediction Limit for Maximum Dynamic Pressure Vibration in the Longitudinal Direction

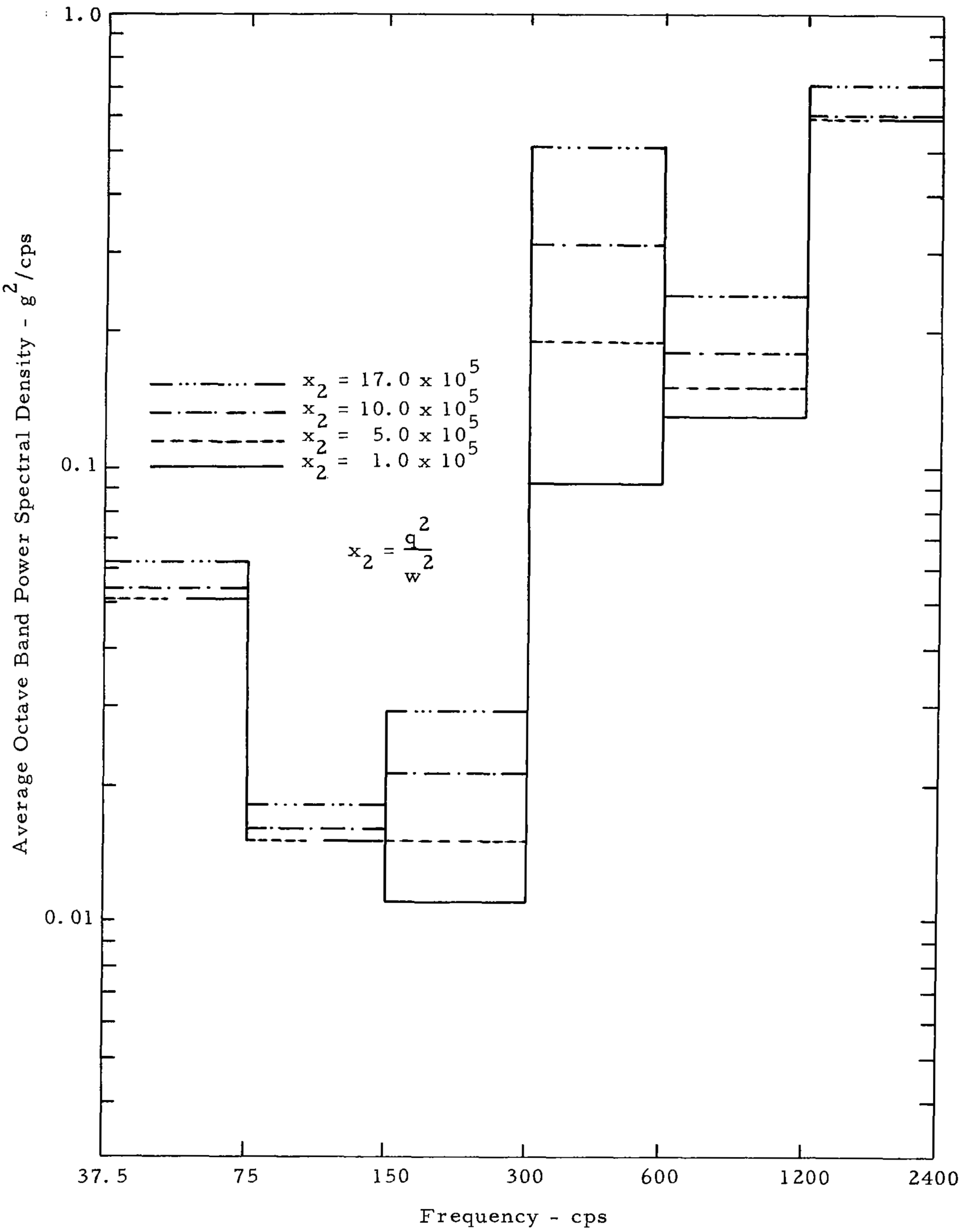

Figure 8. 97.5% Upper Prediction Limit for Maximum Dynamic Pressure Vibration in the Radial Direction

8. REFERENCES

1. Lyon, R. H., Random Noise and Vibration in Space Vehicles, SVM-1, DOD Shock and Vibration Information Center, Washington, D. C., 1967.

2. Measurement Analysis Corporation, "Summary of Random Vibration Prediction Procedures," MAC Report 504-18A, submitted to Marshall SFC, Huntsville, Alabama under Contract NAS 8-20020, October 1967 (to be published as NASA Contractor Report).

3. Piersol, A. G., and W. F. Van Der Laan, "Statistical Analysis of Flight Vibration and Acoustic Data," AFFDL-TR-68-92, Wright-Patterson AFB, Ohio, June 1968.

4. Bowker, A. H., and G. J. Lieberman, Engineering Statistics, Ch. IX, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1959.

5. Dixon, W. J., and F. J. Massey, Jr., Introduction to Statistical Analysis, Ch. 11, McGraw-Hill Book Company, Inc., N. Y., 1967.

6. Condos, F. M., and W. L. Butler, "A Critical Analysis of Vibration Prediction Techniques," Proc. Inst. Envir. Sci., p 321, 1963.

7. Curtis, A. J., "A Statistical Approach to Prediction of the Aircraft Flight Environment," Shock and Vibration Bulletin No. 33, Part 1, 1964.

8. Barrett, R. E., "Statistical Techniques for Describing Localized Vibration Environments in Rocket Vehicles," NASA TN D-2158, Marshall SFC, Huntsville, Alabama, 1964.

9. Bennett, C. A., and N. L. Franklin, Statistical Analysis in Chemistry and Chemical Industry, p 429, John Wiley & Sons, Inc., N. Y., 1954.

10. Barrett, R. E., "Techniques for Predicting Localized Vibration Environments of Rocket Vehicles," NASA TN D-1836, Marshall SFC, Huntsville, Alabama, 1963.

APPENDIX A

RESULTS OF REGRESSION ANALYSIS OF UNSHIFTED LIFTOFF VIBRATION DATA FOR THE LONGITUDINAL DIRECTION

REGRESSION ANALYSIS FREQ. TO 75.0000

REGRESSION COEFFICIENTS A*ZERO= 7.9403E-04 A= 1.0820E-19

97.5 PERCENT CONFIDENCE INTERVAL FOR A

4.4041E-20 1.7235E-19

TEST OF LINEARITY BY ANOVA

PHI= 10.64 D.F.=1, 20

CORRELATION COEFFICIENT= .64

STANDARDIZED FISHERS Z= 3.21 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2.5000E 15	2.7049E-04	4.7051E-03
5.0000E 15	5.4098E-04	4.9730E-03
7.5000E 15	8.1147E-04	5.2491E-03
1.0000E 16	1.0820E-03	5.5334E-03
1.2500E 16	1.3524E-03	5.8258E-03
1.5000E 16	1.6229E-03	6.1262E-03
1.7500E 16	1.8934E-03	6.4343E-03
2.0000E 16	2.1639E-03	6.7500E-03
2.2500E 16	2.4344E-03	7.0729E-03
2.5000E 16	2.7049E-03	7.4028E-03
2.7500E 16	2.9754E-03	7.7393E-03
3.0000E 16	3.2459E-03	8.0822E-03
3.2500E 16	3.5164E-03	8.4310E-03
3.5000E 16	3.7868E-03	8.7855E-03
3.7500E 16	4.0573E-03	9.1454E-03
4.0000E 16	4.3278E-03	9.5102E-03
4.2500E 16	4.5983E-03	9.8798E-03
4.5000E 16	4.8688E-03	1.0254E-02
4.7500E 16	5.1393E-03	1.0632E-02
5.0000E 16	5.4098E-03	1.1014E-02

REGRESSION ANALYSIS FREQ. TO 150.0000

REGRESSION COEFFICIENTS A-ZERO= 6.3283E-04 A= 9.6369E-20

97.5 PERCENT CONFIDENCE INTERVAL FOR A

2.3680E-20 1.6906E-19

TEST OF LINEARITY BY ANOVA

PHI= 6.40 D.F.=1, 21

CORRELATION COEFFICIENT= .50

STANDARDIZED FISHERS Z= 2.42 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2.5000E 15	2.4092E-04	5.0594E-03
5.0000E 15	4.8185E-04	5.2965E-03
7.5000E 15	7.2277E-04	5.5430E-03
1.0000E 16	9.6369E-04	5.7988E-03
1.2500E 16	1.2046E-03	6.0638E-03
1.5000E 16	1.4455E-03	6.3379E-03
1.7500E 16	1.6865E-03	6.6209E-03
2.0000E 16	1.9274E-03	6.9126E-03
2.2500E 16	2.1683E-03	7.2125E-03
2.5000E 16	2.4092E-03	7.5204E-03
2.7500E 16	2.6502E-03	7.8360E-03
3.0000E 16	2.8911E-03	8.1588E-03
3.2500E 16	3.1320E-03	8.4885E-03
3.5000E 16	3.3729E-03	8.8248E-03
3.7500E 16	3.6138E-03	9.1671E-03
4.0000E 16	3.8548E-03	9.5153E-03
4.2500E 16	4.0957E-03	9.8688E-03
4.5000E 16	4.3366E-03	1.0227E-02
4.7500E 16	4.5775E-03	1.0591E-02
5.0000E 16	4.8185E-03	1.0958E-02

REGRESSION ANALYSIS FREQ. TO 300.0000

REGRESSION COEFFICIENTS A*ZERO= 7.8346E-04 A= 3.3425E-19

97.5 PERCENT CONFIDENCE INTERVAL FOR A

2.7101E-19 3.9748E-19

TEST OF LINEARITY BY ANOVA

PHI=100.54 D.F.=1, 22

CORRELATION COEFFICIENT= .92

STANDARDIZED FISHERS Z= 7.22 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2.5000E 15	8.3562E-04	5.2681E-03
5.0000E 15	1.6712E-03	6.1005E-03
7.5000E 15	2.5069E-03	6.9410E-03
1.0000E 16	3.3425E-03	7.7896E-03
1.2500E 16	4.1781E-03	8.6464E-03
1.5000E 16	5.0137E-03	9.5110E-03
1.7500E 16	5.8494E-03	1.0383E-02
2.0000E 16	6.6850E-03	1.1263E-02
2.2500E 16	7.5206E-03	1.2151E-02
2.5000E 16	8.3562E-03	1.3045E-02
2.7500E 16	9.1918E-03	1.3946E-02
3.0000E 16	1.0027E-02	1.4853E-02
3.2500E 16	1.0863E-02	1.5766E-02
3.5000E 16	1.1699E-02	1.6685E-02
3.7500E 16	1.2534E-02	1.7609E-02
4.0000E 16	1.3370E-02	1.8538E-02
4.2500E 16	1.4206E-02	1.9472E-02
4.5000E 16	1.5041E-02	2.0411E-02
4.7500E 16	1.5877E-02	2.1353E-02
5.0000E 16	1.6712E-02	2.2300E-02

REGRESSION ANALYSIS FREQ, TO 600.0000

REGRESSION COEFFICIENTS A-ZERO=-2.0740E-02 A= 1.2615E-17

97.5 PERCENT CONFIDENCE INTERVAL FOR A

1.0223E-17 1.5007E-17

TEST OF LINEARITY BY ANOVA

PHI=100.10 D.F.=1, 22

CORRELATION COEFFICIENT= .91

STANDARDIZED FISHERS Z= 6.94 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2.5000E 15	3.1538E-02	1.4882E-01
5.0000E 15	6.3076E-02	1.8024E-01
7.5000E 15	9.4614E-02	2.1196E-01
1.0000E 16	1.2615E-01	2.4399E-01
1.2500E 16	1.5769E-01	2.7633E-01
1.5000E 16	1.8923E-01	3.0896E-01
1.7500E 16	2.2077E-01	3.4189E-01
2.0000E 16	2.5230E-01	3.7511E-01
2.2500E 16	2.8384E-01	4.0860E-01
2.5000E 16	3.1538E-01	4.4235E-01
2.7500E 16	3.4692E-01	4.7635E-01
3.0000E 16	3.7846E-01	5.1060E-01
3.2500E 16	4.1000E-01	5.4507E-01
3.5000E 16	4.4153E-01	5.7976E-01
3.7500E 16	4.7307E-01	6.1465E-01
4.0000E 16	5.0461E-01	6.4973E-01
4.2500E 16	5.3615E-01	6.8499E-01
4.5000E 16	5.6769E-01	7.2041E-01
4.7500E 16	5.9922E-01	7.5599E-01
5.0000E 16	6.3076E-01	7.9172E-01

REGRESSION ANALYSIS FREQ, TO 1200.0000

REGRESSION COEFFICIENTS A-ZERO= 5.3674E-03 A= 1.7251E-18

97.5 PERCENT CONFIDENCE INTERVAL FOR A

7.9458E-19 2.6555E-18

TEST OF LINEARITY BY ANOVA

PHI= 12.37 D.F.=1, 22

CORRELATION COEFFICIENT= .61

STANDARDIZED FISHERS Z= 3.16 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2.5000E 15	4.3126E-03	6.3375E-02
5.0000E 15	8.6253E-03	6.7639E-02
7.5000E 15	1.2938E-02	7.2024E-02
1.0000E 16	1.7251E-02	7.6528E-02
1.2500E 16	2.1563E-02	8.1151E-02
1.5000E 16	2.5876E-02	8.5892E-02
1.7500E 16	3.0189E-02	9.0746E-02
2.0000E 16	3.4501E-02	9.5710E-02
2.2500E 16	3.8814E-02	1.0078E-01
2.5000E 16	4.3126E-02	1.0596E-01
2.7500E 16	4.7439E-02	1.1123E-01
3.0000E 16	5.1752E-02	1.1659E-01
3.2500E 16	5.6064E-02	1.2205E-01
3.5000E 16	6.0377E-02	1.2759E-01
3.7500E 16	6.4690E-02	1.3320E-01
4.0000E 16	6.9002E-02	1.3889E-01
4.2500E 16	7.3315E-02	1.4465E-01
4.5000E 16	7.7628E-02	1.5048E-01
4.7500E 16	8.1940E-02	1.5636E-01
5.0000E 16	8.6253E-02	1.6230E-01

REGRESSION ANALYSIS FREQ, TO 2400,0000

REGRESSION COEFFICIENTS A=ZERO= 1,2723E-03 A= 1,8550E-19

97.5 PERCENT CONFIDENCE INTERVAL FOR A

9,3948E-20 2,7705E-19

TEST OF LINEARITY BY ANOVA

PHI= 15.48 D.F.=1, 20

CORRELATION COEFFICIENT= ,73

STANDARDIZED FISHERS Z= 3,98 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2,5000E 15	4,6375E-04	6,5287E-03
5,0000E 15	9,2749E-04	6,9908E-03
7,5000E 15	1,3912E-03	7,4656E-03
1,0000E 16	1,8550E-03	7,9528E-03
1,2500E 16	2,3187E-03	8,4524E-03
1,5000E 16	2,7825E-03	8,9640E-03
1,7500E 16	3,2462E-03	9,4874E-03
2,0000E 16	3,7100E-03	1,0022E-02
2,2500E 16	4,1737E-03	1,0568E-02
2,5000E 16	4,6375E-03	1,1123E-02
2,7500E 16	5,1012E-03	1,1689E-02
3,0000E 16	5,5649E-03	1,2264E-02
3,2500E 16	6,0287E-03	1,2847E-02
3,5000E 16	6,4924E-03	1,3439E-02
3,7500E 16	6,9562E-03	1,4038E-02
4,0000E 16	7,4199E-03	1,4644E-02
4,2500E 16	7,8837E-03	1,5257E-02
4,5000E 16	8,3474E-03	1,5876E-02
4,7500E 16	8,8112E-03	1,6501E-02
5,0000E 16	9,2749E-03	1,7131E-02

APPENDIX B

RESULTS OF REGRESSION ANALYSIS OF SHIFTED LIFTOFF VIBRATION DATA FOR THE LONGITUDINAL DIRECTION

REGRESSION ANALYSIS FREQ. TO .0750

REGRESSION COEFFICIENTS A-ZERO= 1.2615E-03 A= 9.5163E-20

97.5 PERCENT CONFIDENCE INTERVAL FOR A

2.9029E-21 1.8742E-19

TEST OF LINEARITY BY ANOVA

PHI= 4.09 D.F.=1, 11

CORRELATION COEFFICIENT= .60

STANDARDIZED FISHERS Z= 2.06 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2.5000E 15	2.3791E-04	6.8194E-03
5.0000E 15	4.7581E-04	7.0398E-03
7.5000E 15	7.1372E-04	7.2727E-03
1.0000E 16	9.5163E-04	7.5184E-03
1.2500E 16	1.1895E-03	7.7766E-03
1.5000E 16	1.4274E-03	8.0472E-03
1.7500E 16	1.6654E-03	8.3300E-03
2.0000E 16	1.9033E-03	8.6248E-03
2.2500E 16	2.1412E-03	8.9311E-03
2.5000E 16	2.3791E-03	9.2485E-03
2.7500E 16	2.6170E-03	9.5766E-03
3.0000E 16	2.8549E-03	9.9149E-03
3.2500E 16	3.0928E-03	1.0263E-02
3.5000E 16	3.3307E-03	1.0620E-02
3.7500E 16	3.5686E-03	1.0985E-02
4.0000E 16	3.8065E-03	1.1359E-02
4.2500E 16	4.0444E-03	1.1740E-02
4.5000E 16	4.2823E-03	1.2128E-02
4.7500E 16	4.5202E-03	1.2523E-02
5.0000E 16	4.7581E-03	1.2924E-02

REGRESSION ANALYSIS FREQ, TO .1500

REGRESSION COEFFICIENTS A-ZERO= 7.7770E-04 A= 9.2518E-20

97.5 PERCENT CONFIDENCE INTERVAL FOR A

1.0275E-20 1.7476E-19

TEST OF LINEARITY BY ANOVA

PHI= 4.65 D.F.=1, 17

CORRELATION COEFFICIENT= .49

STANDARDIZED FISHERS Z= 2.08 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X, E(Y) AND YU

2.5000E 15	2.3129E-04	5.7544E-03
5.0000E 15	4.6259E-04	5.9780E-03
7.5000E 15	6.9388E-04	6.2124E-03
1.0000E 16	9.2518E-04	6.4575E-03
1.2500E 16	1.1565E-03	6.7134E-03
1.5000E 16	1.3878E-03	6.9799E-03
1.7500E 16	1.6191E-03	7.2566E-03
2.0000E 16	1.8504E-03	7.5433E-03
2.2500E 16	2.0816E-03	7.8397E-03
2.5000E 16	2.3129E-03	8.1455E-03
2.7500E 16	2.5442E-03	8.4601E-03
3.0000E 16	2.7755E-03	8.7832E-03
3.2500E 16	3.0068E-03	9.1144E-03
3.5000E 16	3.2381E-03	9.4531E-03
3.7500E 16	3.4694E-03	9.7991E-03
4.0000E 16	3.7007E-03	1.0152E-02
4.2500E 16	3.9320E-03	1.0511E-02
4.5000E 16	4.1633E-03	1.0875E-02
4.7500E 16	4.3946E-03	1.1246E-02
5.0000E 16	4.6259E-03	1.1621E-02

REGRESSION ANALYSIS FREQ. TO .3000

REGRESSION COEFFICIENTS A*ZERO= 2.6292E-04 A= 3.4023E-19

97.5 PERCENT CONFIDENCE INTERVAL FOR A

2.9591E-19 3.8456E-19

TEST OF LINEARITY BY ANOVA

PHI=216.38 D.F.=1, 17

CORRELATION COEFFICIENT= .96

STANDARDIZED FISHERS Z= 7.79 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2.5000E 15	8.5059E-04	3.6709E-03
5.0000E 15	1.7012E-03	4.5173E-03
7.5000E 15	2.5518E-03	5.3696E-03
1.0000E 16	3.4023E-03	6.2277E-03
1.2500E 16	4.2529E-03	7.0915E-03
1.5000E 16	5.1035E-03	7.9610E-03
1.7500E 16	5.9541E-03	8.8361E-03
2.0000E 16	6.8047E-03	9.7166E-03
2.2500E 16	7.6553E-03	1.0602E-02
2.5000E 16	8.5059E-03	1.1493E-02
2.7500E 16	9.3564E-03	1.2388E-02
3.0000E 16	1.0207E-02	1.3289E-02
3.2500E 16	1.1058E-02	1.4193E-02
3.5000E 16	1.1908E-02	1.5101E-02
3.7500E 16	1.2759E-02	1.6014E-02
4.0000E 16	1.3609E-02	1.6930E-02
4.2500E 16	1.4460E-02	1.7849E-02
4.5000E 16	1.5311E-02	1.8772E-02
4.7500E 16	1.6161E-02	1.9697E-02
5.0000E 16	1.7012E-02	2.0625E-02

REGRESSION ANALYSIS FREQ. TO .6000

REGRESSION COEFFICIENTS A-ZERO=-2.0843E-02 A= 1.2620E-17

97.5 PERCENT CONFIDENCE INTERVAL FOR A

1.0229E-17 1.5011E-17

TEST OF LINEARITY BY ANOVA

PHI=100.26 D.F.=1, 22

CORRELATION COEFFICIENT= .91

STANDARDIZED FISHERS Z= 6.95 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2.5000E 15	3.1550E-02	1.4868E-01
5.0000E 15	6.3100E-02	1.8010E-01
7.5000E 15	9.4651E-02	2.1184E-01
1.0000E 16	1.2620E-01	2.4388E-01
1.2500E 16	1.5775E-01	2.7623E-01
1.5000E 16	1.8930E-01	3.0888E-01
1.7500E 16	2.2085E-01	3.4182E-01
2.0000E 16	2.5240E-01	3.7505E-01
2.2500E 16	2.8395E-01	4.0855E-01
2.5000E 16	3.1550E-01	4.4231E-01
2.7500E 16	3.4705E-01	4.7633E-01
3.0000E 16	3.7860E-01	5.1058E-01
3.2500E 16	4.1015E-01	5.4507E-01
3.5000E 16	4.4170E-01	5.7977E-01
3.7500E 16	4.7325E-01	6.1467E-01
4.0000E 16	5.0480E-01	6.4976E-01
4.2500E 16	5.3635E-01	6.8503E-01
4.5000E 16	5.6790E-01	7.2046E-01
4.7500E 16	5.9945E-01	7.5605E-01
5.0000E 16	6.3100E-01	7.9179E-01

REGRESSION ANALYSIS FREQ. TO 1.2000

REGRESSION COEFFICIENTS A-ZERO= 1.6812E-03 A= 1.7749E-19

97.5 PERCENT CONFIDENCE INTERVAL FOR A

6.0398E-20 2.9458E-19

TEST OF LINEARITY BY ANOVA

PHI= 8.67 D.F.=1, 20

CORRELATION COEFFICIENT= .64

STANDARDIZED FISHERS Z= 3.18 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X, E(Y) AND YU

2.5000E 15	4.4372E-04	8.2545E-03
5.0000E 15	8.8743E-04	8.6961E-03
7.5000E 15	1.3311E-03	9.1539E-03
1.0000E 16	1.7749E-03	9.6277E-03
1.2500E 16	2.2186E-03	1.0117E-02
1.5000E 16	2.6623E-03	1.0622E-02
1.7500E 16	3.1060E-03	1.1142E-02
2.0000E 16	3.5497E-03	1.1677E-02
2.2500E 16	3.9934E-03	1.2225E-02
2.5000E 16	4.4372E-03	1.2786E-02
2.7500E 16	4.8809E-03	1.3360E-02
3.0000E 16	5.3246E-03	1.3946E-02
3.2500E 16	5.7683E-03	1.4543E-02
3.5000E 16	6.2120E-03	1.5150E-02
3.7500E 16	6.6557E-03	1.5767E-02
4.0000E 16	7.0995E-03	1.6393E-02
4.2500E 16	7.5432E-03	1.7028E-02
4.5000E 16	7.9869E-03	1.7670E-02
4.7500E 16	8.4306E-03	1.8319E-02
5.0000E 16	8.8743E-03	1.8976E-02

REGRESSION ANALYSIS FREQ. TO 2.4000

REGRESSION COEFFICIENTS A=ZERO= 5.2167E-03 A= 1.7309E-18

97.5 PERCENT CONFIDENCE INTERVAL FOR A

8.0216E-19 2.6597E-18

TEST OF LINEARITY BY ANOVA

PHI= 12.50 D.F.=1, 22

CORRELATION COEFFICIENT= .61

STANDARDIZED FISHERS Z= 3.17 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X, E(Y) AND YU

2.5000E 15	4.3274E-03	6.3140E-02
5.0000E 15	8.6547E-03	6.7419E-02
7.5000E 15	1.2982E-02	7.1818E-02
1.0000E 16	1.7309E-02	7.6337E-02
1.2500E 16	2.1637E-02	8.0975E-02
1.5000E 16	2.5964E-02	8.5729E-02
1.7500E 16	3.0291E-02	9.0597E-02
2.0000E 16	3.4619E-02	9.5575E-02
2.2500E 16	3.8946E-02	1.0066E-01
2.5000E 16	4.3274E-02	1.0585E-01
2.7500E 16	4.7601E-02	1.1113E-01
3.0000E 16	5.1928E-02	1.1651E-01
3.2500E 16	5.6256E-02	1.2198E-01
3.5000E 16	6.0583E-02	1.2753E-01
3.7500E 16	6.4910E-02	1.3316E-01
4.0000E 16	6.9238E-02	1.3886E-01
4.2500E 16	7.3565E-02	1.4463E-01
4.5000E 16	7.7892E-02	1.5047E-01
4.7500E 16	8.2220E-02	1.5637E-01
5.0000E 16	8.6547E-02	1.6232E-01

APPENDIX C

RESULTS OF REGRESSION ANALYSIS OF UNSHIFTED LIFTOFF VIBRATION DATA FOR THE RADIAL DIRECTION

REGRESSION ANALYSIS FREQ, TO 75.0000

REGRESSION COEFFICIENTS A-ZERO= 2.1629E-03 A= 8.7185E-20

97.5 PERCENT CONFIDENCE INTERVAL FOR A

-4.6991E-20 2.2136E-19

TEST OF LINEARITY BY ANOVA

PHI= 1.45 D.F.=1, 12

CORRELATION COEFFICIENT= .40

STANDARDIZED FISHERS Z= 1.34 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2.5000E 15	2.1796E-04	1.0898E-02
5.0000E 15	4.3592E-04	1.1079E-02
7.5000E 15	6.5389E-04	1.1278E-02
1.0000E 16	8.7185E-04	1.1495E-02
1.2500E 16	1.0898E-03	1.1731E-02
1.5000E 16	1.3078E-03	1.1985E-02
1.7500E 16	1.5257E-03	1.2256E-02
2.0000E 16	1.7437E-03	1.2546E-02
2.2500E 16	1.9617E-03	1.2853E-02
2.5000E 16	2.1796E-03	1.3176E-02
2.7500E 16	2.3976E-03	1.3516E-02
3.0000E 16	2.6155E-03	1.3871E-02
3.2500E 16	2.8335E-03	1.4240E-02
3.5000E 16	3.0515E-03	1.4624E-02
3.7500E 16	3.2694E-03	1.5022E-02
4.0000E 16	3.4874E-03	1.5431E-02
4.2500E 16	3.7054E-03	1.5853E-02
4.5000E 16	3.9233E-03	1.6286E-02
4.7500E 16	4.1413E-03	1.6729E-02
5.0000E 16	4.3592E-03	1.7182E-02

REGRESSION ANALYSIS FREQ, TO 150.0000

REGRESSION COEFFICIENTS A-ZERO= 7.6584E-04 A= 1.3621E-19

97.5 PERCENT CONFIDENCE INTERVAL FOR A

7.1915E-20 2.0050E-19

TEST OF LINEARITY BY ANOVA

PHI= 15.43 D.F.=1, 12

CORRELATION COEFFICIENT= .78

STANDARDIZED FISHERS Z= 3.34 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2.5000E 15	3.4052E-04	5.1878E-03
5.0000E 15	6.8105E-04	5.5105E-03
7.5000E 15	1.0216E-03	5.8418E-03
1.0000E 16	1.3621E-03	6.1820E-03
1.2500E 16	1.7026E-03	6.5310E-03
1.5000E 16	2.0431E-03	6.8887E-03
1.7500E 16	2.3837E-03	7.2550E-03
2.0000E 16	2.7242E-03	7.6298E-03
2.2500E 16	3.0647E-03	8.0129E-03
2.5000E 16	3.4052E-03	8.4040E-03
2.7500E 16	3.7458E-03	8.8027E-03
3.0000E 16	4.0863E-03	9.2089E-03
3.2500E 16	4.4268E-03	9.6222E-03
3.5000E 16	4.7673E-03	1.0042E-02
3.7500E 16	5.1079E-03	1.0469E-02
4.0000E 16	5.4484E-03	1.0901E-02
4.2500E 16	5.7889E-03	1.1339E-02
4.5000E 16	6.1294E-03	1.1783E-02
4.7500E 16	6.4700E-03	1.2231E-02
5.0000E 16	6.8105E-03	1.2685E-02

REGRESSION ANALYSIS FREQ, TO 300.0000

REGRESSION COEFFICIENTS A-ZERO= 4.5859E-04 A= 8.7037E-19

97.5 PERCENT CONFIDENCE INTERVAL FOR A

7.2465E-19 1.0161E-18

TEST OF LINEARITY BY ANOVA

PHI=120.71 D.F.=1, 13

CORRELATION COEFFICIENT= .95

STANDARDIZED FISHERS Z= 6.10 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2.5000E 15	2.1759E-03	1.1880E-02
5.0000E 15	4.3518E-03	1.4018E-02
7.5000E 15	6.5278E-03	1.6175E-02
1.0000E 16	8.7037E-03	1.8353E-02
1.2500E 16	1.0880E-02	2.0551E-02
1.5000E 16	1.3056E-02	2.2768E-02
1.7500E 16	1.5231E-02	2.5005E-02
2.0000E 16	1.7407E-02	2.7261E-02
2.2500E 16	1.9583E-02	2.9535E-02
2.5000E 16	2.1759E-02	3.1828E-02
2.7500E 16	2.3935E-02	3.4138E-02
3.0000E 16	2.6111E-02	3.6464E-02
3.2500E 16	2.8287E-02	3.8807E-02
3.5000E 16	3.0463E-02	4.1165E-02
3.7500E 16	3.2639E-02	4.3537E-02
4.0000E 16	3.4815E-02	4.5922E-02
4.2500E 16	3.6991E-02	4.8321E-02
4.5000E 16	3.9167E-02	5.0731E-02
4.7500E 16	4.1343E-02	5.3153E-02
5.0000E 16	4.3518E-02	5.5585E-02

REGRESSION ANALYSIS FREQ. TO 600.0000

REGRESSION COEFFICIENTS A-ZERO=-1.9111E-04 A= 4.8661E-18

97.5 PERCENT CONFIDENCE INTERVAL FOR A

3.6507E-18 6.0814E-18

TEST OF LINEARITY BY ANOVA

PHI= 54.74 D.F.=1, 14

CORRELATION COEFFICIENT= .89

STANDARDIZED FISHERS Z= 4.97 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2.5000E 15	1.2165E-02	8.8820E-02
5.0000E 15	2.4330E-02	1.0071E-01
7.5000E 15	3.6495E-02	1.1276E-01
1.0000E 16	4.8661E-02	1.2498E-01
1.2500E 16	6.0826E-02	1.3735E-01
1.5000E 16	7.2991E-02	1.4989E-01
1.7500E 16	8.5156E-02	1.6259E-01
2.0000E 16	9.7321E-02	1.7544E-01
2.2500E 16	1.0949E-01	1.8845E-01
2.5000E 16	1.2165E-01	2.0160E-01
2.7500E 16	1.3382E-01	2.1489E-01
3.0000E 16	1.4598E-01	2.2831E-01
3.2500E 16	1.5815E-01	2.4187E-01
3.5000E 16	1.7031E-01	2.5555E-01
3.7500E 16	1.8248E-01	2.6934E-01
4.0000E 16	1.9464E-01	2.8325E-01
4.2500E 16	2.0681E-01	2.9726E-01
4.5000E 16	2.1897E-01	3.1137E-01
4.7500E 16	2.3114E-01	3.2557E-01
5.0000E 16	2.4330E-01	3.3985E-01

REGRESSION ANALYSIS FREQ, TO 1200.0000

REGRESSION COEFFICIENTS A-ZERO= 1.6607E-02 A= 1.9132E-18

97.5 PERCENT CONFIDENCE INTERVAL FOR A

1.1003E-20 3.8155E-18

TEST OF LINEARITY BY ANOVA

PHI= 3.45 D.F.=1, 14

CORRELATION COEFFICIENT= .46

STANDARDIZED FISHERS Z= 1.74 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2.5000E 15	4.7831E-03	1.4167E-01
5.0000E 15	9.5661E-03	1.4602E-01
7.5000E 15	1.4349E-02	1.5063E-01
1.0000E 16	1.9132E-02	1.5549E-01
1.2500E 16	2.3915E-02	1.6060E-01
1.5000E 16	2.8698E-02	1.6597E-01
1.7500E 16	3.3482E-02	1.7158E-01
2.0000E 16	3.8265E-02	1.7744E-01
2.2500E 16	4.3048E-02	1.8354E-01
2.5000E 16	4.7831E-02	1.8986E-01
2.7500E 16	5.2614E-02	1.9641E-01
3.0000E 16	5.7397E-02	2.0316E-01
3.2500E 16	6.2180E-02	2.1012E-01
3.5000E 16	6.6963E-02	2.1728E-01
3.7500E 16	7.1746E-02	2.2461E-01
4.0000E 16	7.6529E-02	2.3212E-01
4.2500E 16	8.1312E-02	2.3979E-01
4.5000E 16	8.6095E-02	2.4761E-01
4.7500E 16	9.0878E-02	2.5558E-01
5.0000E 16	9.5661E-02	2.6368E-01

REGRESSION ANALYSIS FREQ. TO 2400.0000

REGRESSION COEFFICIENTS A-ZERO= 5.0594E-03 A= 3.1674E-20

97.5 PERCENT CONFIDENCE INTERVAL FOR A

-3.7191E-19 4.3526E-19

TEST OF LINEARITY BY ANOVA

PHI= .02 D.F.=1, 12

CORRELATION COEFFICIENT= .05

STANDARDIZED FISHERS Z= .17 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2.5000E 15	7.9184E-05	2.6395E-02
5.0000E 15	1.5837E-04	2.6433E-02
7.5000E 15	2.3755E-04	2.6529E-02
1.0000E 16	3.1674E-04	2.6681E-02
1.2500E 16	3.9592E-04	2.6889E-02
1.5000E 16	4.7510E-04	2.7152E-02
1.7500E 16	5.5429E-04	2.7469E-02
2.0000E 16	6.3347E-04	2.7838E-02
2.2500E 16	7.1265E-04	2.8256E-02
2.5000E 16	7.9184E-04	2.8723E-02
2.7500E 16	8.7102E-04	2.9234E-02
3.0000E 16	9.5021E-04	2.9789E-02
3.2500E 16	1.0294E-03	3.0384E-02
3.5000E 16	1.1086E-03	3.1016E-02
3.7500E 16	1.1878E-03	3.1684E-02
4.0000E 16	1.2669E-03	3.2385E-02
4.2500E 16	1.3461E-03	3.3117E-02
4.5000E 16	1.4253E-03	3.3877E-02
4.7500E 16	1.5045E-03	3.4663E-02
5.0000E 16	1.5837E-03	3.5474E-02

APPENDIX D

RESULTS OF REGRESSION ANALYSIS OF SHIFTED LIFTOFF VIBRATION DATA FOR THE RADIAL DIRECTION

REGRESSION ANALYSIS FREQ. TO .0750

REGRESSION COEFFICIENTS A-ZERO= 4.3499E-03 A= 2.1248E-20

97.5 PERCENT CONFIDENCE INTERVAL FOR A

-1.9533E-19 2.3782E-19

TEST OF LINEARITY BY ANOVA

PHI= .03 D.F.=1, 7

CORRELATION COEFFICIENT= .12

STANDARDIZED FISHERS Z= .27 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2.5000E 15	5.3120E-05	1.8748E-02
5.0000E 15	1.0624E-04	1.8651E-02
7.5000E 15	1.5936E-04	1.8589E-02
1.0000E 16	2.1248E-04	1.8563E-02
1.2500E 16	2.6560E-04	1.8574E-02
1.5000E 16	3.1872E-04	1.8622E-02
1.7500E 16	3.7184E-04	1.8706E-02
2.0000E 16	4.2496E-04	1.8827E-02
2.2500E 16	4.7808E-04	1.8985E-02
2.5000E 16	5.3120E-04	1.9178E-02
2.7500E 16	5.8433E-04	1.9405E-02
3.0000E 16	6.3745E-04	1.9666E-02
3.2500E 16	6.9057E-04	1.9958E-02
3.5000E 16	7.4369E-04	2.0281E-02
3.7500E 16	7.9681E-04	2.0632E-02
4.0000E 16	8.4993E-04	2.1011E-02
4.2500E 16	9.0305E-04	2.1414E-02
4.5000E 16	9.5617E-04	2.1842E-02
4.7500E 16	1.0093E-03	2.2292E-02
5.0000E 16	1.0624E-03	2.2763E-02

REGRESSION ANALYSIS FREQ, TO .1500

REGRESSION COEFFICIENTS A-ZERO= 1.0027E-03 A= 1.2901E-19

97.5 PERCENT CONFIDENCE INTERVAL FOR A

5.0774E-20 2.0724E-19

TEST OF LINEARITY BY ANOVA

PHI= 8.97 D.F.=1, 9

CORRELATION COEFFICIENT= .76

STANDARDIZED FISHERS Z= 2.61 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2.5000E 15	3.2252E-04	6.3853E-03
5.0000E 15	6.4504E-04	6.6716E-03
7.5000E 15	9.6756E-04	6.9695E-03
1.0000E 16	1.2901E-03	7.2792E-03
1.2500E 16	1.6126E-03	7.6008E-03
1.5000E 16	1.9351E-03	7.9343E-03
1.7500E 16	2.2576E-03	8.2795E-03
2.0000E 16	2.5802E-03	8.6365E-03
2.2500E 16	2.9027E-03	9.0048E-03
2.5000E 16	3.2252E-03	9.3843E-03
2.7500E 16	3.5477E-03	9.7744E-03
3.0000E 16	3.8702E-03	1.0175E-02
3.2500E 16	4.1928E-03	1.0585E-02
3.5000E 16	4.5153E-03	1.1005E-02
3.7500E 16	4.8378E-03	1.1434E-02
4.0000E 16	5.1603E-03	1.1871E-02
4.2500E 16	5.4829E-03	1.2316E-02
4.5000E 16	5.8054E-03	1.2769E-02
4.7500E 16	6.1279E-03	1.3228E-02
5.0000E 16	6.4504E-03	1.3694E-02

REGRESSION ANALYSIS FREQ. TO .3000

REGRESSION COEFFICIENTS A-ZERO=-5.4022E-05 A= 8.8158E-19

97.5 PERCENT CONFIDENCE INTERVAL FOR A

7.1639E-19 1.0468E-18

TEST OF LINEARITY BY ANOVA

PHI= 95.55 D.F.=1, 10

CORRELATION COEFFICIENT= .95

STANDARDIZED FISHERS Z= 5.22 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2.5000E 15	2.2040E-03	1.2751E-02
5.0000E 15	4.4079E-03	1.4891E-02
7.5000E 15	6.6119E-03	1.7055E-02
1.0000E 16	8.8158E-03	1.9243E-02
1.2500E 16	1.1020E-02	2.1455E-02
1.5000E 16	1.3224E-02	2.3691E-02
1.7500E 16	1.5428E-02	2.5950E-02
2.0000E 16	1.7632E-02	2.8234E-02
2.2500E 16	1.9836E-02	3.0539E-02
2.5000E 16	2.2040E-02	3.2868E-02
2.7500E 16	2.4243E-02	3.5217E-02
3.0000E 16	2.6447E-02	3.7588E-02
3.2500E 16	2.8651E-02	3.9978E-02
3.5000E 16	3.0855E-02	4.2387E-02
3.7500E 16	3.3059E-02	4.4814E-02
4.0000E 16	3.5263E-02	4.7257E-02
4.2500E 16	3.7467E-02	4.9717E-02
4.5000E 16	3.9671E-02	5.2191E-02
4.7500E 16	4.1875E-02	5.4679E-02
5.0000E 16	4.4079E-02	5.7181E-02

REGRESSION ANALYSIS FREQ, TO .6000

REGRESSION COEFFICIENTS A=ZERO=-2.0609E-04 A= 4.8689E-18

97.5 PERCENT CONFIDENCE INTERVAL FOR A

3.6557E-18 6.0822E-18

TEST OF LINEARITY BY ANOVA

PHI= 55.00 D.F.=1, 14

CORRELATION COEFFICIENT= .89

STANDARDIZED FISHERS Z= 4.97 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2.5000E 15	1.2172E-02	8.8678E-02
5.0000E 15	2.4345E-02	1.0058E-01
7.5000E 15	3.6517E-02	1.1264E-01
1.0000E 16	4.8689E-02	1.2486E-01
1.2500E 16	6.0862E-02	1.3724E-01
1.5000E 16	7.3034E-02	1.4979E-01
1.7500E 16	8.5206E-02	1.6249E-01
2.0000E 16	9.7379E-02	1.7535E-01
2.2500E 16	1.0955E-01	1.8836E-01
2.5000E 16	1.2172E-01	2.0151E-01
2.7500E 16	1.3390E-01	2.1481E-01
3.0000E 16	1.4607E-01	2.2824E-01
3.2500E 16	1.5824E-01	2.4180E-01
3.5000E 16	1.7041E-01	2.5548E-01
3.7500E 16	1.8258E-01	2.6928E-01
4.0000E 16	1.9476E-01	2.8319E-01
4.2500E 16	2.0693E-01	2.9721E-01
4.5000E 16	2.1910E-01	3.1132E-01
4.7500E 16	2.3127E-01	3.2552E-01
5.0000E 16	2.4345E-01	3.3981E-01

REGRESSION ANALYSIS FREQ. TO 1.2000

REGRESSION COEFFICIENTS A-ZERO= 1.6510E-02 A= 1.9169E-18

97.5 PERCENT CONFIDENCE INTERVAL FOR A

1.5160E-20 3.8187E-18

TEST OF LINEARITY BY ANOVA

PHI= 3.47 D.F.=1, 14

CORRELATION COEFFICIENT= .46

STANDARDIZED FISHERS Z= 1.74 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2.5000E 15	4.7923E-03	1.4155E-01
5.0000E 15	9.5846E-03	1.4591E-01
7.5000E 15	1.4377E-02	1.5053E-01
1.0000E 16	1.9169E-02	1.5540E-01
1.2500E 16	2.3961E-02	1.6052E-01
1.5000E 16	2.8754E-02	1.6590E-01
1.7500E 16	3.3546E-02	1.7152E-01
2.0000E 16	3.8338E-02	1.7739E-01
2.2500E 16	4.3131E-02	1.8349E-01
2.5000E 16	4.7923E-02	1.8983E-01
2.7500E 16	5.2715E-02	1.9638E-01
3.0000E 16	5.7508E-02	2.0315E-01
3.2500E 16	6.2300E-02	2.1012E-01
3.5000E 16	6.7092E-02	2.1728E-01
3.7500E 16	7.1884E-02	2.2462E-01
4.0000E 16	7.6677E-02	2.3214E-01
4.2500E 16	8.1469E-02	2.3982E-01
4.5000E 16	8.6261E-02	2.4765E-01
4.7500E 16	9.1054E-02	2.5562E-01
5.0000E 16	9.5846E-02	2.6373E-01

REGRESSION ANALYSIS FREQ. TO 2.4000

REGRESSION COEFFICIENTS A-ZERO= 2,9660E-03 A= 7.9681E-20

97.5 PERCENT CONFIDENCE INTERVAL FOR A

-1.2305E-19 2.8241E-19

TEST OF LINEARITY BY ANOVA

PHI= .62 D.F.=1, 12

CORRELATION COEFFICIENT= .29

STANDARDIZED FISHERS Z= .94 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

2.5000E 15	1.9920E-04	1.3843E-02
5.0000E 15	3.9840E-04	1.4022E-02
7.5000E 15	5.9761E-04	1.4229E-02
1.0000E 16	7.9681E-04	1.4465E-02
1.2500E 16	9.9601E-04	1.4729E-02
1.5000E 16	1.1952E-03	1.5020E-02
1.7500E 16	1.3944E-03	1.5339E-02
2.0000E 16	1.5936E-03	1.5684E-02
2.2500E 16	1.7928E-03	1.6053E-02
2.5000E 16	1.9920E-03	1.6447E-02
2.7500E 16	2.1912E-03	1.6863E-02
3.0000E 16	2.3904E-03	1.7301E-02
3.2500E 16	2.5896E-03	1.7760E-02
3.5000E 16	2.7888E-03	1.8237E-02
3.7500E 16	2.9880E-03	1.8732E-02
4.0000E 16	3.1872E-03	1.9243E-02
4.2500E 16	3.3864E-03	1.9770E-02
4.5000E 16	3.5856E-03	2.0312E-02
4.7500E 16	3.7848E-03	2.0866E-02
5.0000E 16	3.9840E-03	2.1433E-02

APPENDIX E

RESULTS OF REGRESSION ANALYSIS OF MACH 1 VIBRATION DATA FOR THE LONGITUDINAL DIRECTION

REGRESSION ANALYSIS FREQ, TO 75.0000

REGRESSION COEFFICIENTS A-ZERO= 3,4449E 02 A=-3,7667E-04

97.5 PERCENT CONFIDENCE INTERVAL FOR A

-2,6650E-03 1,9117E-03

TEST OF LINEARITY BY ANOVA

PHI= .11 D.F.=1, 18

CORRELATION COEFFICIENT= -.08

STANDARDIZED FISHERS Z= -.33 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05	3.766*E 01	2.8822E 03
2.0000E 05	7.533*E 01	2.8623E 03
3.0000E 05	1.130*E 02	2.8638E 03
4.0000E 05	1.506*E 02	2.8859E 03
5.0000E 05	1.883*E 02	2.9272E 03
6.0000E 05	2.260*E 02	2.9861E 03
7.0000E 05	2.636*E 02	3.0610E 03
8.0000E 05	3.013*E 02	3.1501E 03
9.0000E 05	3.390*E 02	3.2516E 03
1.0000E 06	3.766*E 02	3.3642E 03
1.1000E 06	4.143*E 02	3.4864E 03
1.2000E 06	4.520*E 02	3.6169E 03
1.3000E 06	4.896*E 02	3.7547E 03

REGRESSION ANALYSIS FREQ, TO 150.0000

REGRESSION COEFFICIENTS A-ZERO= 1,7672E-03 A= 3.0087E-09

97.5 PERCENT CONFIDENCE INTERVAL FOR A

-1.8487E-09 7,8661E-09

TEST OF LINEARITY BY ANOVA

PHI= 1.40 D.F.=1, 20

CORRELATION COEFFICIENT= ,29

STANDARDIZED FISHERS Z= 1,25 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1,0000E 05	3,0087E-04	1,0295E-02
2,0000E 05	6,0174E-04	1,0598E-02
3,0000E 05	9,0262E-04	1,0935E-02
4,0000E 05	1,2035E-03	1,1305E-02
5,0000E 05	1,5044E-03	1,1708E-02
6,0000E 05	1,8052E-03	1,2143E-02
7,0000E 05	2,1061E-03	1,2608E-02
8,0000E 05	2,4070E-03	1,3102E-02
9,0000E 05	2,7078E-03	1,3622E-02
1,0000E 06	3,0087E-03	1,4167E-02
1,1000E 06	3,3096E-03	1,4735E-02
1,2000E 06	3,6105E-03	1,5325E-02
1,3000E 06	3,9113E-03	1,5933E-02

REGRESSION ANALYSIS FREQ. TO 300.0000

REGRESSION COEFFICIENTS A-ZERO= 2,9518E-03 A= 1.0065E-08

97.5 PERCENT CONFIDENCE INTERVAL FOR A

2,6084E-09 1,7522E-08

TEST OF LINEARITY BY ANOVA

PHI= 6.62 D.F.=1, 21

CORRELATION COEFFICIENT= ,55

STANDARDIZED FISHERS Z= 2.67 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05	1.0065E-03	1.6583E-02
2.0000E 05	2.0130E-03	1.7594E-02
3.0000E 05	3.0195E-03	1.8658E-02
4.0000E 05	4.0260E-03	1.9773E-02
5.0000E 05	5.0325E-03	2.0938E-02
6.0000E 05	6.0390E-03	2.2152E-02
7.0000E 05	7.0455E-03	2.3412E-02
8.0000E 05	8.0520E-03	2.4715E-02
9.0000E 05	9.0585E-03	2.6060E-02
1.0000E 06	1.0065E-02	2.7442E-02
1.1000E 06	1.1071E-02	2.8860E-02
1.2000E 06	1.2078E-02	3.0310E-02
1.3000E 06	1.3084E-02	3.1789E-02

REGRESSION ANALYSIS FREQ. TO 600.0000

REGRESSION COEFFICIENTS A-ZERO=-8.8683E-03 A= 4.7856E-07

97.5 PERCENT CONFIDENCE INTERVAL FOR A

2.4517E-07 7.1196E-07

TEST OF LINEARITY BY ANOVA

PHI= 15.28 D.F.=1, 21

CORRELATION COEFFICIENT= .65

STANDARDIZED FISHERS Z= 3.38 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05	4.7856E-02	4.3415E-01
2.0000E 05	9.5713E-02	4.8215E-01
3.0000E 05	1.4357E-01	5.3179E-01
4.0000E 05	1.9143E-01	5.8305E-01
5.0000E 05	2.3928E-01	6.3587E-01
6.0000E 05	2.8714E-01	6.9022E-01
7.0000E 05	3.3499E-01	7.4600E-01
8.0000E 05	3.8285E-01	8.0316E-01
9.0000E 05	4.3071E-01	8.6160E-01
1.0000E 06	4.7856E-01	9.2122E-01
1.1000E 06	5.2642E-01	9.8194E-01
1.2000E 06	5.7428E-01	1.0437E 00
1.3000E 06	6.2213E-01	1.1063E 00

REGRESSION ANALYSIS FREQ. TO 1200.0000

REGRESSION COEFFICIENTS A-ZERO= 1.3034E-02 A= 4.2422E-08

97.5 PERCENT CONFIDENCE INTERVAL FOR A

1.2819E-08 7.2025E-08

TEST OF LINEARITY BY ANOVA

PHI= 7.46 D.F.=1, 21

CORRELATION COEFFICIENT= .59

STANDARDIZED FISHERS Z= 2.93 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05	4.2422E-03	6.7397E-02
2.0000E 05	8.4844E-03	7.1657E-02
3.0000E 05	1.2727E-02	7.6126E-02
4.0000E 05	1.6969E-02	8.0799E-02
5.0000E 05	2.1211E-02	8.5671E-02
6.0000E 05	2.5453E-02	9.0736E-02
7.0000E 05	2.9695E-02	9.5985E-02
8.0000E 05	3.3938E-02	1.0141E-01
9.0000E 05	3.8180E-02	1.0699E-01
1.0000E 06	4.2422E-02	1.1273E-01
1.1000E 06	4.6664E-02	1.1860E-01
1.2000E 06	5.0907E-02	1.2460E-01
1.3000E 06	5.5149E-02	1.3072E-01

REGRESSION ANALYSIS FREQ, TO 2400.0000

REGRESSION COEFFICIENTS A-ZERO= 8,4218E-03 A= 4,0701E-09

97.5 PERCENT CONFIDENCE INTERVAL FOR A

-2,0834E-08 2,8974E-08

TEST OF LINEARITY BY ANOVA

PHI= .10 D.F,=1, 20

CORRELATION COEFFICIENT= ,09

STANDARDIZED FISHERS Z= ,39 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1,0000E 05	4,0701E-04	3,7786E-02
2,0000E 05	8.1401E-04	3,8340E-02
3,0000E 05	1,2210E-03	3,9136E-02
4,0000E 05	1,6280E-03	4,0167E-02
5,0000E 05	2,0350E-03	4,1416E-02
6,0000E 05	2,4420E-03	4,2867E-02
7,0000E 05	2,8490E-03	4,4502E-02
8,0000E 05	3,2560E-03	4,6300E-02
9,0000E 05	3.6630E-03	4,8242E-02
1,0000E 06	4,0701E-03	5,0312E-02
1,1000E 06	4,4771E-03	5,2493E-02
1,2000E 06	4.8841E-03	5,4770E-02
1,3000E 06	5,2911E-03	5,7132E-02

APPENDIX F

RESULTS OF REGRESSION ANALYSIS OF MACH 1 VIBRATION DATA FOR THE RADIAL DIRECTION

REGRESSION ANALYSIS FREQ. TO 75.0000

REGRESSION COEFFICIENTS A-ZERO= 1.6396E-02 A= 1.8616E-09

97.5 PERCENT CONFIDENCE INTERVAL FOR A

-3.6208E-08 3.9931E-08

TEST OF LINEARITY BY ANOVA

PHI= .01 D.F.=1, 9

CORRELATION COEFFICIENT= .03

STANDARDIZED FISHERS Z= .09 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05	1.8616E-04	9.9094E-02
2.0000E 05	3.7233E-04	9.8610E-02
3.0000E 05	5.5849E-04	9.8403E-02
4.0000E 05	7.4465E-04	9.8476E-02
5.0000E 05	9.3081E-04	9.8830E-02
6.0000E 05	1.1170E-03	9.9464E-02
7.0000E 05	1.3031E-03	1.0037E-01
8.0000E 05	1.4893E-03	1.0155E-01
9.0000E 05	1.6755E-03	1.0298E-01
1.0000E 06	1.8616E-03	1.0467E-01
1.1000E 06	2.0478E-03	1.0658E-01
1.2000E 06	2.2340E-03	1.0872E-01
1.3000E 06	2.4201E-03	1.1107E-01

REGRESSION ANALYSIS FREQ, TO 150.0000

REGRESSION COEFFICIENTS A-ZERO= 5.7248E-03 A= 1.2428E-08

97.5 PERCENT CONFIDENCE INTERVAL FOR A

3.6539E-09 2.1201E-08

TEST OF LINEARITY BY ANOVA

PHI= 6.50 D.F.=1, 9

CORRELATION COEFFICIENT= .80

STANDARDIZED FISHERS Z= 2.88 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05	1.2428E-03	2.5984E-02
2.0000E 05	2.4855E-03	2.7072E-02
3.0000E 05	3.7283E-03	2.8224E-02
4.0000E 05	4.9710E-03	2.9441E-02
5.0000E 05	6.2138E-03	3.0722E-02
6.0000E 05	7.4566E-03	3.2068E-02
7.0000E 05	8.6993E-03	3.3477E-02
8.0000E 05	9.9421E-03	3.4948E-02
9.0000E 05	1.1185E-02	3.6479E-02
1.0000E 06	1.2428E-02	3.8067E-02
1.1000E 06	1.3670E-02	3.9708E-02
1.2000E 06	1.4913E-02	4.1401E-02
1.3000E 06	1.6156E-02	4.3141E-02

REGRESSION ANALYSIS FREQ, TO 300.0000

REGRESSION COEFFICIENTS A-ZERO= 5.8274E-03 A= 8.8583E-08

97.5 PERCENT CONFIDENCE INTERVAL FOR A

2,2661E-08 1,5451E-07

TEST OF LINEARITY BY ANOVA

PHI= 5.88 D.F.=1, 10

CORRELATION COEFFICIENT= .61

STANDARDIZED FISHERS Z= 2.01 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05	8.8583E-03	1.5660E-01
2.0000E 05	1.7717E-02	1.6447E-01
3.0000E 05	2.6575E-02	1.7281E-01
4.0000E 05	3.5433E-02	1.8162E-01
5.0000E 05	4.4292E-02	1.9090E-01
6.0000E 05	5.3150E-02	2.0065E-01
7.0000E 05	6.2008E-02	2.1085E-01
8.0000E 05	7.0867E-02	2.2151E-01
9.0000E 05	7.9725E-02	2.3259E-01
1.0000E 06	8.8583E-02	2.4408E-01
1.1000E 06	9.7442E-02	2.5596E-01
1.2000E 06	1.0630E-01	2.6821E-01
1.3000E 06	1.1516E-01	2.8080E-01

REGRESSION ANALYSIS FREQ. TO 600.0000

REGRESSION COEFFICIENTS A-ZERO= 3.2245E-02 A= 2.5477E-07

97.5 PERCENT CONFIDENCE INTERVAL FOR A

-4.6409E-09 5.1418E-07

TEST OF LINEARITY BY ANOVA

PHI= 3.19 D.F.=1, 11

CORRELATION COEFFICIENT= .46

STANDARDIZED FISHERS Z= 1.56 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05	2.5477E-02	6.1275E-01
2.0000E 05	5.0953E-02	6.3500E-01
3.0000E 05	7.6430E-02	6.5903E-01
4.0000E 05	1.0191E-01	6.8484E-01
5.0000E 05	1.2738E-01	7.1244E-01
6.0000E 05	1.5286E-01	7.4180E-01
7.0000E 05	1.7834E-01	7.7289E-01
8.0000E 05	2.0381E-01	8.0566E-01
9.0000E 05	2.2929E-01	8.4004E-01
1.0000E 06	2.5477E-01	8.7596E-01
1.1000E 06	2.8024E-01	9.1334E-01
1.2000E 06	3.0572E-01	9.5209E-01
1.3000E 06	3.3120E-01	9.9214E-01

REGRESSION ANALYSIS FREQ. TO 1200.0000

REGRESSION COEFFICIENTS A-ZERO= 4.8870E-02 A= 4.1401E-08

97.5 PERCENT CONFIDENCE INTERVAL FOR A

-3.8023E-08 1.2083E-07

TEST OF LINEARITY BY ANOVA

PHI= .90 D.F.=1, 11

CORRELATION COEFFICIENT= .37

STANDARDIZED FISHERS Z= 1.16 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,F(Y) AND YU

1.0000E 05	4.1401E-03	2.2295E-01
2.0000E 05	8.2802E-03	2.2610E-01
3.0000E 05	1.2420E-02	2.2979E-01
4.0000E 05	1.6560E-02	2.3404E-01
5.0000E 05	2.0701E-02	2.3883E-01
6.0000E 05	2.4841E-02	2.4416E-01
7.0000E 05	2.8981E-02	2.5001E-01
8.0000E 05	3.3121E-02	2.5639E-01
9.0000E 05	3.7261E-02	2.6325E-01
1.0000E 06	4.1401E-02	2.7059E-01
1.1000E 06	4.5541E-02	2.7837E-01
1.2000E 06	4.9681E-02	2.8658E-01
1.3000E 06	5.3821E-02	2.9518E-01

REGRESSION ANALYSIS FREQ. TO 2400.0000

REGRESSION COEFFICIENTS A-ZERO= 2.6175E-02 A=-7.2442E-09

97.5 PERCENT CONFIDENCE INTERVAL FOR A

-8.3445E-08 6.8957E-08

TEST OF LINEARITY BY ANOVA

PHI= .04 D.F.=1, 9

CORRELATION COEFFICIENT= -.09

STANDARDIZED FISHERS Z= -.25 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05	7.244*E-04	1.1509E-01
2.0000E 05	1.448*E-03	1.1431E-01
3.0000E 05	2.173*E-03	1.1433E-01
4.0000E 05	2.897*E-03	1.1514E-01
5.0000E 05	3.622*E-03	1.1669E-01
6.0000E 05	4.346*E-03	1.1894E-01
7.0000E 05	5.071*E-03	1.2181E-01
8.0000E 05	5.795*E-03	1.2526E-01
9.0000E 05	6.519*E-03	1.2920E-01
1.0000E 06	7.244*E-03	1.3359E-01
1.1000E 06	7.968*E-03	1.3835E-01
1.2000E 06	8.693*E-03	1.4346E-01
1.3000E 06	9.417*E-03	1.4885E-01

APPENDIX G

RESULTS OF REGRESSION ANALYSIS OF MAXIMUM DYNAMIC PRESSURE VIBRATION DATA FOR THE LONGITUDINAL DIRECTION

REGRESSION ANALYSIS FREQ, TO 75.0000

REGRESSION COEFFICIENTS A-ZERO=-3.0050E-04 A= 5.3072E-08

97.5 PERCENT CONFIDENCE INTERVAL FOR A

3.8344E-08 6.7799E-08

TEST OF LINEARITY BY ANOVA

PHI= 50.82 D.F.=1, 15

CORRELATION COEFFICIENT= .88

STANDARDIZED FISHERS Z= 4.94 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05	5.3072E-03	3.9567E-02
2.0000E 05	1.0614E-02	4.4829E-02
3.0000E 05	1.5921E-02	5.0164E-02
4.0000E 05	2.1229E-02	5.5572E-02
5.0000E 05	2.6536E-02	6.1052E-02
6.0000E 05	3.1843E-02	6.6604E-02
7.0000E 05	3.7150E-02	7.2224E-02
8.0000E 05	4.2457E-02	7.7913E-02
9.0000E 05	4.7764E-02	8.3666E-02
1.0000E 06	5.3072E-02	8.9484E-02
1.1000E 06	5.8379E-02	9.5361E-02
1.2000E 06	6.3686E-02	1.0130E-01
1.3000E 06	6.8993E-02	1.0729E-01
1.4000E 06	7.4300E-02	1.1333E-01
1.5000E 06	7.9607E-02	1.1942E-01
1.6000E 06	8.4914E-02	1.2556E-01
1.7000E 06	9.0222E-02	1.3174E-01

REGRESSION ANALYSIS FREQ. TO 150.0000

REGRESSION COEFFICIENTS A=ZERO=-2.9373E-04 A= 3.6299E-08

97.5 PERCENT CONFIDENCE INTERVAL FOR A

2.8722E-08 4.3876E-08

TEST OF LINEARITY BY ANOVA

PHI= 87.03 D.F.=1, 17

CORRELATION COEFFICIENT= .91

STANDARDIZED FISHERS Z= 6.03 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05	3.6299E-03	2.1237E-02
2.0000E 05	7.2598E-03	2.4845E-02
3.0000E 05	1.0890E-02	2.8490E-02
4.0000E 05	1.4520E-02	3.2173E-02
5.0000E 05	1.8150E-02	3.5894E-02
6.0000E 05	2.1779E-02	3.9651E-02
7.0000E 05	2.5409E-02	4.3444E-02
8.0000E 05	2.9039E-02	4.7272E-02
9.0000E 05	3.2669E-02	5.1134E-02
1.0000E 06	3.6299E-02	5.5028E-02
1.1000E 06	3.9929E-02	5.8954E-02
1.2000E 06	4.3559E-02	6.2910E-02
1.3000E 06	4.7189E-02	6.6894E-02
1.4000E 06	5.0819E-02	7.0905E-02
1.5000E 06	5.4449E-02	7.4942E-02
1.6000E 06	5.8079E-02	7.9002E-02
1.7000E 06	6.1709E-02	8.3085E-02

REGRESSION ANALYSIS FREQ, TO 300.0000

REGRESSION COEFFICIENTS A-ZERO=-4,4382E-04 A= 5,4426E-08

97.5 PERCENT CONFIDENCE INTERVAL FOR A

4,0176E-08 6,8676E-08

TEST OF LINEARITY BY ANOVA

PHI= 55.35 D.F.=1, 18

CORRELATION COEFFICIENT= ,87

STANDARDIZED FISHERS Z= 5.31 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05	5.4426E-03	3.8608E-02
2.0000E 05	1.0885E-02	4.4017E-02
3.0000E 05	1.6328E-02	4.9497E-02
4.0000E 05	2.1770E-02	5.5046E-02
5.0000E 05	2.7213E-02	6.0666E-02
6.0000E 05	3.2656E-02	6.6353E-02
7.0000E 05	3.8098E-02	7.2107E-02
8.0000E 05	4.3541E-02	7.7927E-02
9.0000E 05	4.8983E-02	8.3809E-02
1.0000E 06	5.4426E-02	8.9752E-02
1.1000E 06	5.9869E-02	9.5753E-02
1.2000E 06	6.5311E-02	1.0181E-01
1.3000E 06	7.0754E-02	1.0792E-01
1.4000E 06	7.6196E-02	1.1408E-01
1.5000E 06	8.1639E-02	1.2029E-01
1.6000E 06	8.7082E-02	1.2654E-01
1.7000E 06	9.2524E-02	1.3283E-01

REGRESSION ANALYSIS FREQ. TO 600.0000

REGRESSION COEFFICIENTS A-ZERO=-2.3850E-02 A= 7.5394E-07

97.5 PERCENT CONFIDENCE INTERVAL FOR A

6.7148E-07 8.3640E-07

TEST OF LINEARITY BY ANOVA

PHI=314.76 D.F.=1, 18

CORRELATION COEFFICIENT= .97

STANDARDIZED FISHERS Z= 8.70 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05	7.5394E-02	2.4621E-01
2.0000E 05	1.5079E-01	3.2139E-01
3.0000E 05	2.2618E-01	3.9698E-01
4.0000E 05	3.0158E-01	4.7298E-01
5.0000E 05	3.7697E-01	5.4938E-01
6.0000E 05	4.5236E-01	6.2618E-01
7.0000E 05	5.2776E-01	7.0337E-01
8.0000E 05	6.0315E-01	7.8095E-01
9.0000E 05	6.7855E-01	8.5889E-01
1.0000E 06	7.5394E-01	9.3718E-01
1.1000E 06	8.2933E-01	1.0158E 00
1.2000E 06	9.0473E-01	1.0948E 00
1.3000E 06	9.8012E-01	1.1740E 00
1.4000E 06	1.0555E 00	1.2536E 00
1.5000E 06	1.1309E 00	1.3334E 00
1.6000E 06	1.2063E 00	1.4135E 00
1.7000E 06	1.2817E 00	1.4938E 00

REGRESSION ANALYSIS FREQ. TO 1200.0000

REGRESSION COEFFICIENTS A-ZERO= 1.9261E-03 A= 6.6738E-08

97.5 PERCENT CONFIDENCE INTERVAL FOR A

5.7469E-08 7.6007E-08

TEST OF LINEARITY BY ANOVA

PHI=195.20 D.F.=1, 18

CORRELATION COEFFICIENT= .96

STANDARDIZED FISHERS Z= 7.70 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05	6.6738E-03	3.0481E-02
2.0000E 05	1.3348E-02	3.7131E-02
3.0000E 05	2.0021E-02	4.3826E-02
4.0000E 05	2.6695E-02	5.0568E-02
5.0000E 05	3.3369E-02	5.7356E-02
6.0000E 05	4.0043E-02	6.4188E-02
7.0000E 05	4.6717E-02	7.1064E-02
8.0000E 05	5.3391E-02	7.7982E-02
9.0000E 05	6.0064E-02	8.4942E-02
1.0000E 06	6.6738E-02	9.1942E-02
1.1000E 06	7.3412E-02	9.8980E-02
1.2000E 06	8.0086E-02	1.0605E-01
1.3000E 06	8.6760E-02	1.1316E-01
1.4000E 06	9.3434E-02	1.2030E-01
1.5000E 06	1.0011E-01	1.2748E-01
1.6000E 06	1.0678E-01	1.3468E-01
1.7000E 06	1.1345E-01	1.4191E-01

REGRESSION ANALYSIS FREQ. TO 2400.0000

REGRESSION COEFFICIENTS A-ZERO= 4.4992E-03 A= 1.7696E-08

97.5 PERCENT CONFIDENCE INTERVAL FOR A

8.8129E-09 2.6578E-08

TEST OF LINEARITY BY ANOVA

PHI= 14.93 D.F.=1, 17

CORRELATION COEFFICIENT= .73

STANDARDIZED FISHERS Z= 3.59 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05	1.7696E-03	2.7272E-02
2.0000E 05	3.5391E-03	2.9014E-02
3.0000E 05	5.3087E-03	3.0799E-02
4.0000E 05	7.0783E-03	3.2630E-02
5.0000E 05	8.8478E-03	3.4504E-02
6.0000E 05	1.0617E-02	3.6422E-02
7.0000E 05	1.2387E-02	3.8382E-02
8.0000E 05	1.4157E-02	4.0383E-02
9.0000E 05	1.5926E-02	4.2425E-02
1.0000E 06	1.7696E-02	4.4505E-02
1.1000E 06	1.9465E-02	4.6622E-02
1.2000E 06	2.1235E-02	4.8774E-02
1.3000E 06	2.3004E-02	5.0960E-02
1.4000E 06	2.4774E-02	5.3178E-02
1.5000E 06	2.6544E-02	5.5426E-02
1.6000E 06	2.8313E-02	5.7702E-02
1.7000E 06	3.0083E-02	6.0005E-02

APPENDIX H

RESULTS OF REGRESSION ANALYSIS OF MAXIMUM DYNAMIC PRESSURE VIBRATION DATA FOR THE RADIAL DIRECTION

REGRESSION ANALYSIS FREQ, TO 75.0000

REGRESSION COEFFICIENTS A-ZERO= 9.7165E-03 A=-2.2993E-09

97.5 PERCENT CONFIDENCE INTERVAL FOR A

-2.6231E-08 2.1633E-08

TEST OF LINEARITY BY ANOVA

PHI= .05 D.F.=1, 5

CORRELATION COEFFICIENT= -.13

STANDARDIZED FISHERS Z= -.23 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05	2.299*E-04	5.2374E-02
2.0000E 05	4.598*E-04	5.1808E-02
3.0000E 05	6.897*E-04	5.1420E-02
4.0000E 05	9.197*E-04	5.1214E-02
5.0000E 05	1.149*E-03	5.1188E-02
6.0000E 05	1.379*E-03	5.1339E-02
7.0000E 05	1.609*E-03	5.1664E-02
8.0000E 05	1.839*E-03	5.2156E-02
9.0000E 05	2.069*E-03	5.2806E-02
1.0000E 06	2.299*E-03	5.3606E-02
1.1000E 06	2.529*E-03	5.4545E-02
1.2000E 06	2.759*E-03	5.5615E-02
1.3000E 06	2.989*E-03	5.6804E-02
1.4000E 06	3.219*E-03	5.8103E-02
1.5000E 06	3.448*E-03	5.9502E-02
1.6000E 06	3.678*E-03	6.0993E-02
1.7000E 06	3.908*E-03	6.2567E-02

```
**REGRESSION ANALYSIS** FREQ, TO   150.0000

REGRESSION COEFFICIENTS  A-ZERO= 2.9512E-03  A=-4.8842E-10

97.5 PERCENT CONFIDENCE INTERVAL FOR   A

          -7.3508E-09  6.3740E-09

TEST OF LINEARITY BY ANOVA


 PHI=   .02   D.F.=1,  5

CORRELATION COEFFICIENT= -.10

STANDARDIZED FISHERS Z= -.18 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05      4.884*E-05      1.5200E-02
2.0000E 05      9.768*E-05      1.5055E-02
3.0000E 05      1.465*E-04      1.4961E-02
4.0000E 05      1.953*E-04      1.4919E-02
5.0000E 05      2.442*E-04      1.4928E-02
6.0000E 05      2.930*E-04      1.4989E-02
7.0000E 05      3.418*E-04      1.5099E-02
8.0000E 05      3.907*E-04      1.5257E-02
9.0000E 05      4.395*E-04      1.5461E-02
1.0000E 06      4.884*E-04      1.5707E-02
1.1000E 06      5.372*E-04      1.5994E-02
1.2000E 06      5.861*E-04      1.6317E-02
1.3000E 06      6.349*E-04      1.6675E-02
1.4000E 06      6.837*E-04      1.7065E-02
1.5000E 06      7.326*E-04      1.7483E-02
1.6000E 06      7.814*E-04      1.7928E-02
1.7000E 06      8.303*E-04      1.8396E-02
```

REGRESSION ANALYSIS FREQ, TO 300.0000

REGRESSION COEFFICIENTS A-ZERO= 2.1955E-03 A= 9.5004E-09

97.5 PERCENT CONFIDENCE INTERVAL FOR A

4.8857E-09 1.4115E-08

TEST OF LINEARITY BY ANOVA

PHI= 19.38 D.F.=1, 6

CORRELATION COEFFICIENT= .94

STANDARDIZED FISHERS Z= 3.50 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05	9.5004E-04	1.1316E-02
2.0000E 05	1.9001E-03	1.2214E-02
3.0000E 05	2.8501E-03	1.3146E-02
4.0000E 05	3.8002E-03	1.4113E-02
5.0000E 05	4.7502E-03	1.5114E-02
6.0000E 05	5.7003E-03	1.6148E-02
7.0000E 05	6.6503E-03	1.7215E-02
8.0000E 05	7.6004E-03	1.8313E-02
9.0000E 05	8.5504E-03	1.9441E-02
1.0000E 06	9.5004E-03	2.0596E-02
1.1000E 06	1.0450E-02	2.1778E-02
1.2000E 06	1.1401E-02	2.2983E-02
1.3000E 06	1.2351E-02	2.4211E-02
1.4000E 06	1.3301E-02	2.5459E-02
1.5000E 06	1.4251E-02	2.6726E-02
1.6000E 06	1.5201E-02	2.8009E-02
1.7000E 06	1.6151E-02	2.9307E-02

REGRESSION ANALYSIS FREQ, TO 600.0000

REGRESSION COEFFICIENTS A=ZERO=-1.5175E-02 A= 2.4511E-07

97.5 PERCENT CONFIDENCE INTERVAL FOR A

1.9818E-07 2.9203E-07

TEST OF LINEARITY BY ANOVA

PHI=124.73 D.F.=1, 6

CORRELATION COEFFICIENT= .98

STANDARDIZED FISHERS Z= 4.75 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05	2.4511E-02	9.2418E-02
2.0000E 05	4.9021E-02	1.1640E-01
3.0000E 05	7.3532E-02	1.4073E-01
4.0000E 05	9.8042E-02	1.6541E-01
5.0000E 05	1.2255E-01	1.9043E-01
6.0000E 05	1.4706E-01	2.1580E-01
7.0000E 05	1.7157E-01	2.4150E-01
8.0000E 05	1.9608E-01	2.6752E-01
9.0000E 05	2.2060E-01	2.9384E-01
1.0000E 06	2.4511E-01	3.2044E-01
1.1000E 06	2.6962E-01	3.4730E-01
1.2000E 06	2.9413E-01	3.7441E-01
1.3000E 06	3.1864E-01	4.0174E-01
1.4000E 06	3.4315E-01	4.2928E-01
1.5000E 06	3.6766E-01	4.5701E-01
1.6000E 06	3.9217E-01	4.8491E-01
1.7000E 06	4.1668E-01	5.1296E-01

REGRESSION ANALYSIS FREQ, TO 1200.0000

REGRESSION COEFFICIENTS A-ZERO= 2.2470E-02 A= 4.5273E-08

97.5 PERCENT CONFIDENCE INTERVAL FOR A

-1.3090E-08 1.0364E-07

TEST OF LINEARITY BY ANOVA

PHI= 2.75 D.F.=1, 6

CORRELATION COEFFICIENT= .65

STANDARDIZED FISHERS Z= 1.56 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05	4.5273E-03	1.3033E-01
2.0000E 05	9.0546E-03	1.3420E-01
3.0000E 05	1.3582E-02	1.3850E-01
4.0000E 05	1.8109E-02	1.4324E-01
5.0000E 05	2.2636E-02	1.4841E-01
6.0000E 05	2.7164E-02	1.5400E-01
7.0000E 05	3.1691E-02	1.6001E-01
8.0000E 05	3.6218E-02	1.6641E-01
9.0000E 05	4.0746E-02	1.7318E-01
1.0000E 06	4.5273E-02	1.8031E-01
1.1000E 06	4.9800E-02	1.8776E-01
1.2000E 06	5.4328E-02	1.9552E-01
1.3000E 06	5.8855E-02	2.0356E-01
1.4000E 06	6.3382E-02	2.1185E-01
1.5000E 06	6.7909E-02	2.2038E-01
1.6000E 06	7.2437E-02	2.2912E-01
1.7000E 06	7.6964E-02	2.3806E-01

REGRESSION ANALYSIS FREQ. TO 2400.0000

REGRESSION COEFFICIENTS A-ZERO= 9.4854E-02 A=-5.1912E-08

97.5 PERCENT CONFIDENCE INTERVAL FOR A

-3.4232E-07 2.3850E-07

TEST OF LINEARITY BY ANOVA

PHI= .15 D.F.=1, 6

CORRELATION COEFFICIENT= -.18

STANDARDIZED FISHERS Z= -.36 WHEN RHO=0

97.5 PERCENT UPPER LIMIT X,E(Y) AND YU

1.0000E 05	5.191*E-03	6.0383E-01
2.0000E 05	1.038*E-02	5.9537E-01
3.0000E 05	1.557*E-02	5.8906E-01
4.0000E 05	2.076*E-02	5.8491E-01
5.0000E 05	2.595*E-02	5.8291E-01
6.0000E 05	3.114*E-02	5.8303E-01
7.0000E 05	3.633*E-02	5.8519E-01
8.0000E 05	4.153*E-02	5.8931E-01
9.0000E 05	4.672*E-02	5.9530E-01
1.0000E 06	5.191*E-02	6.0305E-01
1.1000E 06	5.710*E-02	6.1242E-01
1.2000E 06	6.229*E-02	6.2331E-01
1.3000E 06	6.748*E-02	6.3559E-01
1.4000E 06	7.267*E-02	6.4914E-01
1.5000E 06	7.786*E-02	6.6387E-01
1.6000E 06	8.305*E-02	6.7965E-01
1.7000E 06	8.825*E-02	6.9639E-01

NASA-Langley, 1968 — 31 CR-1227