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# FLIGHT VIBRATION SURVEY OF XC-123D AIRCRAFT

CHARLES E. THOMAS

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## FOREWORD

This technical report was prepared in the Environmental Criteria Branch, Environmental Division, Directorate of Engineering Test, Deputy for Test and Support, under Project 1309, Task 130906. The Project Engineer on this survey was Mr. Charles E. Thomas of the Environmental Criteria Branch. The survey covered by this technical report is one of a series which have been conducted on operational aircraft by the Environmental Criteria Branch. The flights discussed in this report occurred during March 1957. The information obtained from this effort was submitted as raw data to the requesting agency upon completion of the tests, and is now being presented in a formal report for the purpose of wider distribution.

ABSTRACT

The information contained in this report is based on research leading to new and improved extreme temperature range (ETR) coolants for electronic equipment.

This is a continuation study of the thermal and electrical properties of the four candidate -80°F to 400°F materials as discussed in WADD TR 60-795, Part I.

Research was also continued on new experimental materials of an additional silicone fluid which possesses desirable properties for use over the aforementioned temperature range.

These fluids are intended to operate as single liquid phase coolants at nominal ambient pressures throughout the specified temperature range and to have desirable electrical and chemical properties. They may be used as primary heat transfer fluids in an electronic or aerospace system.

PUBLICATION REVIEW

This report has been reviewed and is approved.

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## SECTION I

### INTRODUCTION

One of the major problems in the design, application, testing, and use of airborne equipment is the lack of sufficient data to define the actual dynamic environment in which the vehicle equipment must operate. In most cases this lack of data has resulted in either (1) overdesigning the equipment, with its attendant excessive development costs, time, specimen size, and weight, or (2) underdesigning the equipment with a resulting lack of reliability and limited service life. To acquire the needed information, the Environmental Criteria Branch, Environmental Division, Directorate of Engineering Test, Deputy for Test and Support, has implemented a comprehensive data acquisition program aimed at obtaining vibration data on all available aircraft and missiles.

This is one of a series of reports which present vibration data measured on the structure of aircraft and missiles. The primary objective of these reports is the dissemination of important dynamics data to those concerned with developing airborne accessories. These data can be used as the basis for preparing design and testing specifications, estimating environments on air vehicles in the "drawing-board" stage, establishing optimum locations and installation practices, etc. The data in this report have been interpreted only with respect to the specific vehicle of this study, i. e., XC-123D, and no attempt has been made to assimilate this information with existing data on other similar vehicles or to present complete explanations of all the vibration phenomena involved. Reports will be published later to interpret the data and to draw comprehensive conclusions concerning vibration generation, propagation, structural response characteristics, and the like. However, the test instrumentation, procedures, and data reduction methods are covered in considerable detail in this report.

## SECTION II

### DISCUSSION

#### A. Description of the XC-123D Aircraft

The XC-123D medium assault cargo airplane is a twin-engine, high-wing, land monoplane, and is of all metal, semi-monocoque construction. The airplane is primarily a troop transport and cargo carrier with the capability of operating from hastily prepared airfields. It was designed and built by the Fairchild Aircraft and Missiles Division.

The aircraft is equipped with a retractable tricycle landing gear incorporating a steerable nose gear. Power is supplied by two Pratt and Whitney R-2800-99W, 18-cylinder, twin-row aircooled engines, each of which is equipped

with a single-stage, two-speed supercharger, and water injection system. Each engine is rated at 2300 bhp without water at 2800 rpm at sea level. With water injection the rating is increased to 2500 bhp. Each engine drives a three-blade propeller through a 2.22 to 1 reduction ratio gearbox. Table I presents the principal dimensions of the XC-123D aircraft.

TABLE I

XC-123D GENERAL SPECIFICATION DATA

Wing Span	110.0 feet
Length	76.3 feet
Height	34.5 feet
Tread	12.6 feet
Gross Wt.	54,000 lbs.

B. Test Instrumentation

The test instrumentation comprised the following: (1) forty-eight MB Manufacturing Co. Type 124 velocity pickups, (2) one Davies Laboratories, Inc. Model 501, 14-channel magnetic tape recorder, and (3) a remotely controlled pickup selector switch. The pickups were attached to the aircraft structure and engines at twenty-three points of interest. Thirty-six of the pickups were mounted in groups of three and oriented to sense vibration along each of the three major axes of the aircraft. Ten of the pickups were mounted individually on the sidewall at various stations and heights to sense vibration in the lateral direction. The remaining two pickups were mounted together, one oriented to sense vibration in the lateral direction and the other for sensing in the vertical direction. The locations are shown in Figure I, Appendix A which presents a more detailed description of the instrumentation.

C. Test Procedure

Four flights were made during this survey. Vibration records were obtained during all of the normal conditions expected in service, such as taxi, ground runup, takeoff, climb, straight and level flight (at various altitudes, airspeeds, and power settings), descent, landing, and landing roll. Magnetic tape recordings were obtained from all test pickups for each of the specified test conditions. A reel of recorded magnetic tape data consisted of approximately 90 data samples, each having, generally, a length of 75 inches and covering a period of 5 seconds. Further information concerning the test procedure is contained in Appendix A.

D. Data Processing

The reels of recorded data were edited in the laboratory. Then, each data sample, which includes twelve channels of test data, was spliced into an endless loop. Next, each loop was placed on a Davies Model 502 tape playback system. Then, a narrow bandwidth (10 cycles per second) analysis was conducted simultaneously on six of the twelve data channels of the loop and the analyzed data were

recorded on six modified Brown strip chart recorders in the form of a continuous spectrum of frequency (cps) versus transducer voltage (rms). This procedure was repeated to analyze and record the analyzed data of the other six data channels of the loop. The analyzer used is a heterodyne type, Davies Model 510.

The data points of interest were then extracted from the strip chart recording, tabulated, and punched into IBM cards. Corresponding decks of "master cards" which contain detailed descriptive information concerning pickup location, flight test conditions, and source and order of vibration were also produced. Next, the raw data together with the formula for computing double amplitude in inches and acceleration in g units and the appropriate descriptive information on the "master cards" were fed to an ERA 1103A computer. The completed data cards were then sorted into the desired order and the data were plotted by an automatic plotter having IBM card input capabilities.

#### E. Presentation of Data

The plots contained in this report are: (1) summary plots for each individual pickup for all of the flight test conditions, (2) summary plots for each cluster of pickups (2 or 3) at any given test point, and (3) summary plots for structural "zones" for all of the flight test conditions. These types of data presentation have proven satisfactory for use in establishing specification requirements and in estimating vibration environments in other similar vehicles. However, in instances where more detailed analysis of the vibration characteristics is required, graphs could be prepared to show variations of many parameters affecting the vibration conditions in the vehicle. For example, graphs can be made showing variation of vibration as a function of the following parameters: (1) indicated airspeed, (2) altitude, (3) power, (4) flight condition, (5) propeller order, etc. Plots of this type can be furnished if requested. A more detailed description of data handling procedures, data analysis, and presentation methods is contained in Appendix A.

### SECTION III

#### RESULTS

During the four flights flown for this survey, 364 data samples were obtained. As evidenced by the graphs contained in Appendix A, the data are of the discrete frequency type. The sources of these frequencies are: (1) the engines and (2) the propellers.

The frequencies produced by the engines are apparent in the engine accessory section and in the equipment rigidly mounted on the engine accessory. The engine order frequencies are 46, 93, 139, 186, 233 cps, etc. at 2800 rpm.

As expected, the frequencies produced by the blade passage unbalance are quite dominant throughout the aircraft. The frequencies are discrete in nature and

range from the first order of fundamental (58 to 62 cps) up to the eighth order (480 to 500 cps). The dominant orders are the first, second, and third.

The test data indicated that the following overall vibration envelope would be satisfactory for equipment used on the XC-123D aircraft.

5 to 10 cps	-	0.10 inches double amplitude
10 to 16 cps	-	<u>+0.5</u> g vibratory acceleration
16 to 52 cps	-	0.036 inches double amplitude
52 to 500 cps	-	<u>+5</u> g vibratory acceleration

However, this overall vibration envelope would require modifications when applied to the following items of equipment: (1) those rigidly mounted to an engine accessory, (2) those mounted to the sidewall in the area of the propeller, and (3) those attached to the outer one-third of the wing.

Modifications to overall vibration envelope for equipment rigidly mounted to an engine accessory:

16 to 72 cps	-	0.036 inches double amplitude
72 to 500 cps	-	<u>+10</u> g vibratory acceleration

Modifications to overall vibration envelope for small equipment fastened to the sidewall in the area of the propeller:

50 to 90 cps	-	0.06 inches double amplitude
90 to 500 cps	-	<u>+25</u> g vibratory acceleration

Modifications to overall vibration envelope for equipment attached to the outer one-third of the wing:

5 to 6 cps	-	0.25 inches double amplitude
6 to 16 cps	-	<u>+0.5</u> g vibratory acceleration

These modifications will be used in conjunction with the overall vibration envelope.

#### SECTION IV

#### CONCLUSIONS

The resonant frequency of any vibration isolators used should be in the 20-to 30-cps frequency band to have satisfactory operation and service life and to avoid resonant excitation.

# APPENDIX A

## Instrumentation

Forty-eight MB Type 124 velocity pickups were mounted in clusters (generally three) and individually at 23 separate test points on the aircraft engine and structure. The locations are summarized in Table II and shown in Figure 1. The Type 124 velocity pickup has the following characteristics:

Nominal sensitivity	-	96.4 mv(rms) per inch per sec. (rms)
Usable frequency range	-	5 to 2000 cps
Temperature range	-	-65 to 250°F

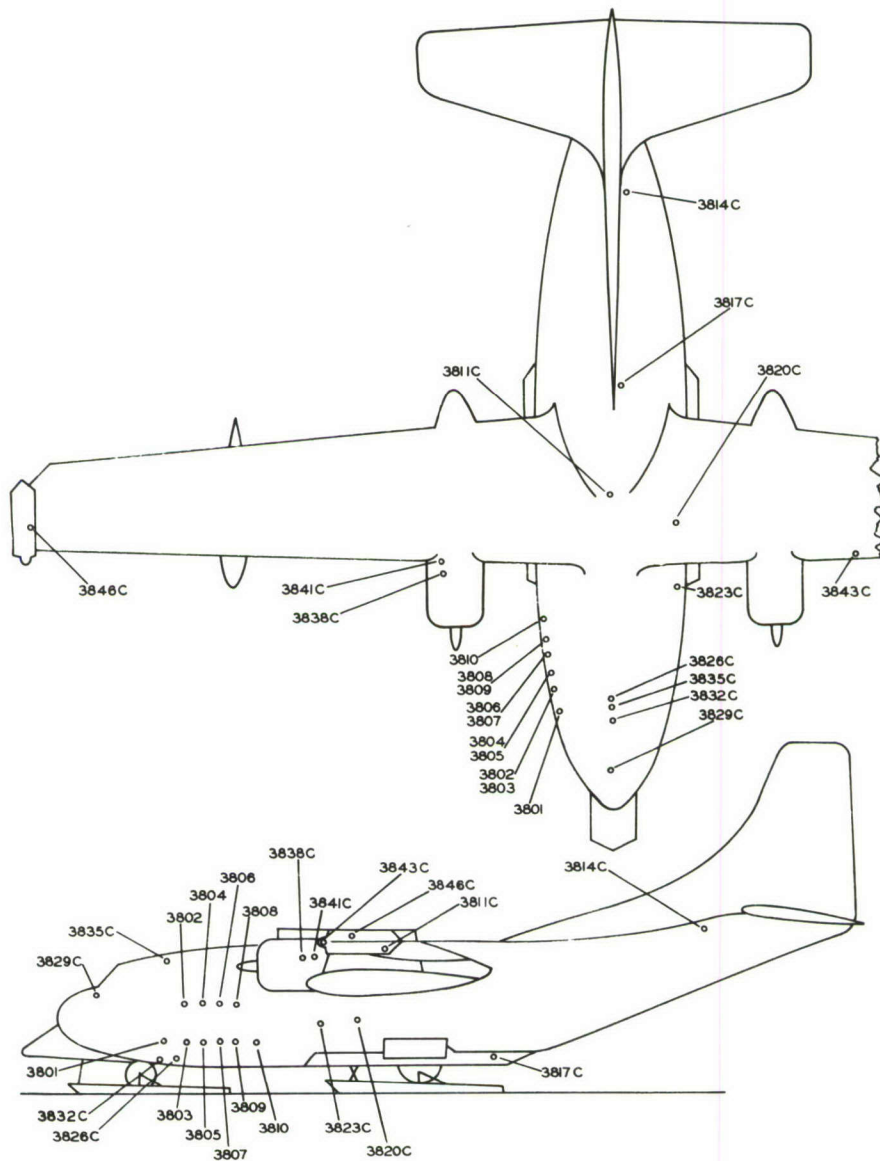


Figure 1. Schematic Presentation of Pickup Locations

TABLE II  
PICKUP LOCATIONS

PUID	Location	Direction	PUID	Location	Direction
01	Lower R.H. of Fuselage - Sta. 165	Lat	23	Secondary A/C Structure to which	Vert
02	Upper R.H. of Fuselage - Sta. 185	Lat	24	Main Inverter Attached - Sta. 340	Lat
			25		F/A
03	Lower R.H. of Fuselage - Sta. 185	Lat	26	Forward End of Cargo Deck Tie-	Vert
04	Upper R.H. of Fuselage - Sta. 205	Lat	27	down - Sta. C-3	Lat
			28		F/A
05	Lower R.H. of Fuselage - Sta. 205	Lat	29	Structure of Instrument Panel	Vert
06	Upper R.H. of Fuselage - Sta. 225	Lat	30		F/A
			31		Lat
07	Lower R.H. of Fuselage - Sta. 225	Lat	32	Left Forward Side of Nose Wheel	Vert
08	Upper R.H. of Fuselage - Sta. 245	Lat	33	Well	Lat
			34		F/A
09	Lower R.H. of Fuselage - Sta. 245	Lat	35	Top Center of Fuselage - Sta. 165	Vert
10	Lower R.H. of Fuselage - Sta. 265	Lat	36		Lat
			37		F/A
11	Top Center of Fuselage - Sta. 410	Vert	38	Accessory Section of No. 2 Engine	Vert
12		Lat	39		Lat
13		F/A	40		F/A
14	Aft Section of A/C Structure -	Vert	41	Brush Section of D. C. Generator	Vert
15	Sta. 779	Lat	42		Lat
16		F/A	43	Rt. Wing at Landing Light Loca-	Vert
17	Aft End of Cargo Deck Tiedown -	Vert	44	tion	Lat
18	Sta. C-17	Lat	45		F/A
19		F/A	46	Structure of Rt. Wing Tip	Vert
20	Left Side (APx6 Mtg Shelf) -	Vert	47		Lat
21	Sta. 380	Lat	48		F/A
22		F/A			

A typical response curve is shown in Figure 2. The three-position mounting blocks used to attach the pickups to the vehicle structure have no resonances below 500 cps.

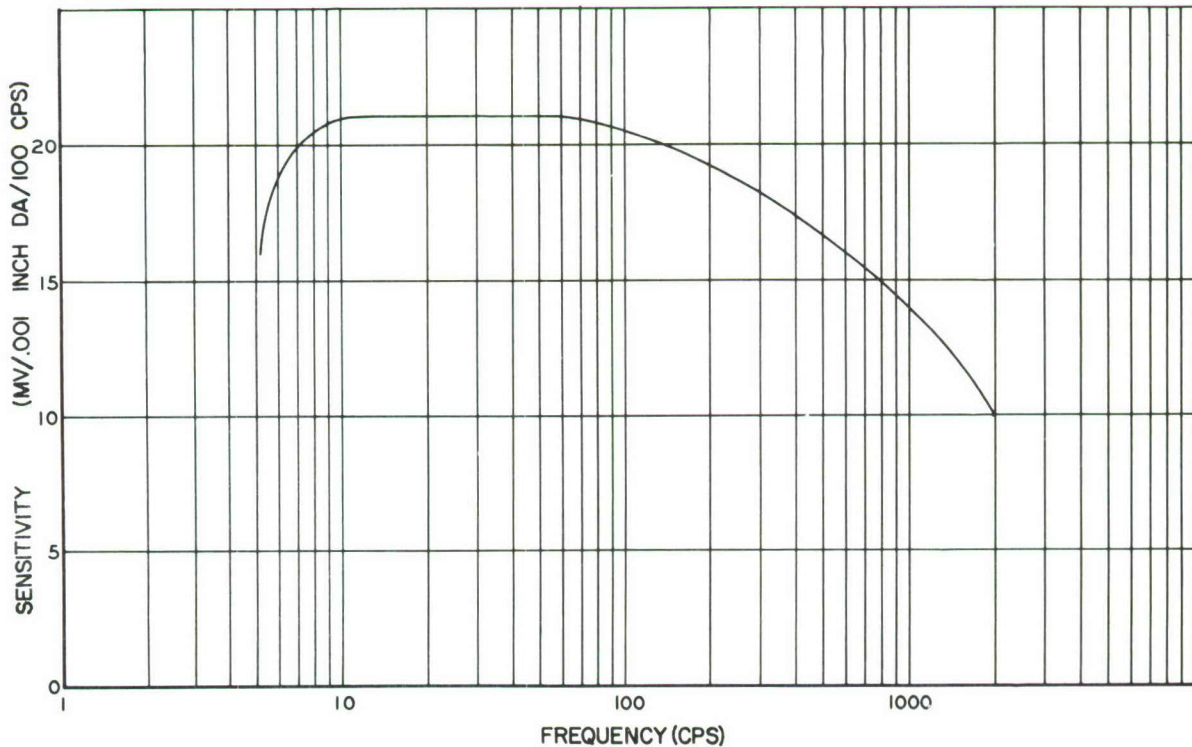


Figure 2. Frequency Response of MB Type 124 Vibration Pickup

A Davies Model 501, 14-channel magnetic tape recorder was used to record the outputs of the vibration pickups. The recorder, complete with control box and shock mount, and the pickup selector switch were installed in the nose section of the aircraft. The 26-to 28-volt DC power, required for operation of the recorder and the selector switch, was obtained from the aircraft's DC system. The recorder was preset for a recording time of five seconds. The Model 501 recorder is an FM type having the following characteristics: (1) FM carrier frequency of 10 KC, (2) intelligence frequency response of 3 to 2000 cps, (3) dynamic recording range of 45 db, (4) tape speed of 15 inches per second, (5) total recording time of approximately eight minutes, (6) weight of 55 lbs., and (7) overall dimensions, including shockmount, of 10-1/2 x 11 x 21 inches. The twelve data channels have an input impedance in excess of 100,000 ohms. The thirteenth channel has an input attenuation of approximately 45 to 1 and is designed for direct connection to the engine tachometer generator. The fourteenth channel is used to record the output from an internal, 10 KC, crystal-controlled oscillator. This channel is used during tape playback to control the playback speed by means of a servo, and it is also utilized in the electronic compensation of the tape playback and analysis system. The recorder uses 1-3/4-inch wide magnetic tape in 400-to 600-foot reels.

TABLE III  
FLIGHT CONDITIONS FOR XC-123D

<u>Flight Attitude</u>	<u>RPM</u>	<u>IAS</u>	<u>Alt x 10<sup>3</sup></u>	<u>MP</u>	<u>IHP</u>
Ground Runup	21.5	000	0	29.0	36
Takeoff	28.0	120	1	50.0	71
Climb	24.0	120	3	42.0	61
Straight and Level	16.0-28.0	110-180	3	28.0-62.0	38-96
Verticle Drive	28.0	055	7	50.0	73
Cruise (turbulent air)	24.0-14.8	103-147	3	24.0-33.0	21-96
Normal Approach W/Flaps and Gear Extended	240	110	3	31.0-34.0	50
Touchdown	14.0	100	0	21.0	30
Stall-Low Speed	28.0	055	7	40.0	73
Landing Roll	10.0	070	0	000	00
Drag Chute or Reverse Thrust	10.0	050	0	000	00

### Test Procedure

Four test flights were flown during this survey. A summary of the test conditions is shown in Table III. The test plan was based on requirements of interested laboratories at ASD and on information obtained from USAF flight test pilots.

Data were obtained during all of the normal operational configurations expected of the aircraft. Test conditions were also established which permitted the evaluation of variables, such as altitude, indicated airspeed, engine thrust at constant airspeeds and altitudes, and the effects of using the speed brakes gear and other control surfaces at various airspeeds. Prior to each flight, the test pilot was thoroughly briefed on the desired flight test conditions and was given the appropriate flight test data card. As soon as the desired flight test condition was attained, the output of each of the 48 pickups was recorded in successive groups of 12 each by means of a remotely controlled selector switch. The number of data samples acquired during the four test flights totaled 364. The reels of recorded data were sent to the laboratory for analysis.

### Data Processing

The reels of tape were edited and each five-second record (data sample) was spliced into a continuous loop and properly labeled. These records were analyzed by means of a Davies Model 510 automatic analyzer, which was used in conjunction with a Davies Model 502 magnetic tape playback system. The complete playback and analysis system is shown in Figure 3.

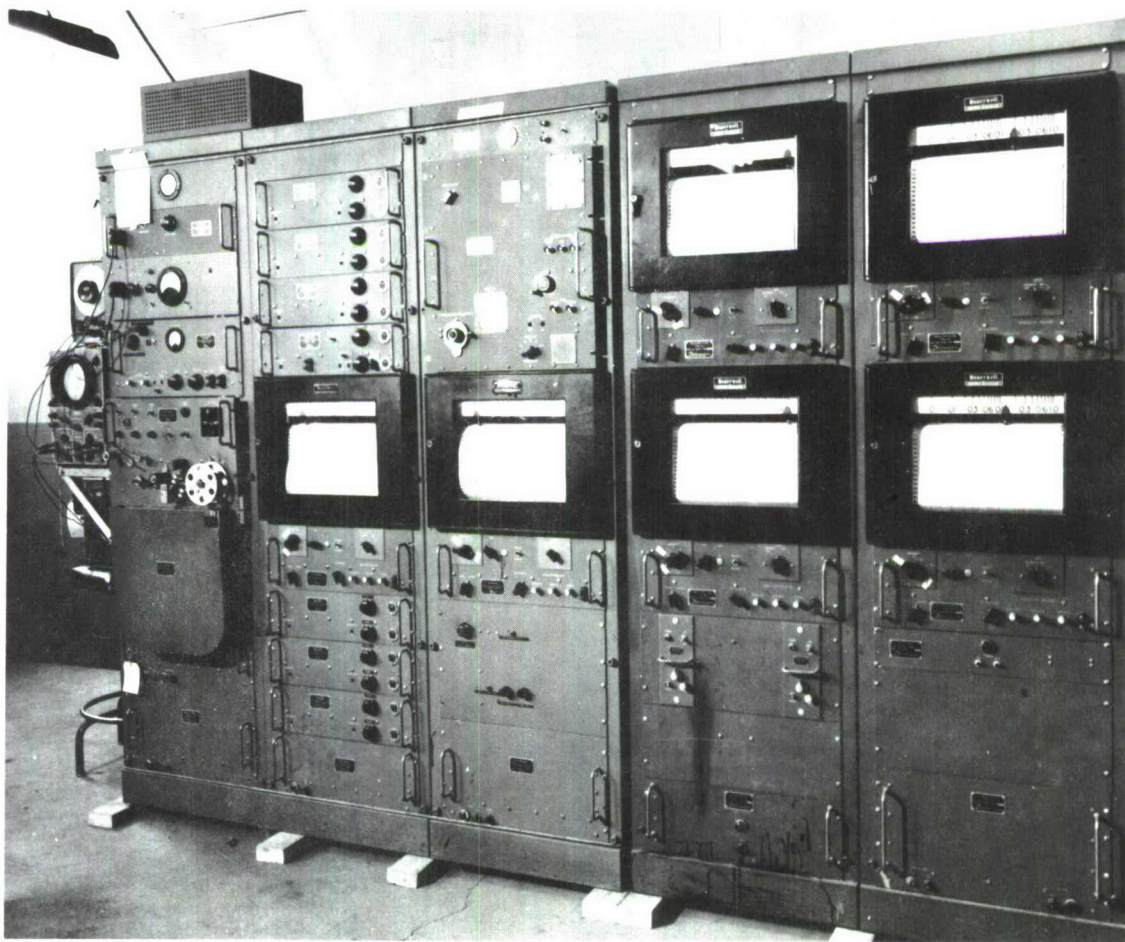


Figure 3. Photograph of Automatic Tape Playback and Analysis Equipment

The Model 502 magnetic tape playback system had been modified to provide playback at either 15 or 30 inches per second. The tape playback contains a servo-control system which permits playback of the tape within very close tolerances of its originally recorded speed. During playback the output from all fourteen tracks is fed simultaneously into the fourteen FM playback discriminators. The output signal from each of the twelve data channels is a 1 to 1 reproduction of the original analog signal.

An important feature of the playback system, i. e., electronic compensation, should be discussed briefly at this point. During the data recording process, the input of the fourteenth channel is the voltage from a very stable, 10 KC, crystal-controlled, reference frequency oscillator contained within the recorder. During playback, a portion of this 10 KC signal is fed into a standard FM discriminator channel. Assuming there were no wow and flutter during playback, the output voltage from this particular discriminator, i. e., the fourteenth channel, would be zero. Therefore, if any voltage is obtained from this channel during playback, it is an "error" voltage produced by wow and flutter. This "error" voltage with its phase shifted 180 degrees is fed simultaneously into the output stage of each of the twelve data channels. In this manner, the extraneous voltages due to wow and flutter are eliminated from the signal output of the data channels. Prior to playback of data, each of the data channels is adjusted for optimum cancellation (approximately 40 db). Hence, an overall dynamic range of 45 db (record through playback) can be maintained consistently. Table IV contains a summary of facts pertinent to the Davies Model 502 magnetic tape playback system and the Davies Model 510 automatic wave analyzer.

TABLE IV  
SPECIFICATIONS FOR DAVIES LABORATORIES  
MODEL 502 MAGNETIC TAPE PLAYBACK  
AND MODEL 510 AUTOMATIC ANALYZER

Frequency Range	3 cps to 2,000 cps
Frequency Accuracy	0.2 cps from 3 to 40 cps 0.5% from 40 to 2,000 cps
Input Voltage Range (2-position switch)	1.0 volt or 10 volts rms maximum
Amplitude Accuracy	5% of reading or 0.2% of full scale
Selectivity	Narrow Range - continuously variable from 1/2 to 8 cps Broad Range - continuously variable from 8 to 45 cps
Scanning Speeds, Motor Drive	Speed Range 25:1 - continuously adjustable Minimum Sweep Time - 15 minutes Maximum Sweep Time - 6 hrs. and 15 min.
Recorder Speed of Response	2 seconds for 90% full scale
Tape Speed	15 or 30 inches per second
Loop Length	Approx. 2-1/2 ft. to at least 75 ft.
Tape Width	1 and 1-3/4 inch

The Davies Model 510 automatic analyzer is a constant-bandwidth, heterodyne analyzer complete with motor-driven, variable frequency oscillator. The system has six separate analyzers and can analyze six data channels simultaneously. Both the oscillator scanning rate and analyzer bandwidth are adjustable over the following limits: (1) scan rate 0.3 to 3.0 cps/sec. and (2) bandwidth 1 to 40 cps. The output of the six wave analyzer channels was fed into six modified Brown strip chart recorders. A continuous spectrum plot of frequency (cps) vs voltage (rms) was produced by the strip chart recorders. The chart speed is servo-controlled and can be varied from 0.08 to 13.5 inches per minute. The voltage was plotted on a logarithmic scale and the time required for full-scale deflection, i.e., zero to one volt, was approximately two seconds. A sample analysis of a 100-cps square wave is shown in Figure 4.

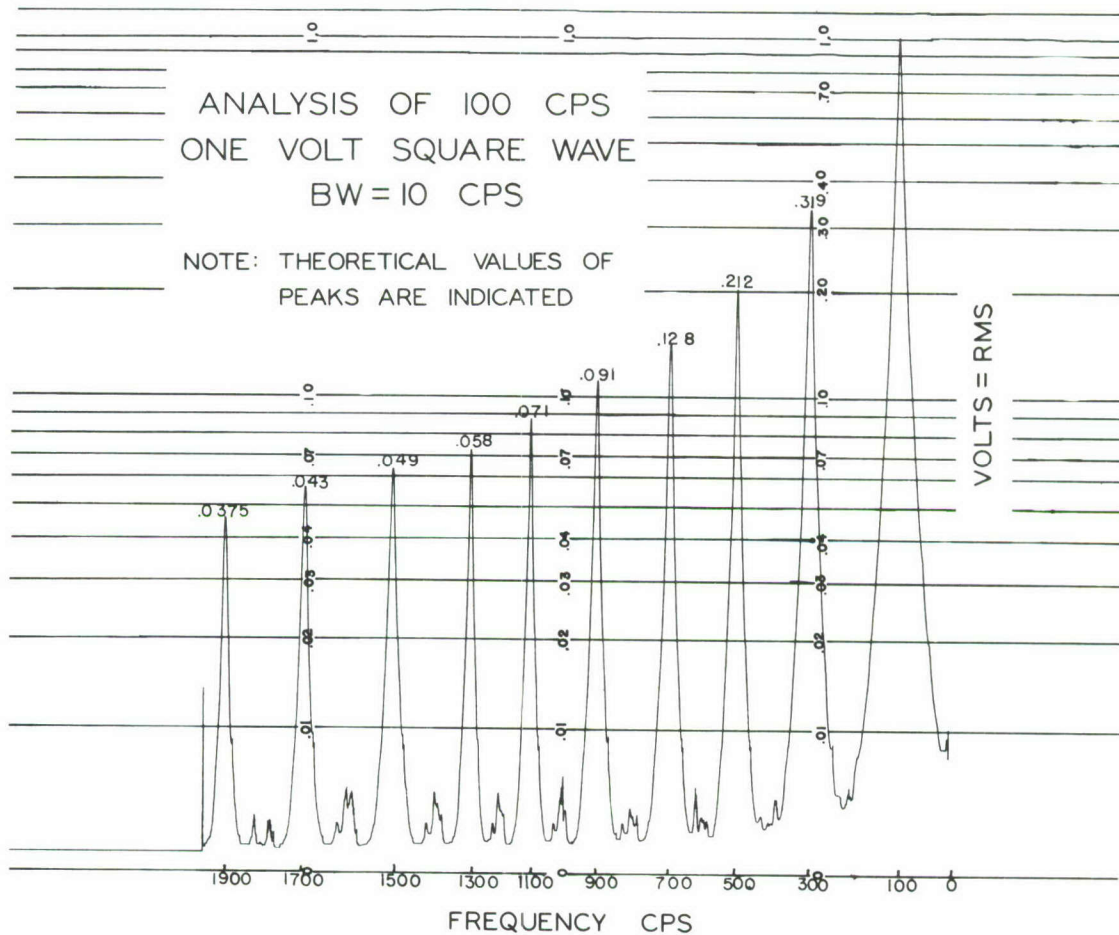


Figure 4. Graphic Presentation of Analysis of 100 cps One Volt Square Wave

In selecting the bandwidth to be used in an analysis of this type, the following must be considered: (1) the frequency resolution desired, (2) the rate of scan, (3) the length of the data sample, (4) the time available for data analysis, (5) the quantity of data to be analyzed, (6) the type of data being analyzed, and (7) the type of presentation of the completed data. Based on a consideration of these variables, a bandwidth of ten cycles per second was selected for these analyses.

Following the harmonic analysis, the Brown strip chart recordings were edited and the voltage peaks of interest were marked. Each of these peaks constitutes a data point. The corresponding values of frequency and voltage for each of these peaks were tabulated, and subsequently punched into IBM cards. Each data point goes on a separate card. Then these cards were processed through the ERA 1103A computer at the rate of ninety cards per minute. Prior to processing each set or flight of data cards through the computer, a series of three sets of "master cards" was made and fed into the computer. These sets of "master" cards are:

- (1) The "Flight Condition Masters"; these contain all of the necessary flight parameters, i. e., altitude, IAS, power, etc., associated with each of the data cards. This information is obtained from the flight test data card.
- (2) The "Pickup Location Masters"; these contain the information required to identify each data point of each channel and record number with a particular pickup.
- (3) The "Source and Order Masters"; these contain sufficient information to identify specific vibration frequencies with known orders of engine and propeller unbalance and also blade passage frequencies of the propeller or rotor blades, as the case may be.

As the data cards are processed, a new and complete "answer" card having the following information is produced: (1) the computed values of double amplitude in inches, acceleration in g's, log of frequency, log of double amplitude, and log of acceleration, (2) all of the data on the original data card, and (3) all of the appropriate data obtained from the "Master" cards. The order and limits of the information in the final analysis are shown in Table V.

After the computations were completed, all of the data cards were arranged in the desired sequence by means of an IBM sorter. Then a multi-copy IBM listing was made of all data. These listings were used in detail studies of the data and in checking the accuracy of the completed graphs.

Automatic plotters utilizing IBM card input produced the graphs of frequency in cycles per second vs. vibratory double amplitude in inches. The plotting rate ranged from 30 to 60 points per minute. The three types of graphs plotted are:

- (1) Summary plots (all test conditions) for each individual vibration pickup,
- (2) Summary plots for each cluster of pickups (2 or 3),
- (3) Summary plots for each structural zone.

Each of the three types of graphs has all the appropriate data obtained from the four flights. No plots were made to indicate the effects of variables, such as power, altitude, IAS, etc.; however, such plots can be obtained upon request.

TABLE V

## SUMMARY OF INFORMATION ON IBM CARDS

<u>Card Column</u>	<u>Range</u>	<u>Category</u>
1 - 2	0 - 99	Pickup Location
3 - 4	1 - 31	Day
5 - 6	1 - 12	Month
7 - 8	1 - 24	Time
9 - 10	1 - 12	Channel Number
11 - 12	0 - 99	Record Number
13 - 16	0 - 2000	Frequency in cps
17 - 20	0 - .9999	Voltage
21 - 23	0 - 285	Engine Speed
24 - 26	0 - 999	IAS in Knots
27 - 28	0 - 60	Altitude in 1000 feet
29 - 30	1 - 12	Source
31 - 32	0 - 24	Order
33 - 34	1 - 63	Flight Condition
35 - 36	N. A.	Blank
37 - 41	0 - .9999	Double Amplitude in Inches
42 - 45	0 - 99.99	Acceleration in g
46 - 50	N. A.	Log of Frequency
51 - 55	N. A.	Log of Double Amplitude
56 - 60	N. A.	Log of Acceleration
61 - 62	0 - 45	Aircraft I.D. Number
63 - 65	0 - 100	Man. Pres. -- in. Hg
66 - 68	0 - 150	Power Lever Angle in Degrees Percent of Rated H. P. Percent of Rated Thrust
69 - 70	1 - 27	Structural Zone
71 - 80	N. A.	Blank

The Type 1 graphs permit a detailed study of the vibration characteristics along a single axis at a particular location in the test vehicle.

The Type 2 graphs present the overall vibration environment, measured under all test conditions, at each of the test points where 2 or 3 pickups were mounted in a cluster.

The Type 3 graphs show the overall vibration environment for a structural zone, e.g., front quarter of the fuselage. The structure of the test vehicle has been arbitrarily divided into nine major areas. Each of these major areas has been further subdivided into the following three categories: (1) vehicle structure, (2) rigidly mounted equipment, and (3) shock mounted equipment. A complete listing of these structural zones is contained in Table VI. A diagram of seven of the nine major areas is shown in Figure 5.

TABLE VI  
CODE FOR STRUCTURAL ZONE OF A/C

<u>Code Nr.</u>	<u>Structural Zone</u>
01	Forward Quarter of Fuselage
02	Center Half of Fuselage
03	Aft Quarter of Fuselage
04	Vert. & Horiz. Stab. Incl. Rudder & Elevators
05	Outer one-third of Wing
06	Inner two-thirds of Wing
07	Engine
08	Rigidly Mounted Equipment in Forward Quarter of Fuselage
09	Rigidly Mounted Equipment in Center Half of Fuselage
10	Rigidly Mounted Equipment in Aft Quarter of Fuselage
11	Rigidly Mounted Equipment in Vert. & Horiz. Stab. Incl. Rudder & Elevators
12	Rigidly Mounted Equipment in Outer one-third of Wing
13	Rigidly Mounted Equipment in Inner two-thirds of Wing
14	Rigidly Mounted Equipment in Engine
15	Shock Mounted Equipment in Forward Quarter of Fuselage
16	Shock Mounted Equipment in Center Half of Fuselage
17	Shock Mounted Equipment in Aft Quarter of Fuselage
18	Shock Mounted Equipment in Vert. & Horiz. Stab. Incl. Rudder & Elevators
19	Shock Mounted Equipment in Outer one-third of Wing
20	Shock Mounted Equipment in Inner two-thirds of Wing
21	Shock Mounted Equipment in Engine
22	Engine Accessory Section
23	Main Rotor Transmission Case
24	Rigidly Mounted on Engine Accessory Section
25	Rigidly Mounted on Main Rotor Transmission Case
26	Shock Mounted on Engine Accessory Section
27	Shock Mounted on Main Rotor Transmission Case

All graphs are log-log (3 x 5 cycle) plots of frequency vs. vibratory double amplitude. As indicated previously, the logs of frequency, double amplitude, and acceleration were determined during the computation phase of data reduction. These

computations are necessary for the automatic plotting of frequency vs. double amplitude on a log-log scale. For the standard automatic plotters available can not accept linear input and then plot on a log scale. Therefore, by using the proper scale factors, the logarithms of the desired variables can be fed to any standard plotter to produce log-log plots of the original data. On these graphs of frequency vs. double amplitude, levels of vibratory acceleration appear as straight lines of constant slope. Reference lines having values of  $\pm 0.5$ ,  $\pm 1.0$ ,  $\pm 5.0$ , and  $\pm 10.0$  g are included on all graphs. This arrangement permits simultaneous readings of double amplitude and acceleration at any given frequency.

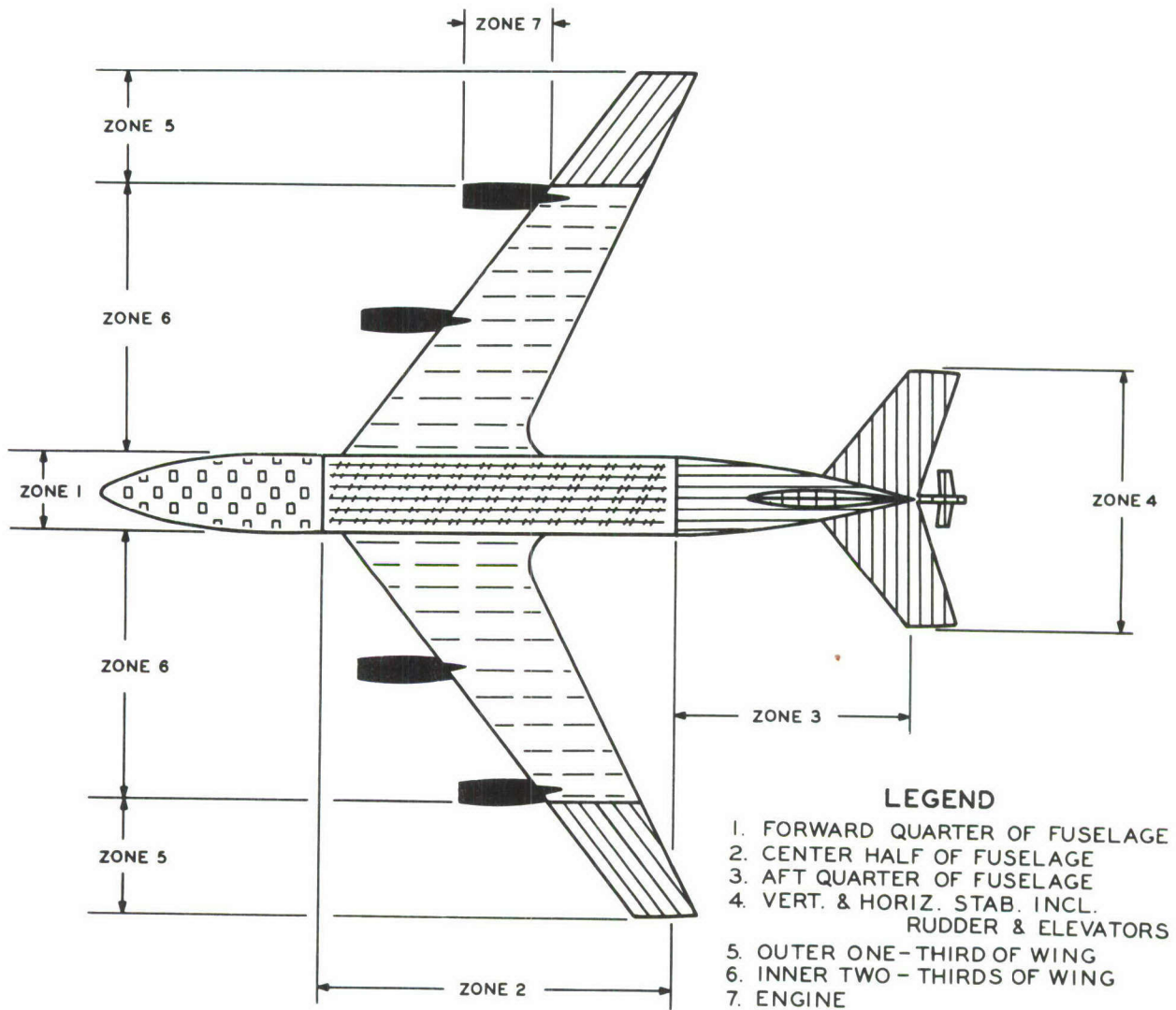


Figure 5. Aircraft Configuration Depicting Seven Structural Zones

A more detailed description of the data reduction processes used to reduce the vibration data is contained in WADC TN 59-44, ASTIA Document Nr. AD210478, dated February 1959, which is titled, "Data Reduction Techniques for Flight Vibration Measurements."

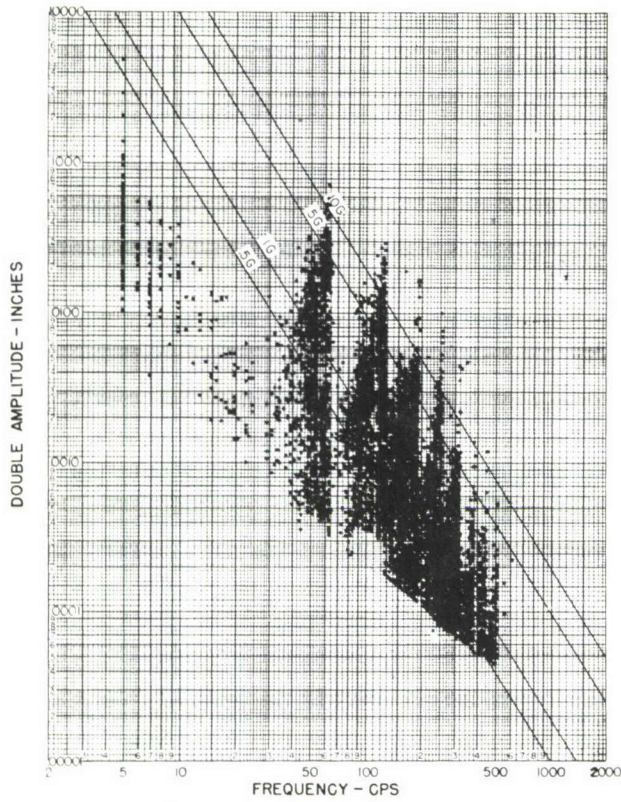


Figure 6. LOCATION: FORWARD QUARTER OF FUSELAGE

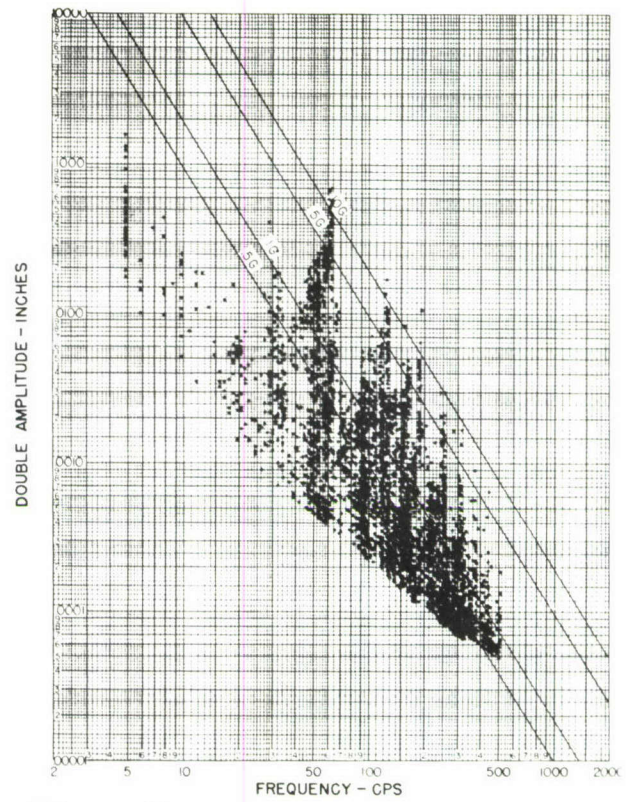


Figure 7. LOCATION: CENTER HALF OF FUSELAGE

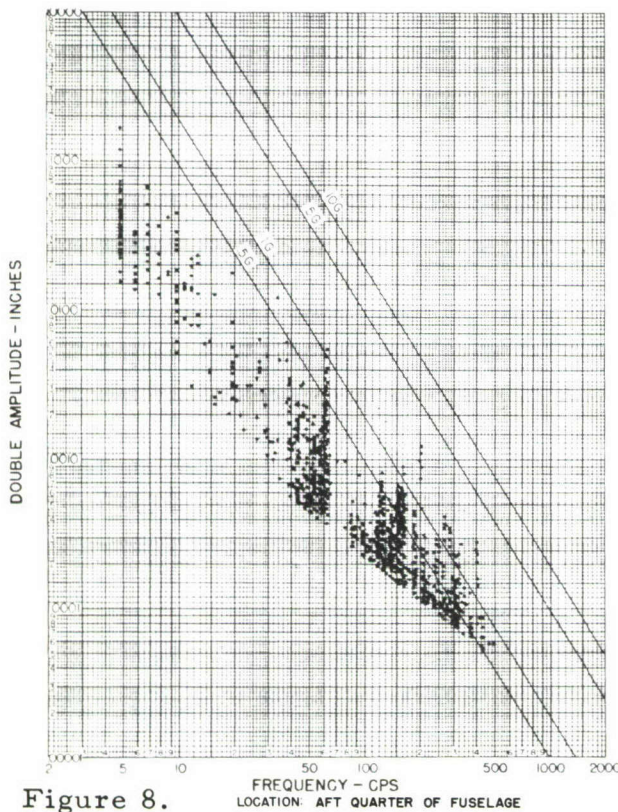


Figure 8. LOCATION: AFT QUARTER OF FUSELAGE

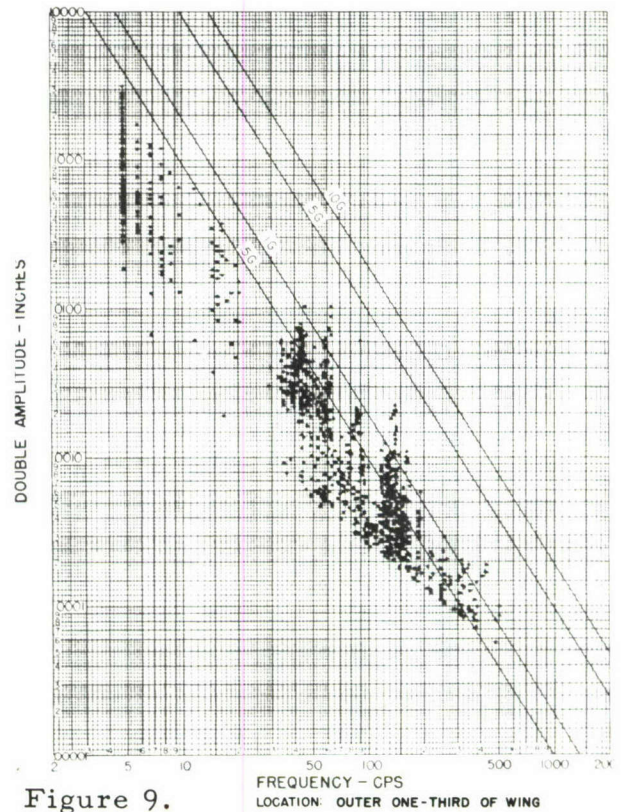


Figure 9. LOCATION: OUTER ONE-THIRD OF WING

Figures 6 to 9. Summary Plots for Structural Zones

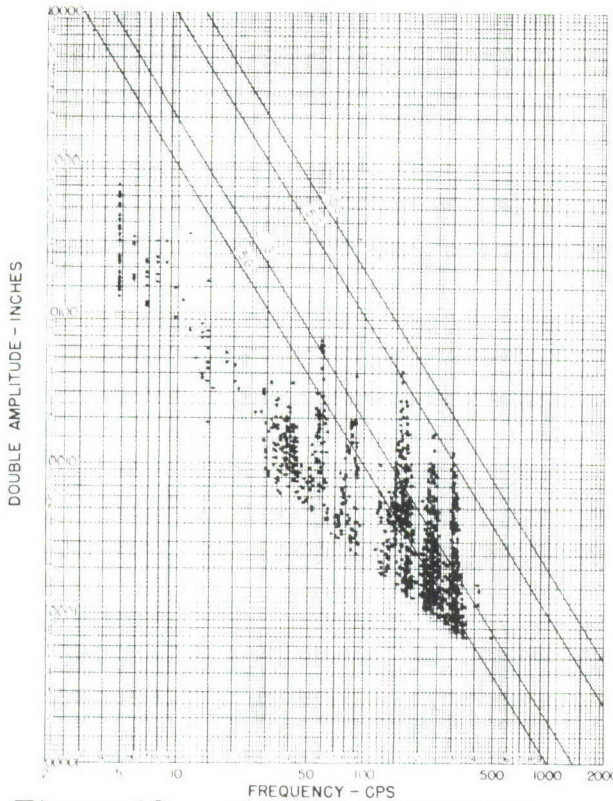


Figure 10. LOCATION: INNER TWO-THIRDS OF WING

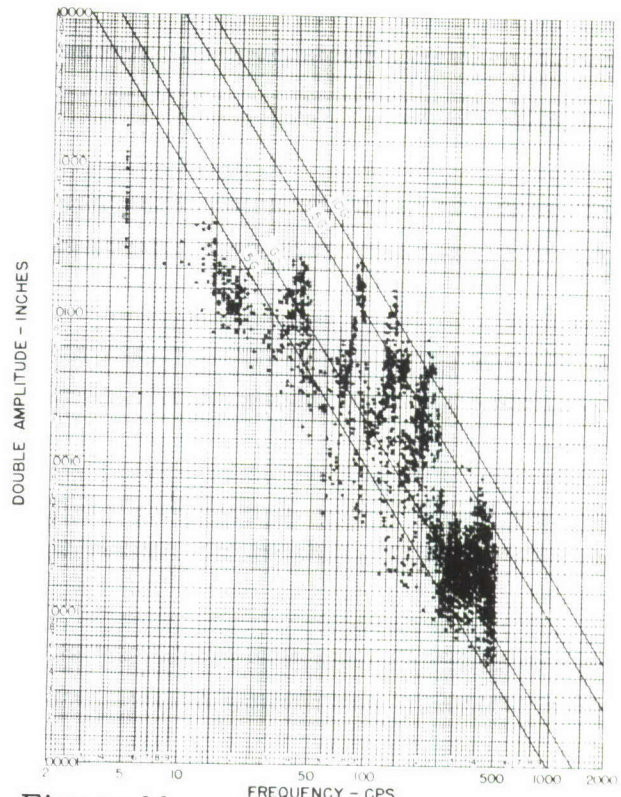


Figure 11. LOCATION: RIGIDLY MOUNTED ON ENGINE ACCESSORY

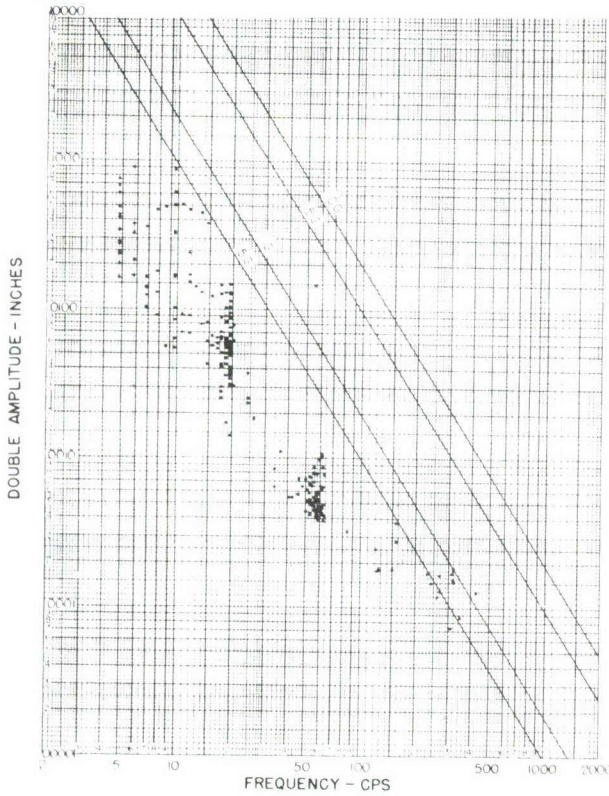


Figure 12. LOCATION: SHOCK MOUNTED EQUIPMENT IN FORWARD QUARTER OF FUSELAGE

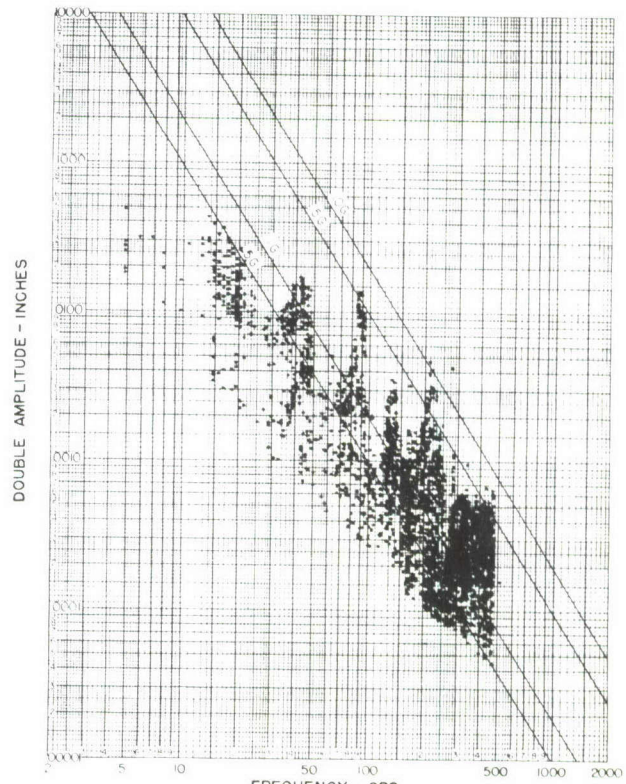


Figure 13. LOCATION: ENGINE ACCESSORY SECTION

Figures 10 to 13. Summary Plots for Structural Zones

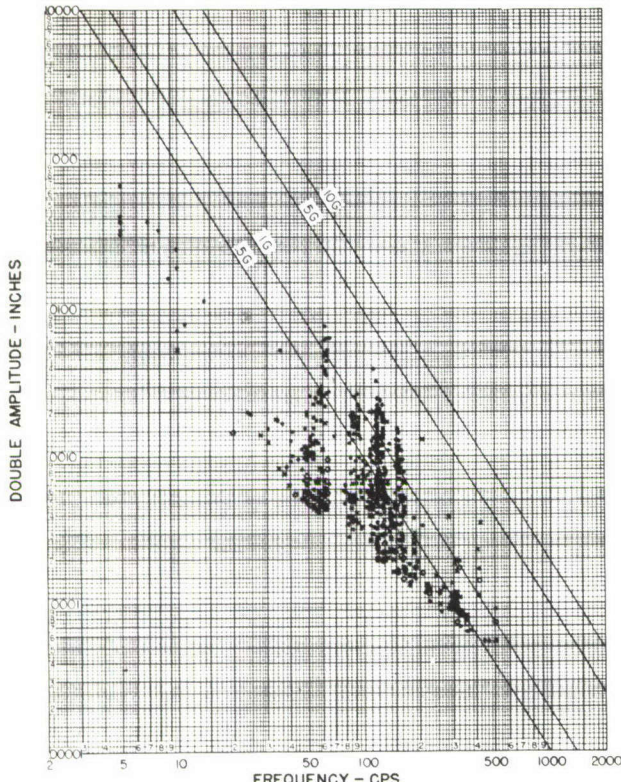


Figure 14. DIRECTION: VERT; • LAT; x F/A  
LOCATION: TOP CENTER OF FUSELAGE, STA. 410

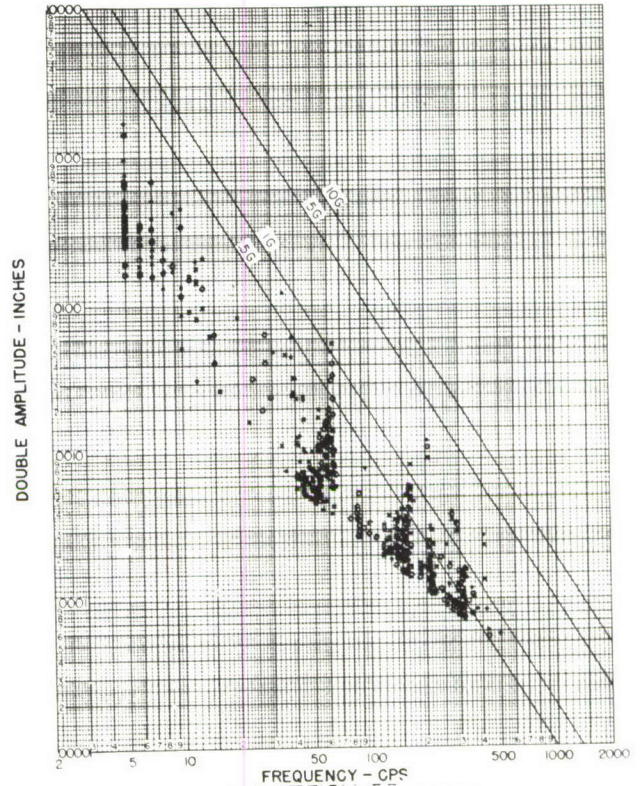


Figure 15. DIRECTION: VERT; • LAT; x F/A  
LOCATION: AFT SECTION, A/C STRUCTURE STA. 779

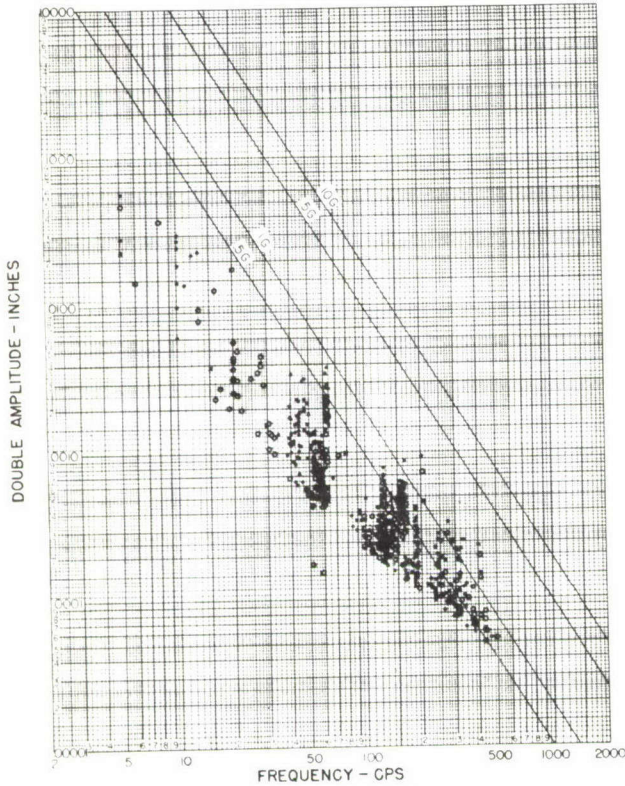


Figure 16. DIRECTION: VERT; • LAT; x F/A  
LOCATION: AFT END OF CARGO DECK TIE DOWN STA. C-17

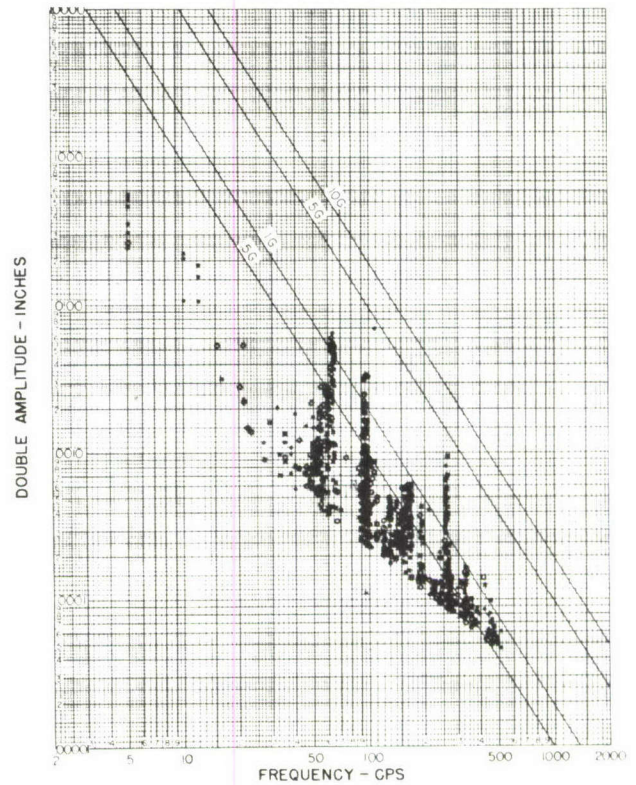


Figure 17. DIRECTION: VERT; • LAT; x F/A  
LOCATION: LEFT SIDE (AP X 6 MTG. SHELF) STA. 380

Figures 14 to 17. Summary Plots for Clusters of Two or Three Pickups

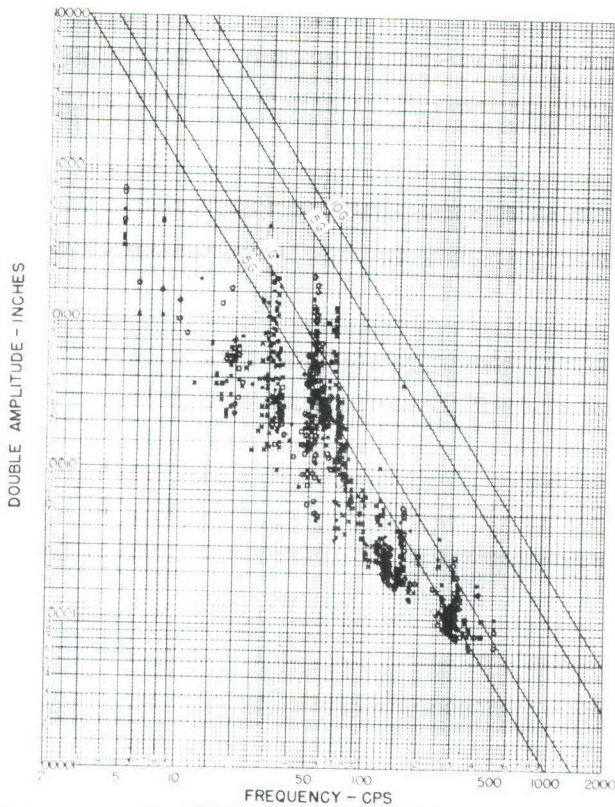


Figure 18. DIRECTION: • VERT; • LAT; x F/A  
 LOCATION: SECONDARY A/C STRUCTURE WITH MAIN INVERTER ATTACHED

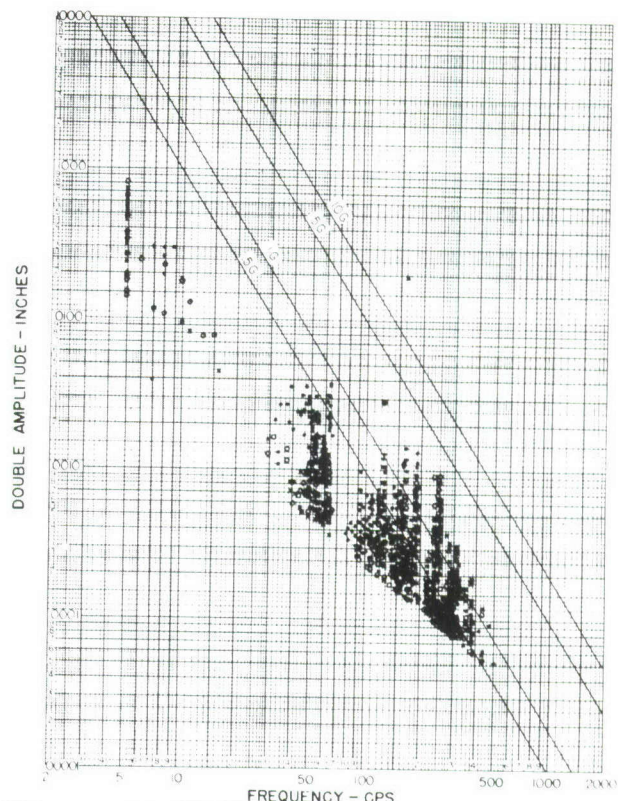


Figure 19. DIRECTION: • VERT; • LAT; x F/A  
 LOCATION: FORWARD END OF CARGO DECK TIE DOWN STA C-3

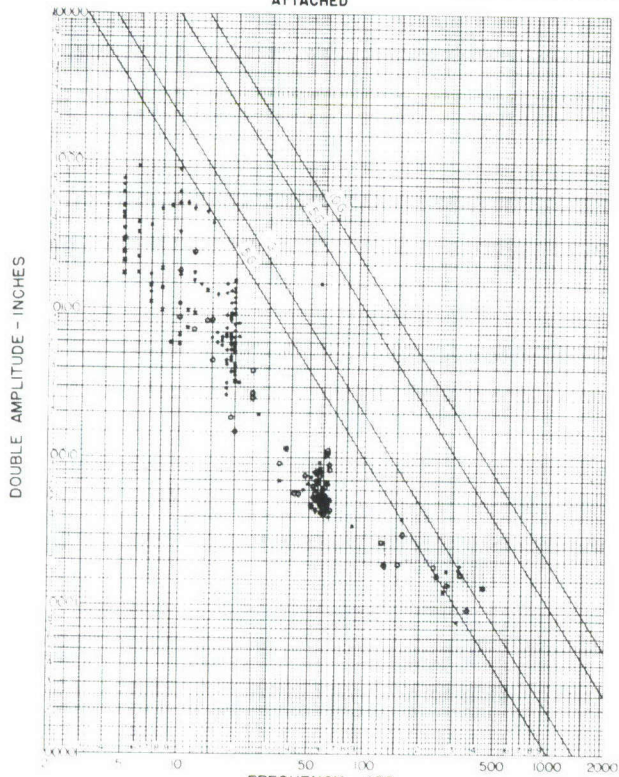


Figure 20. DIRECTION: • VERT; • LAT; x F/A  
 LOCATION: STRUCTURE OF INSTRUMENT PANEL

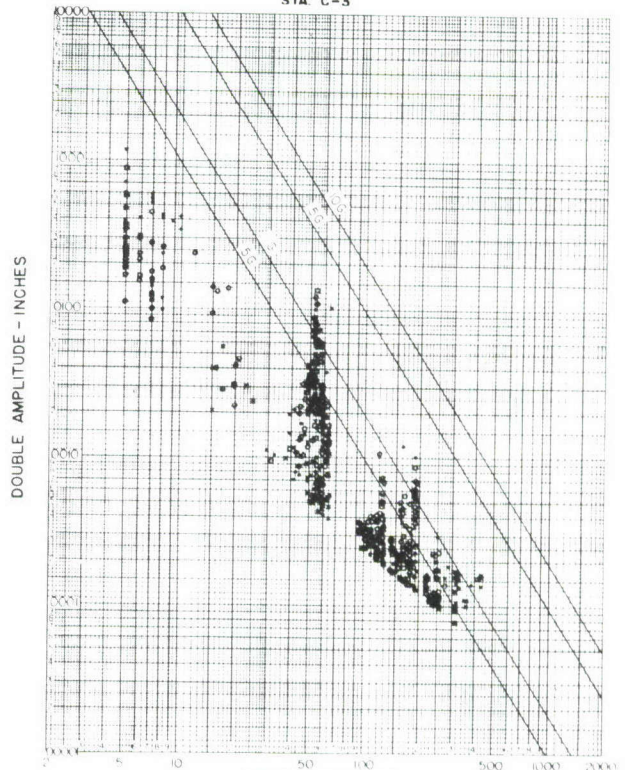


Figure 21. DIRECTION: • VERT; • LAT; x F/A  
 LOCATION: LEFT FWD SIDE OF NOSE WHEEL WELL

Figures 18 to 21. Summary Plots for Clusters of Two or Three Pickups

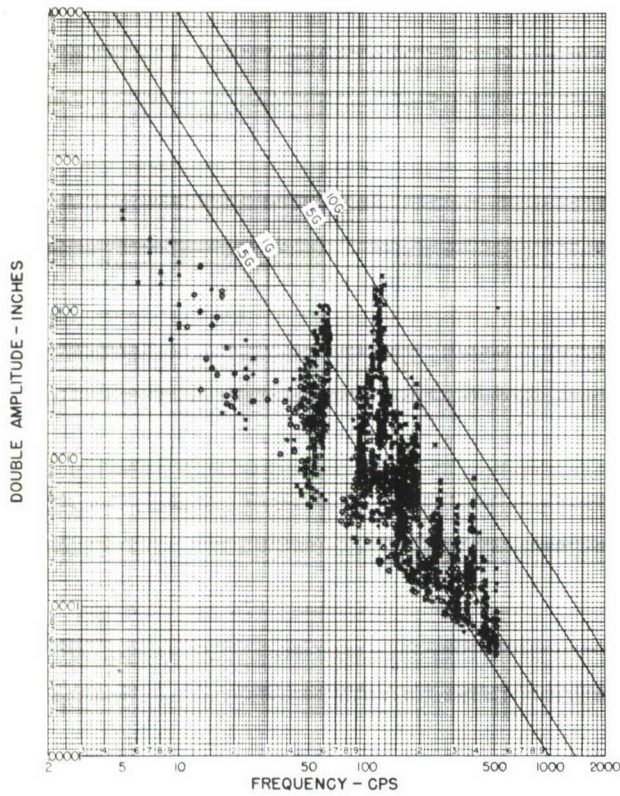


Figure 22. DIRECTION: · VERT; ○ LAT; × F/A  
LOCATION: TOP CENTER OF FUSELAGE AT STA. 165

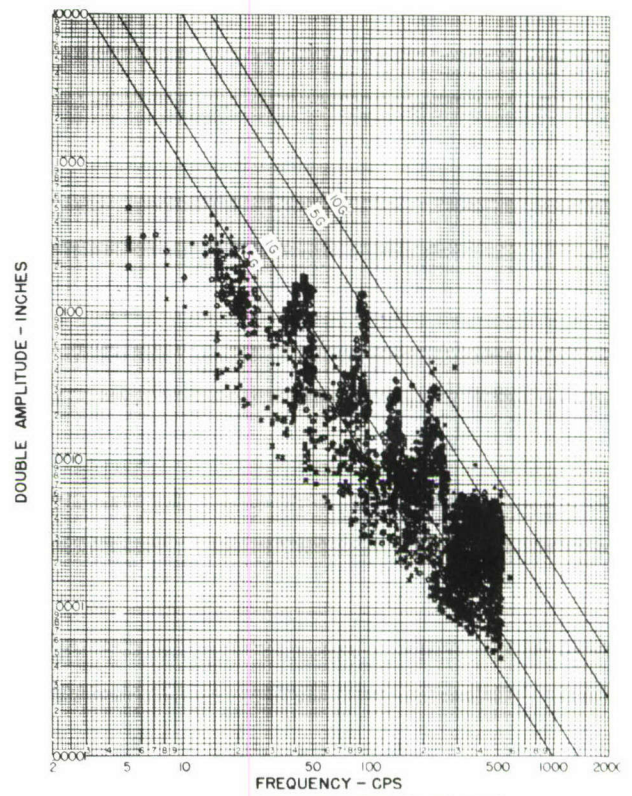


Figure 23. DIRECTION: · VERT; ○ LAT; × F/A  
LOCATION: ACCESSORY SECTION OF #2 ENGINE

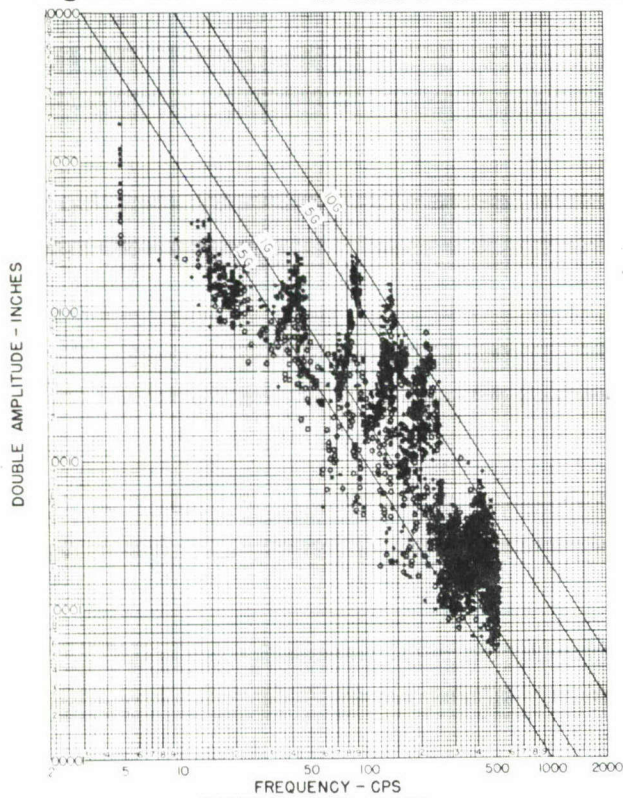


Figure 24. DIRECTION: VERT; ○ LAT  
LOCATION: BRUSH SECTION ON D.C. GENERATOR

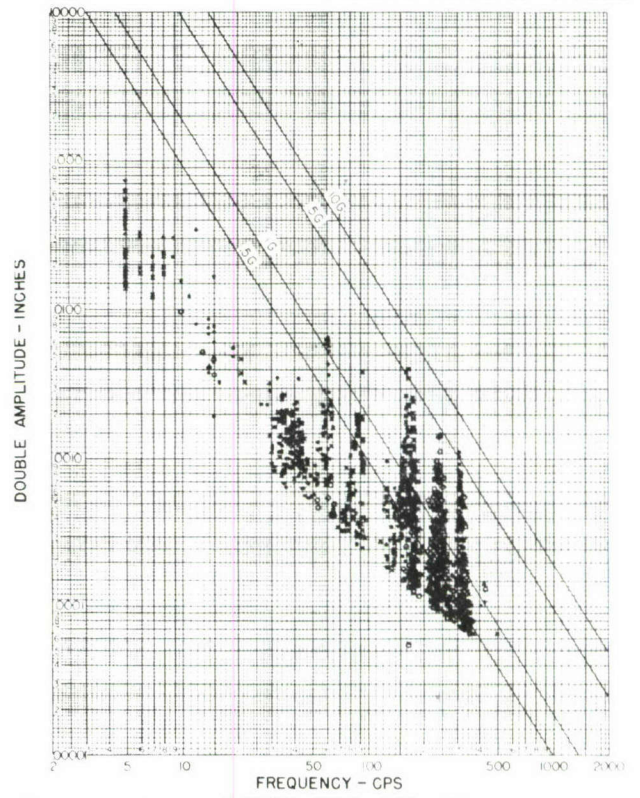


Figure 25. DIRECTION: · VERT; ○ LAT; × F/A  
LOCATION: RIGHT WING AT LANDING LIGHT LOCATION

Figures 22 to 25. Summary Plots for Clusters of Two or Three Pickups

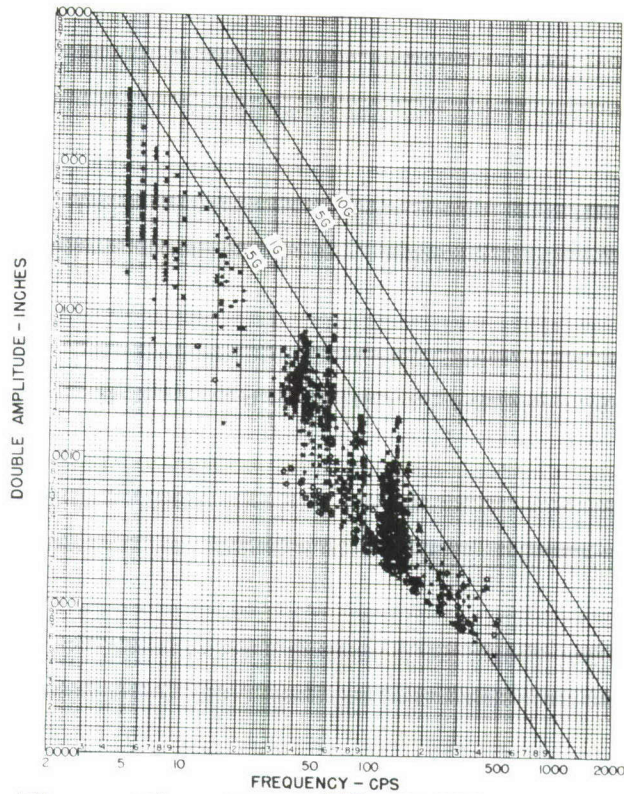


Figure 26. DIRECTION: VERT; • LAT; \* F/A  
LOCATION: STRUCTURE OF RIGHT WING TIP

Figure 26. Summary Plot for Cluster of Two or Three Pickups

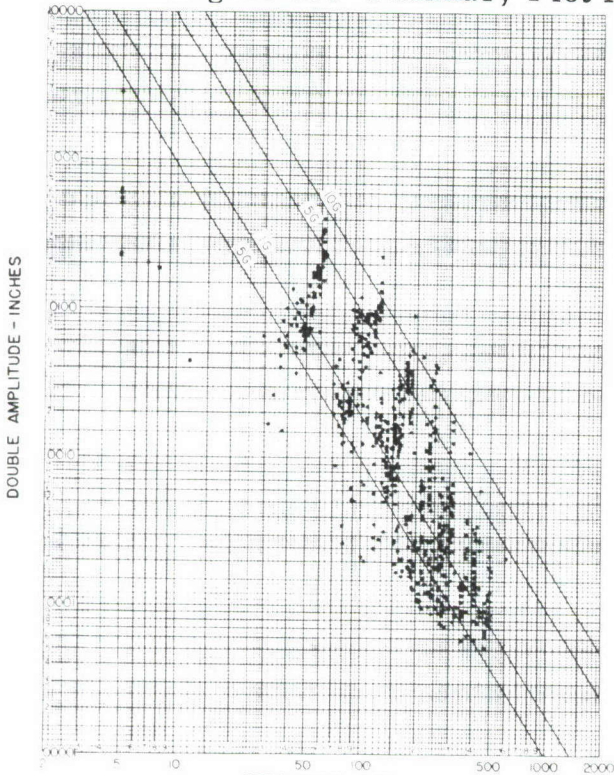


Figure 27. DIRECTION: LATERAL  
LOCATION: LOWER R.H. SIDE OF FUSELAGE, STA. 165

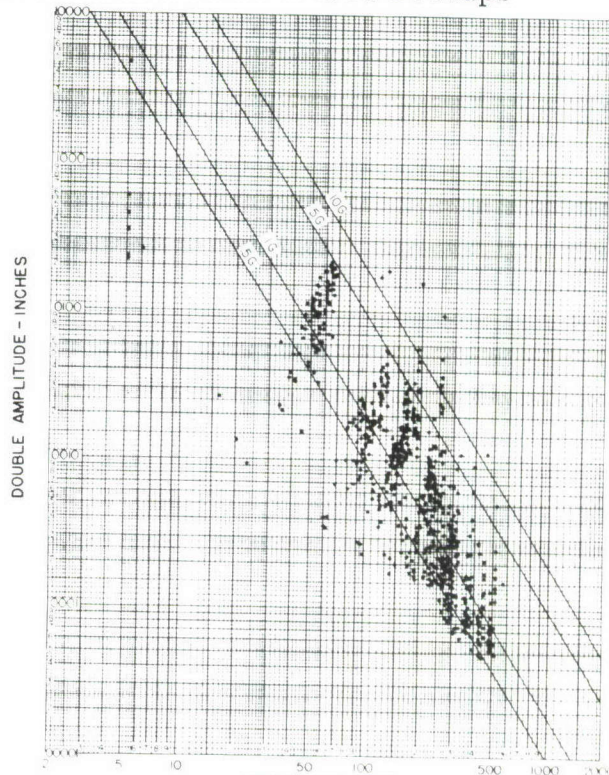


Figure 28. DIRECTION: LATERAL  
LOCATION: UPPER R.H. SIDE OF FUSELAGE, STA. 185

Figures 27 to 28. Summary Plots for Individual Vibration Pickups

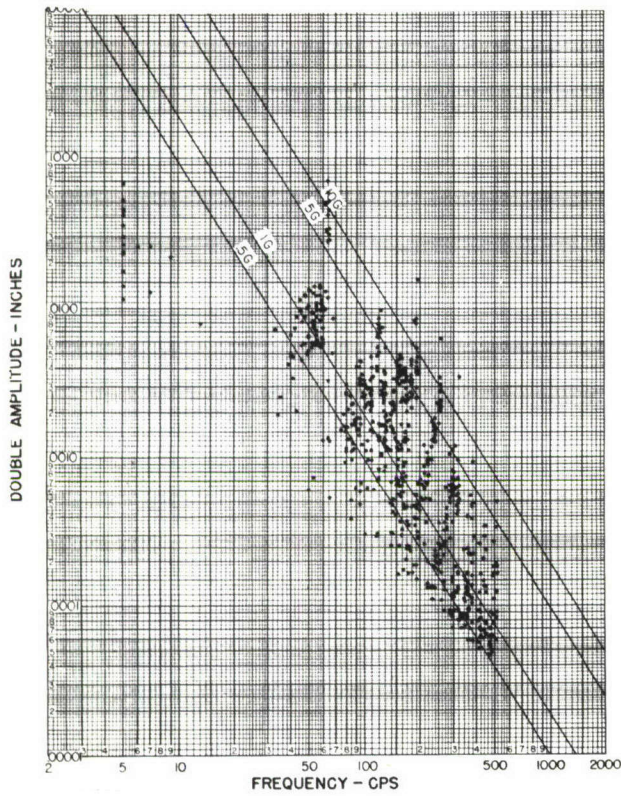


Figure 29. DIRECTION: LATERAL  
LOCATION: LOWER R.H. SIDE OF FUSELAGE, STA. 185

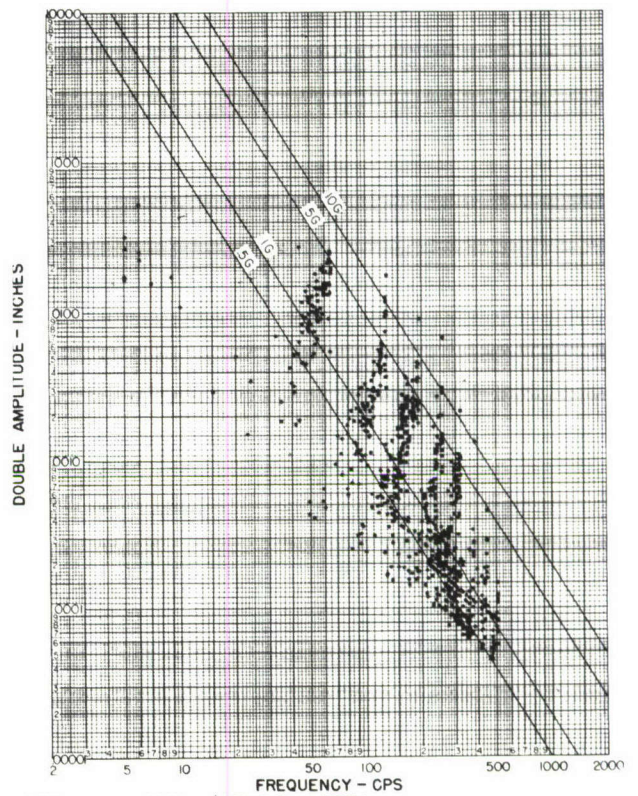


Figure 30. DIRECTION: LATERAL  
LOCATION: UPPER R.H. SIDE OF FUSELAGE STA. 2C

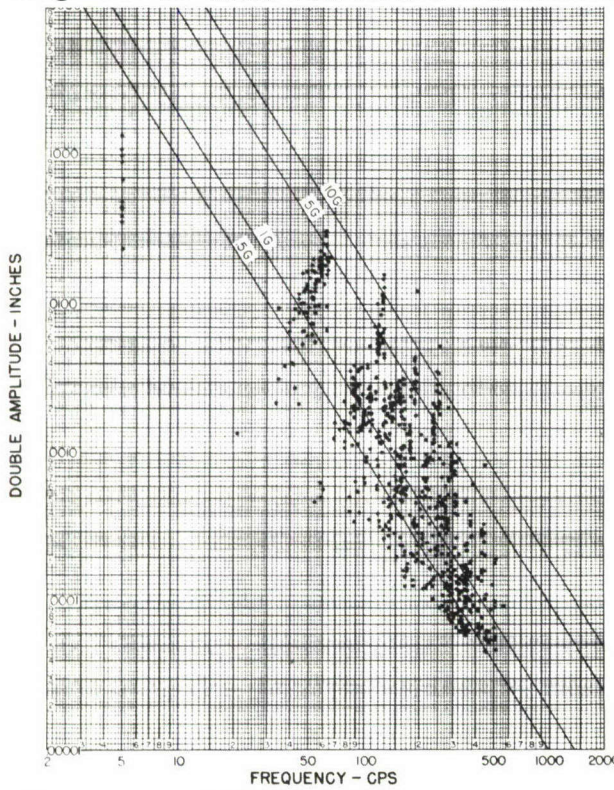


Figure 31. DIRECTION: LATERAL  
LOCATION: LOWER R.H. SIDE OF FUSELAGE, STA. 205

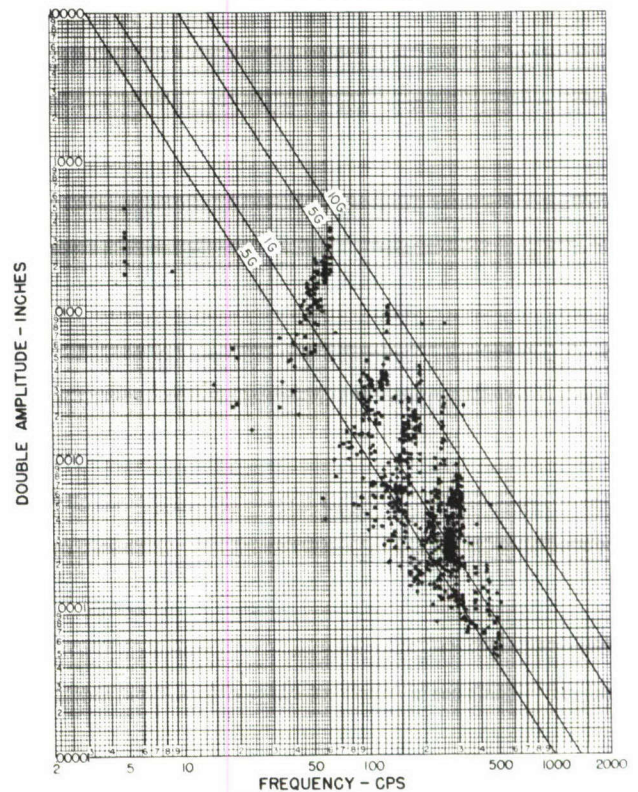


Figure 32. DIRECTION: LATERAL  
LOCATION: UPPER R.H. SIDE OF FUSELAGE, STA. 225

Figures 29 to 32. Summary Plots for Individual Vibration Pickups

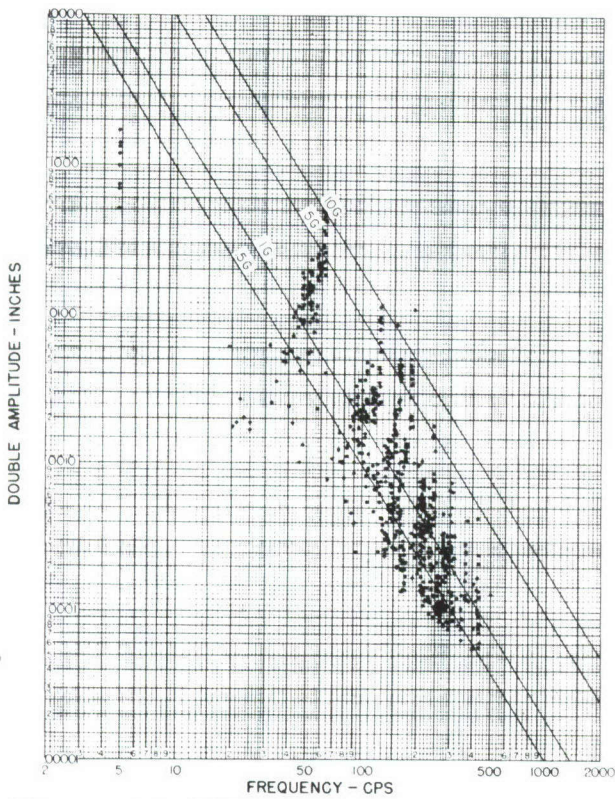


Figure 33. DIRECTION: LATERAL  
LOCATION: LOWER R.H. SIDE OF FUSELAGE, STA. 225

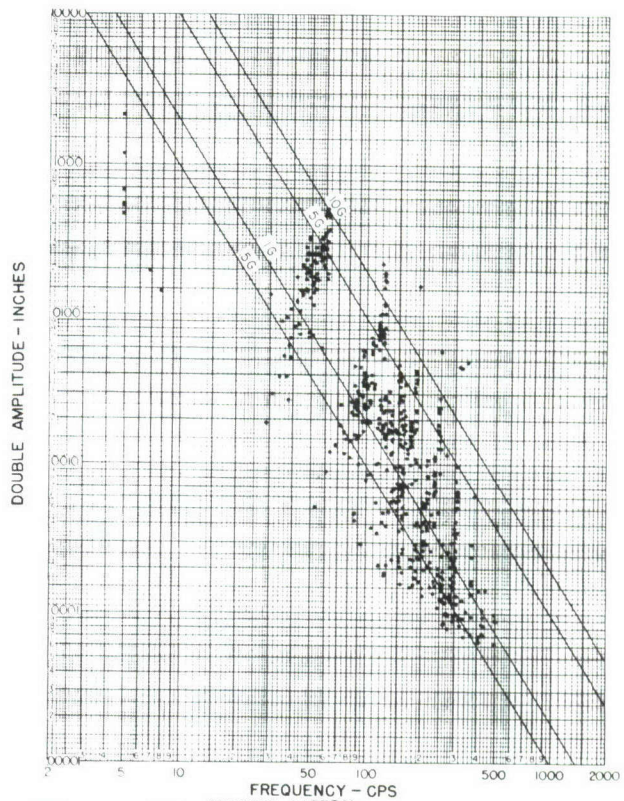


Figure 34. DIRECTION: LATERAL  
LOCATION: UPPER R.H. SIDE OF FUSELAGE, STA. 245

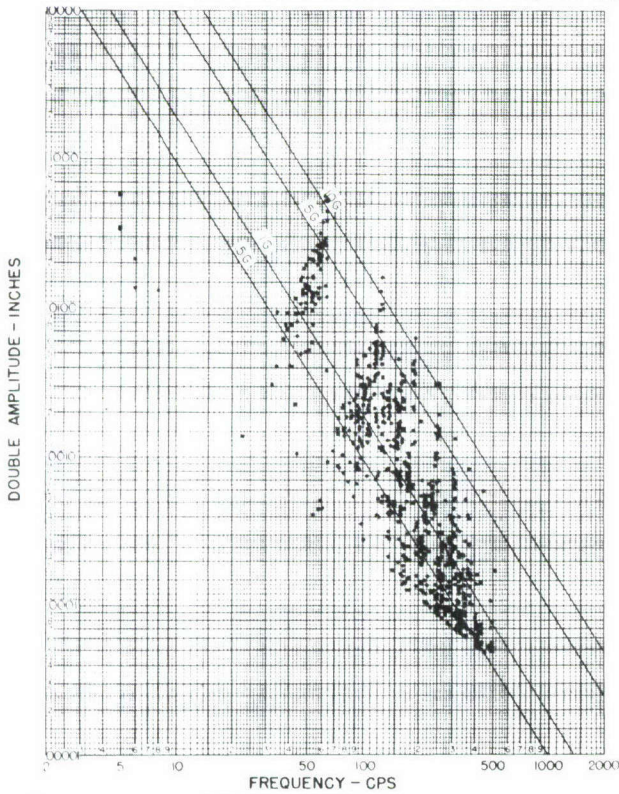


Figure 35. DIRECTION: LATERAL  
LOCATION: LOWER R.H. SIDE OF FUSELAGE, STA. 245

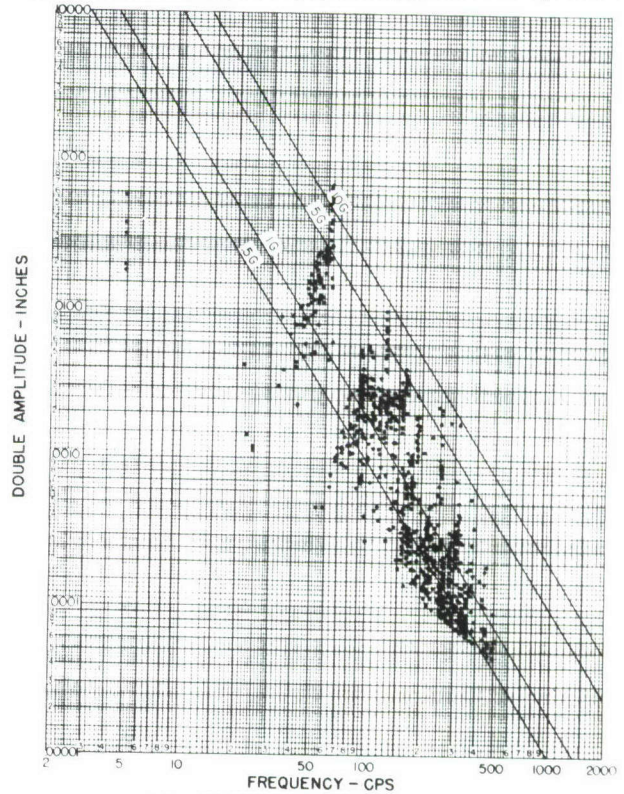


Figure 36. DIRECTION: LATERAL  
LOCATION: LOWER R.H. SIDE OF FUSELAGE, STA. 265

Figures 33 to 36. Summary Plots for Individual Vibration Pickups

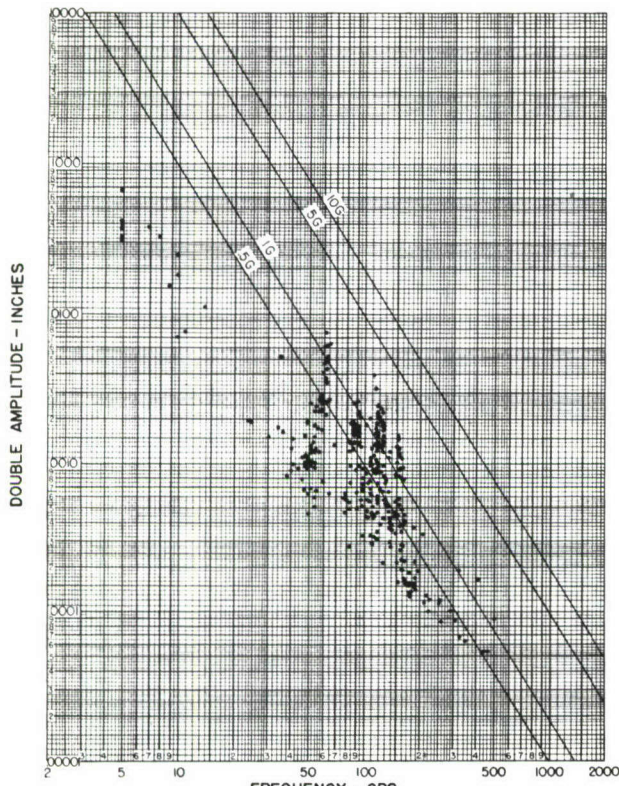


Figure 37. FREQUENCY - CPS  
DIRECTION: VERTICAL  
LOCATION: TOP CENTER OF FUSELAGE, STA. 410

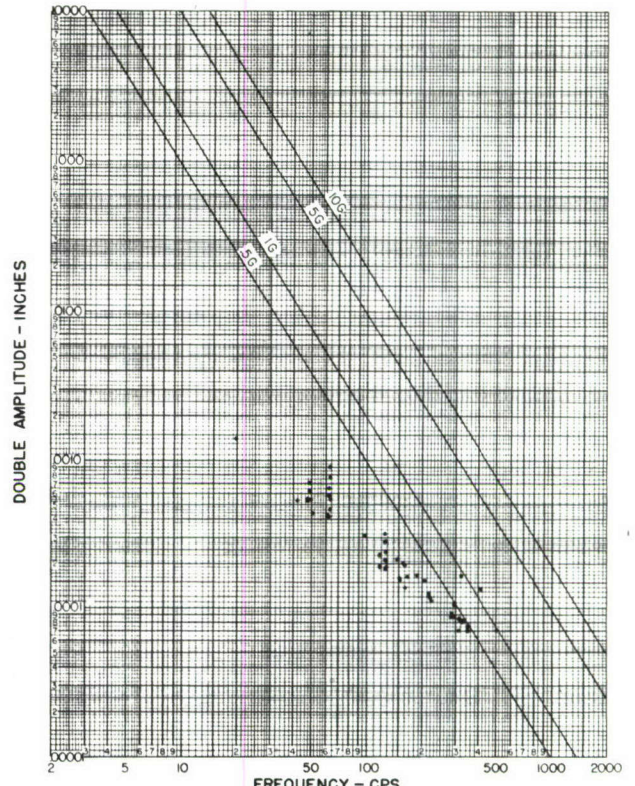


Figure 38. FREQUENCY - CPS  
DIRECTION: LATERAL  
LOCATION: TOP CENTER OF FUSELAGE, STA. 410

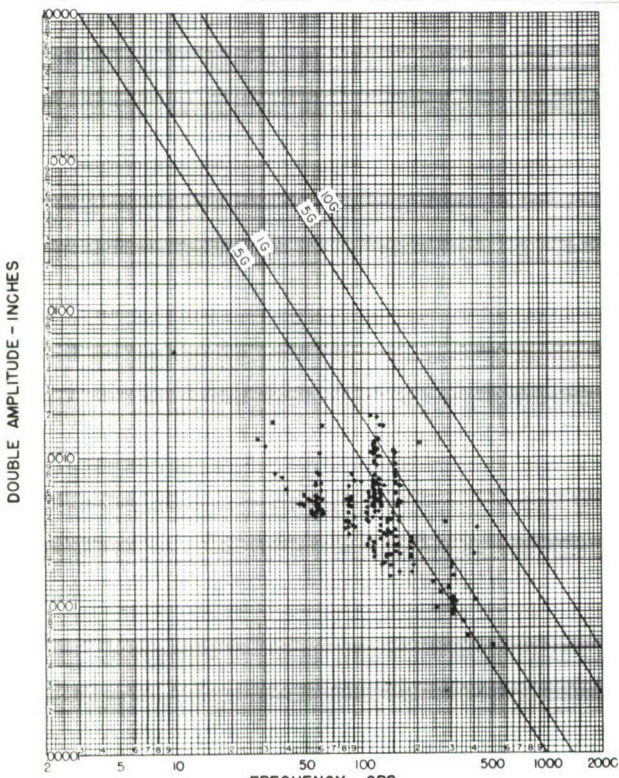


Figure 39. FREQUENCY - CPS  
DIRECTION: F/A  
LOCATION: TOP CENTER OF FUSELAGE, STA. 410

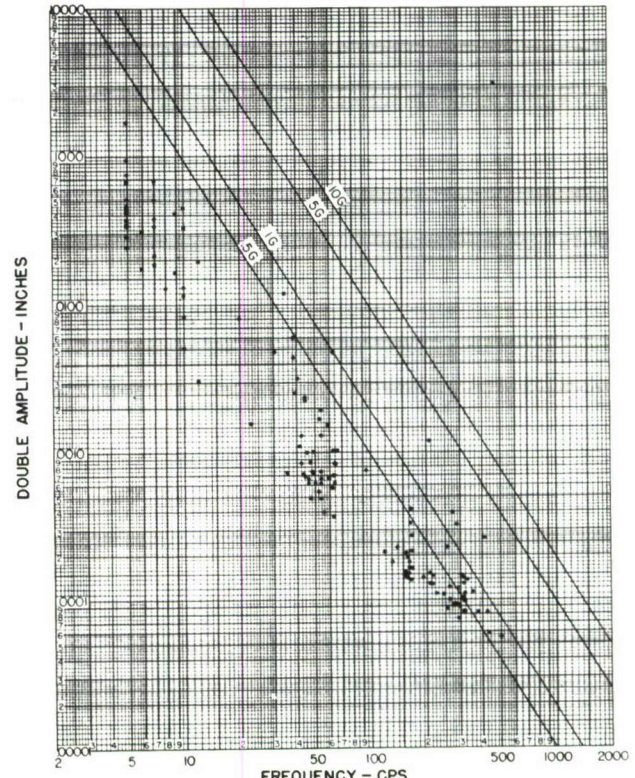


Figure 40. FREQUENCY - CPS  
DIRECTION: VERTICAL  
LOCATION: AFT SECTION, A/C STRUCTURE STA. 779

Figures 37 to 40. Summary Plots for Individual Vibration Pickups

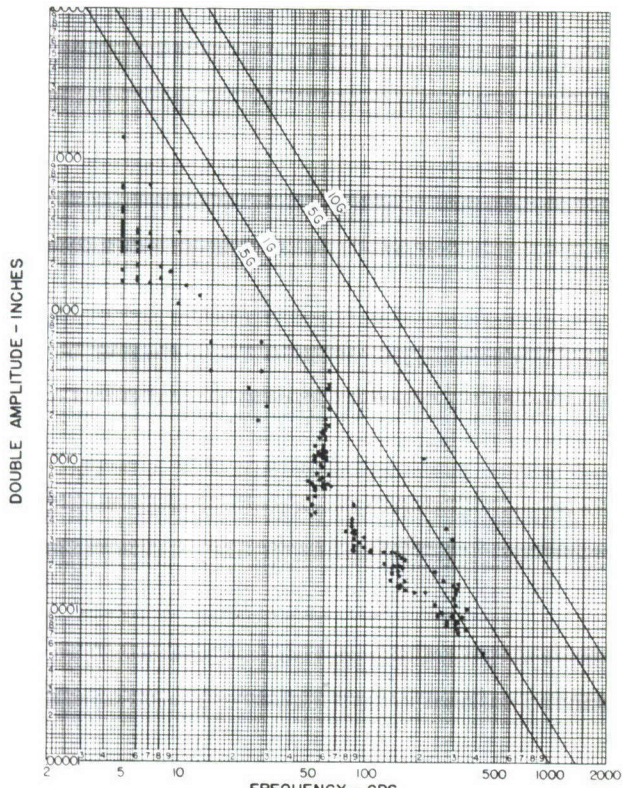


Figure 41. DIRECTION: LATERAL  
LOCATION: AFT SECTION, A/C STRUCTURE STA. 779

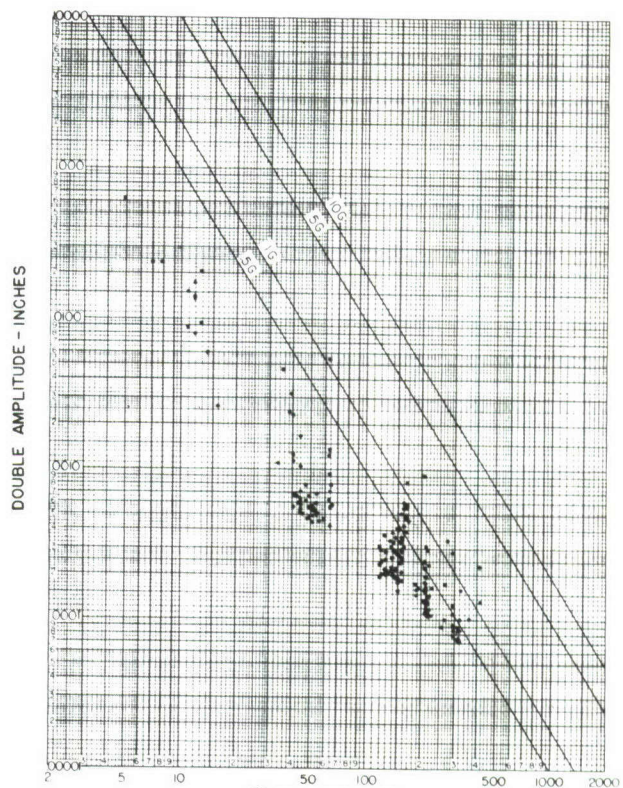


Figure 42. DIRECTION: F/A  
LOCATION: AFT SECTION, A/C STRUCTURE STA. 779

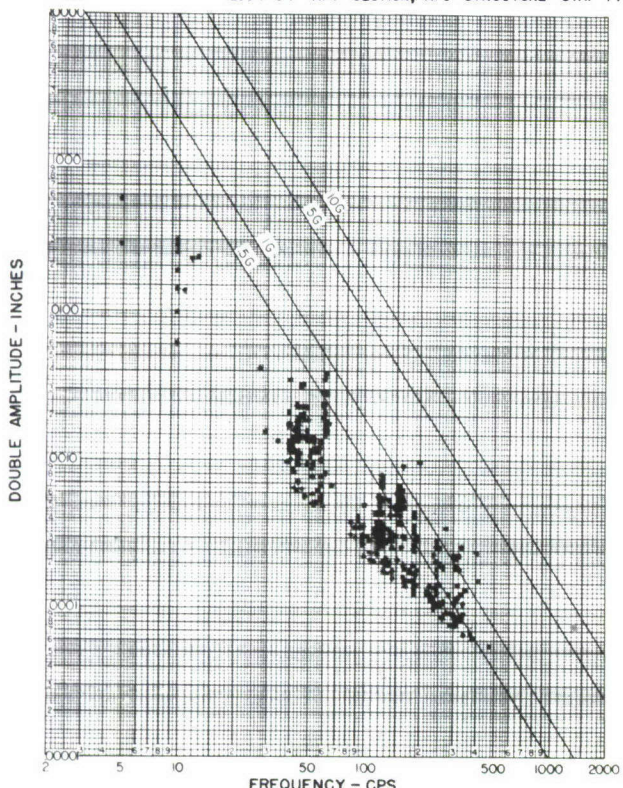


Figure 43. DIRECTION: VERTICAL  
LOCATION: AFT END OF CARGO DECK TIE DOWN STA. C-17

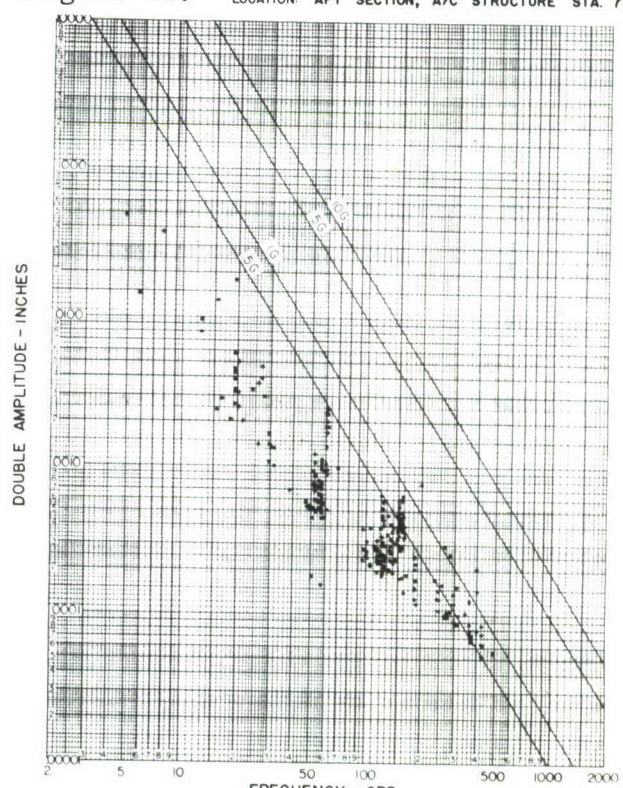


Figure 44. DIRECTION: LATERAL  
LOCATION: AFT END OF CARGO DECK TIE DOWN STA. C-17

Figures 41 to 44. Summary Plots for Individual Vibration Pickups

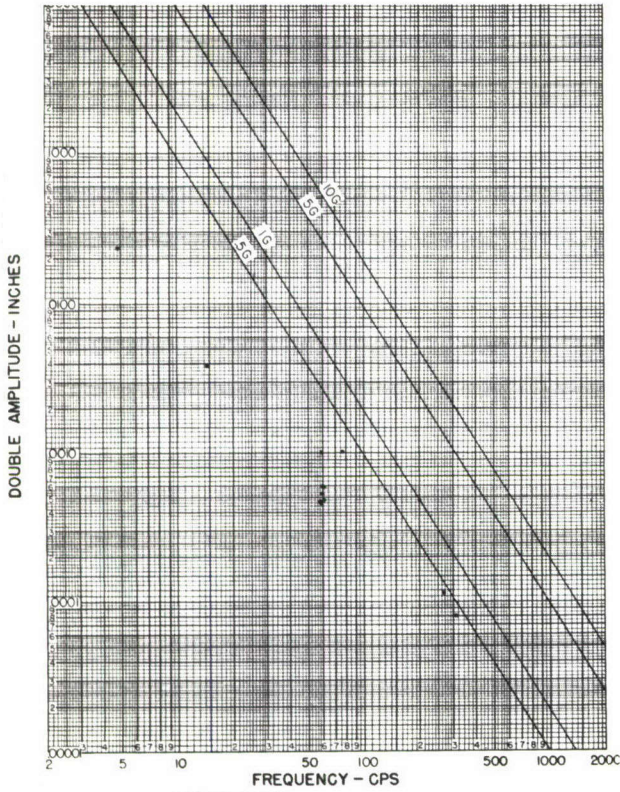


Figure 45. DIRECTION: F/A  
LOCATION: AFT END OF CARGO DECK TIE DOWN STA. C-17

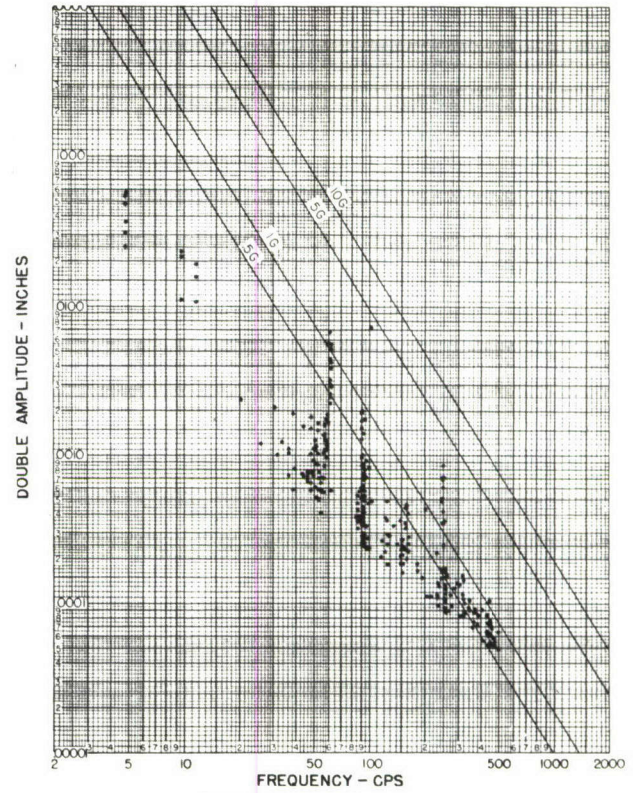


Figure 46. DIRECTION: VERTICAL  
LOCATION: LEFT SIDE (AP X 6 MTG. SHELF) STA. 380

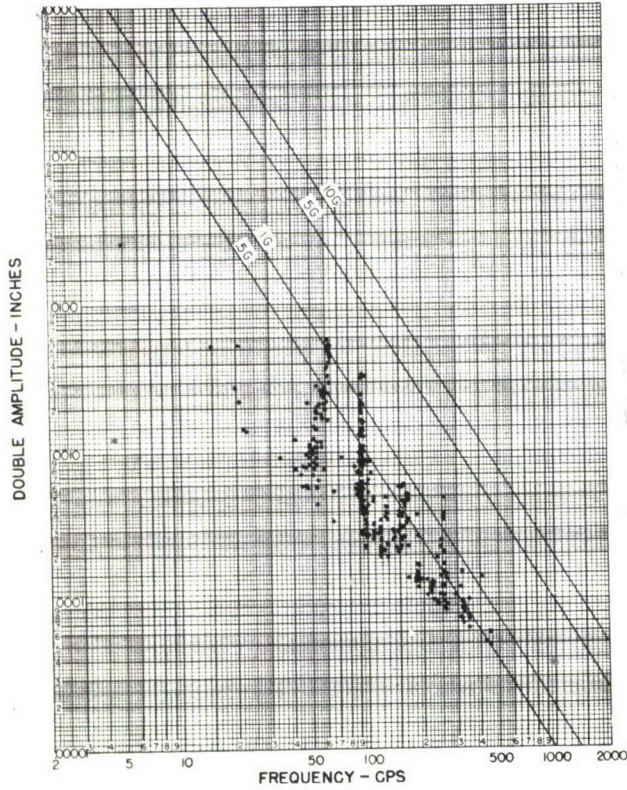


Figure 47. DIRECTION: LATERAL  
LOCATION: LEFT SIDE (AP X 6 MTG. SHELF) STA. 380

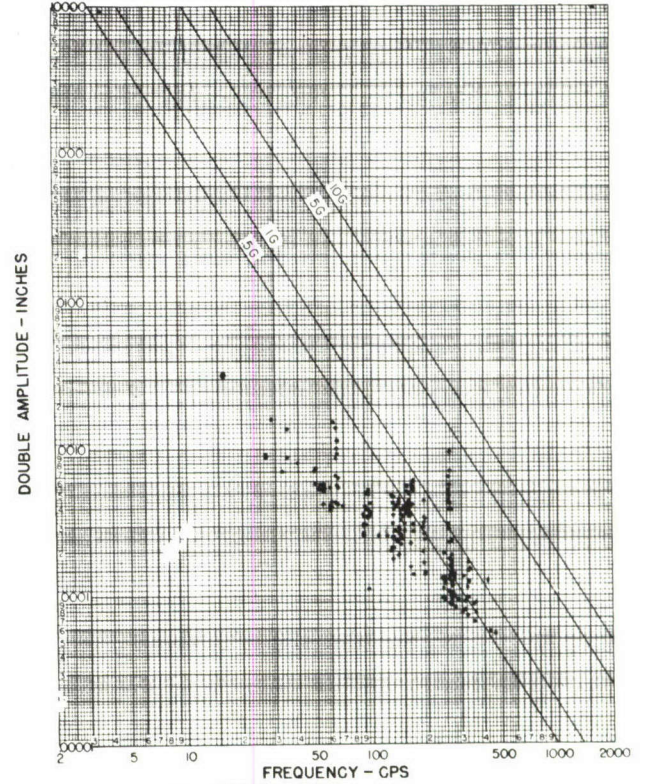


Figure 48. DIRECTION: F/A  
LOCATION: LEFT SIDE (AP X 6 MTG. SHELF) STA. 380

Figures 45 to 48. Summary Plots for Individual Vibration Pickups

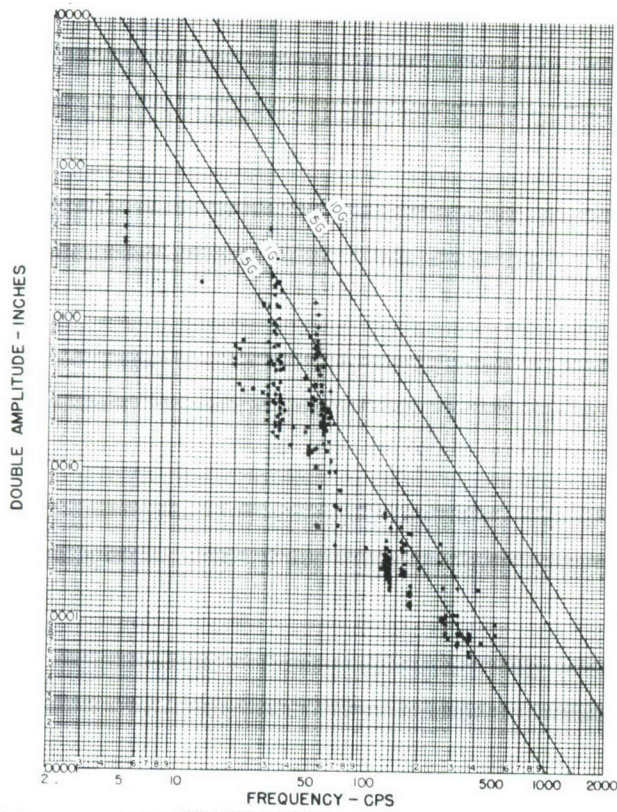


Figure 49. DIRECTION: VERTICAL  
 LOCATION: SECONDARY A/C STRUCTURE WITH MAIN INVERTER ATTACHED STA. 340

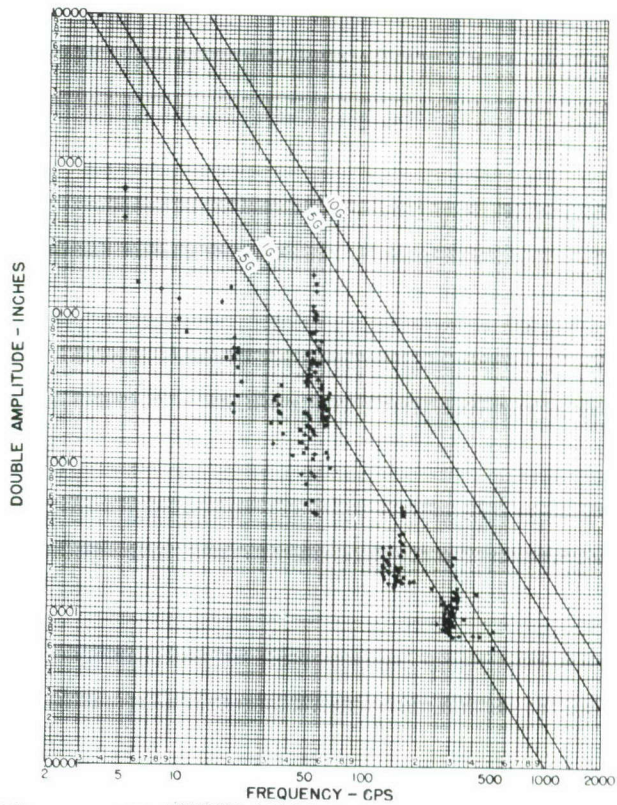


Figure 50. DIRECTION: LATERAL  
 LOCATION: SECONDARY A/C STRUCTURE WITH MAIN INVERTER

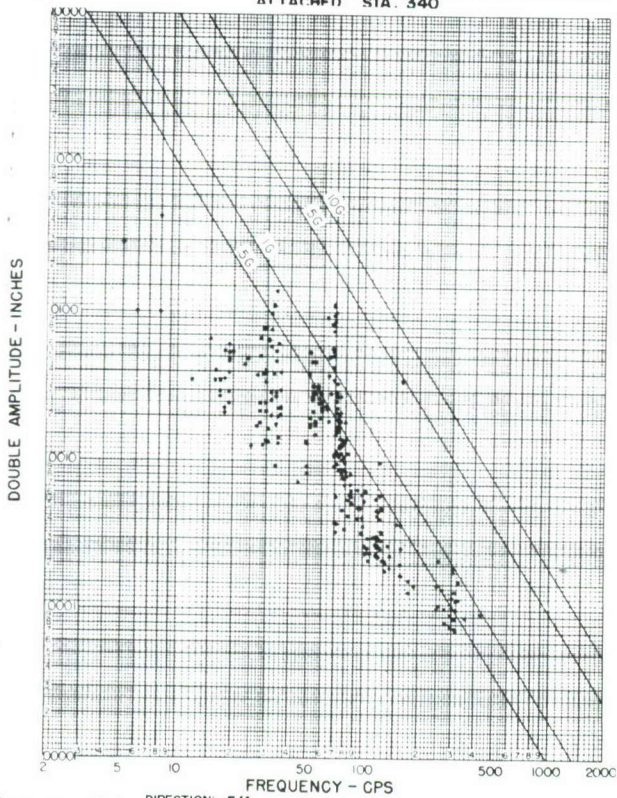


Figure 51. DIRECTION: F/A  
 LOCATION: SECONDARY A/C STRUCTURE WITH MAIN INVERTER ATTACHED STA. 340

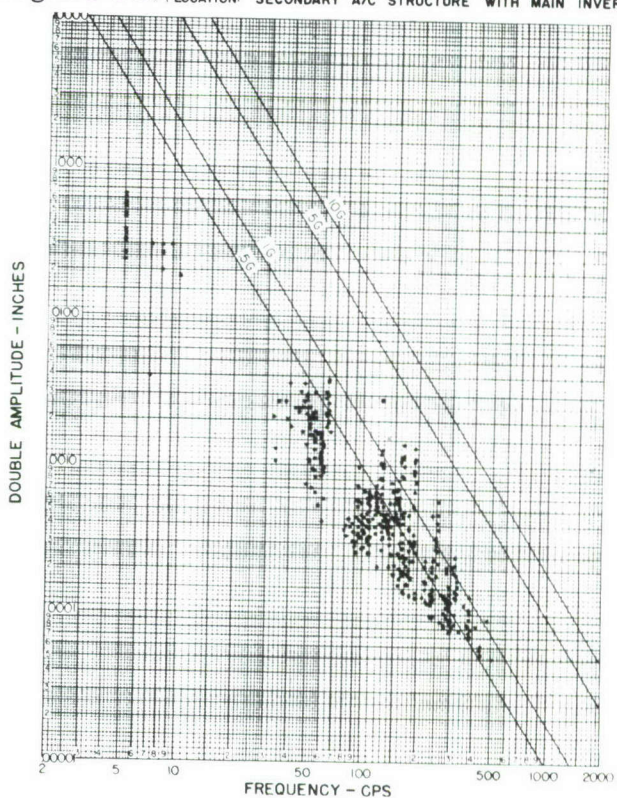


Figure 52. DIRECTION: VERTICAL  
 LOCATION: FORWARD END OF CARGO DECK TIE DOWN STA. C-3

Figures 49 to 52. Summary Plots for Individual Vibration Pickups

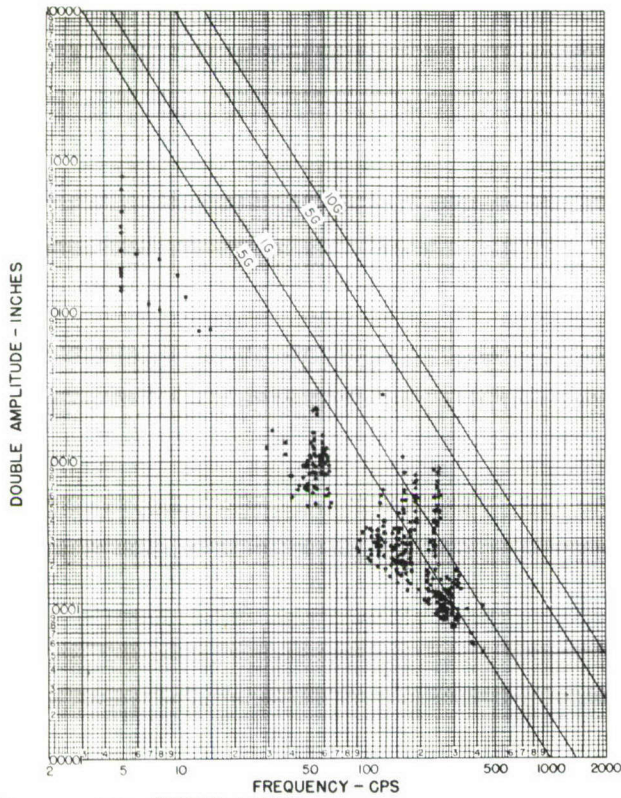


Figure 53. DIRECTION: LATERAL  
LOCATION: FORWARD END OF CARGO DECK TIE DOWN STA. C-3

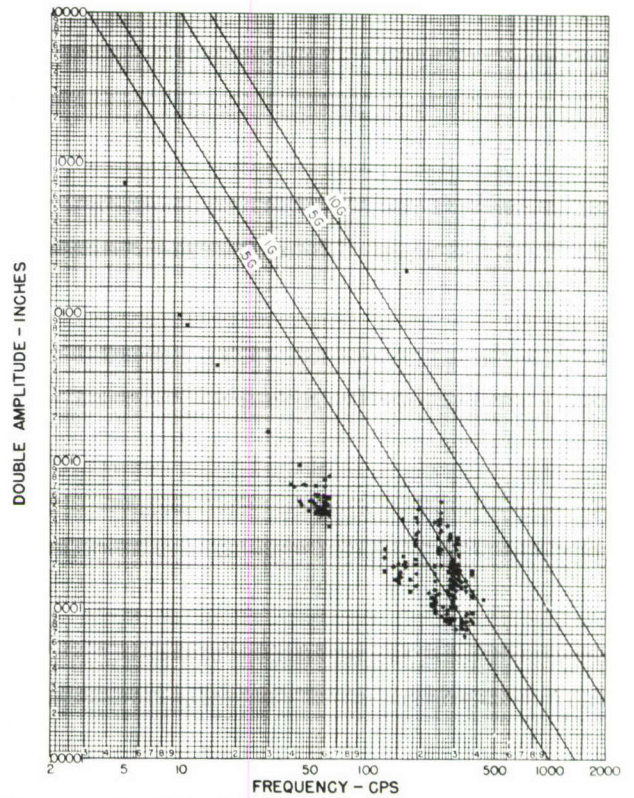


Figure 54. DIRECTION: F/A  
LOCATION: FORWARD END OF CARGO DECK TIE DOWN STA. C-3

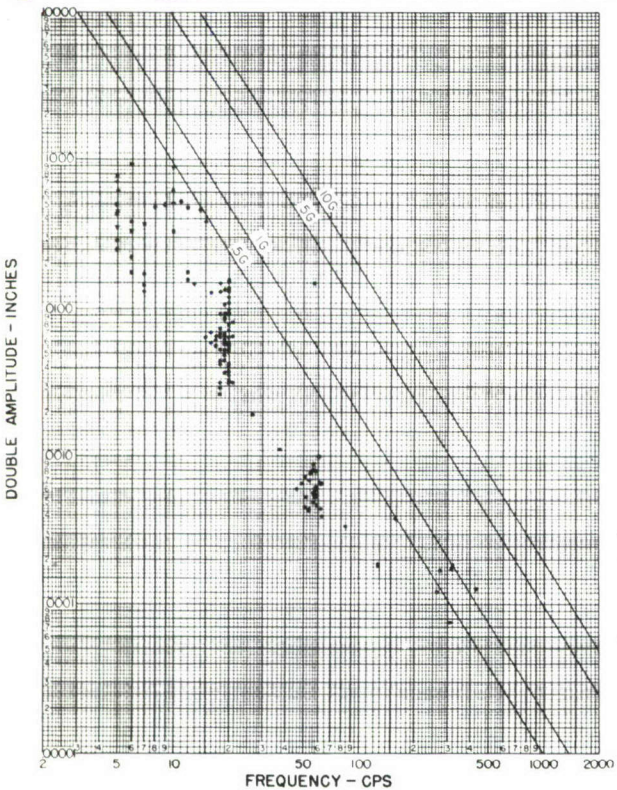


Figure 55. DIRECTION: VERTICAL  
LOCATION: STRUCTURE OF INSTRUMENT PANEL

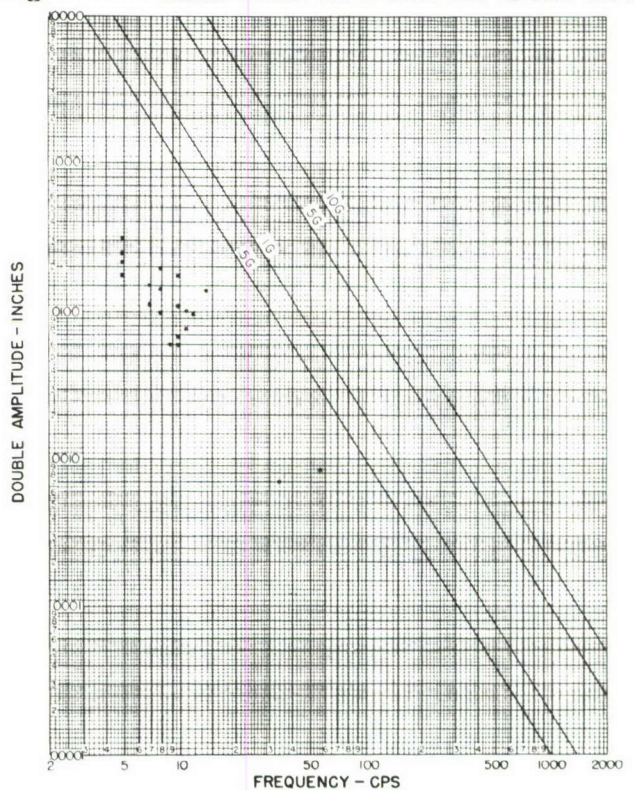


Figure 56. DIRECTION: F/A  
LOCATION: STRUCTURE OF INSTRUMENT PANEL

Figures 53 to 56. Summary Plots for Individual Vibration Pickups

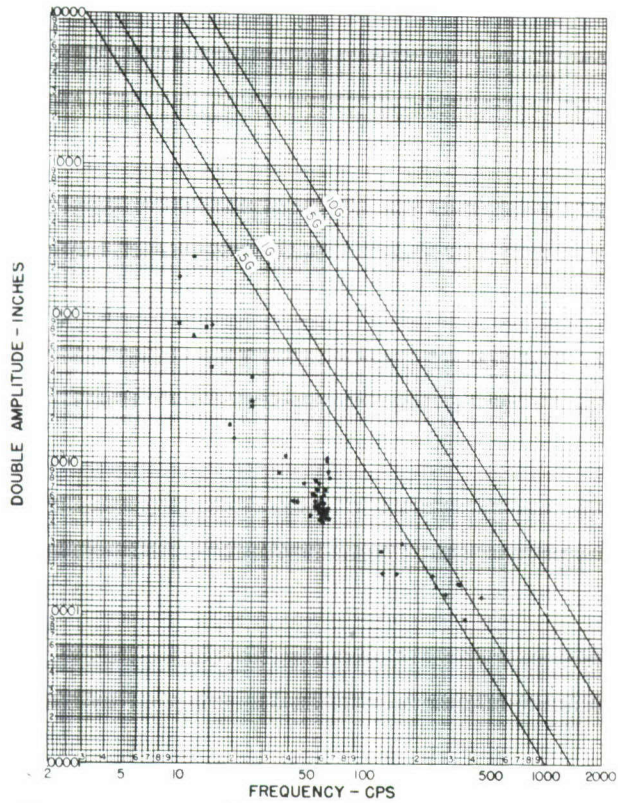


Figure 57. DIRECTION: LATERAL  
LOCATION: STRUCTURE OF INSTRUMENT PANEL

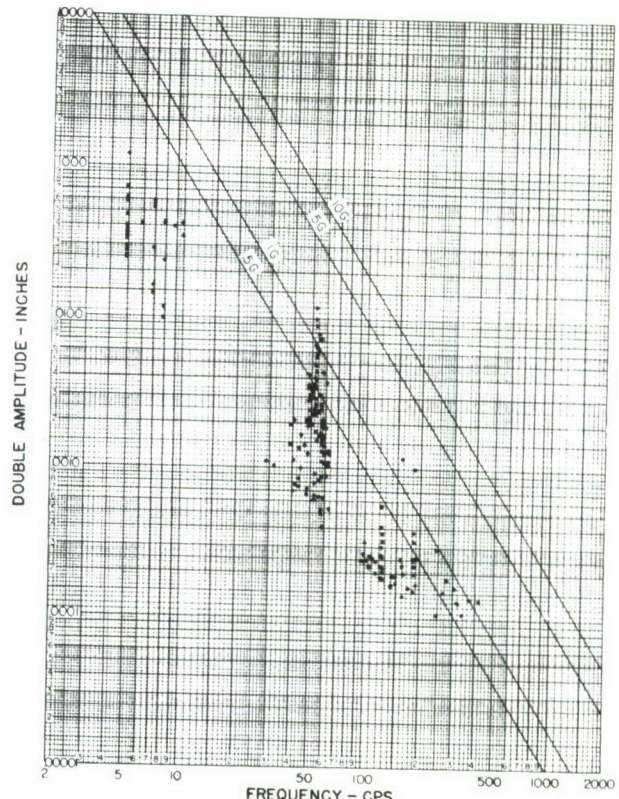


Figure 58. DIRECTION: VERTICAL  
LOCATION: LEFT FWD SIDE OF NOSE WHEEL WELL

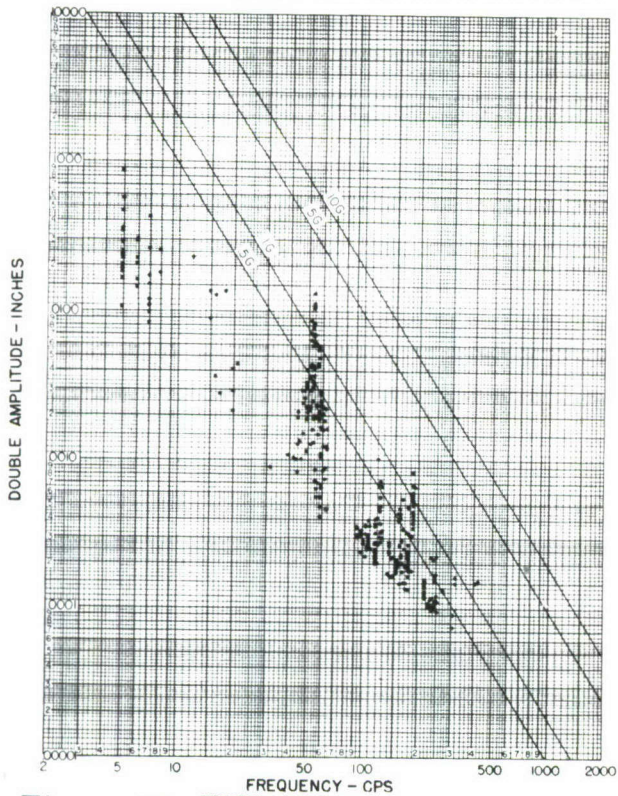


Figure 59. DIRECTION: LATERAL  
LOCATION: LEFT FWD SIDE OF NOSE WHEEL WELL

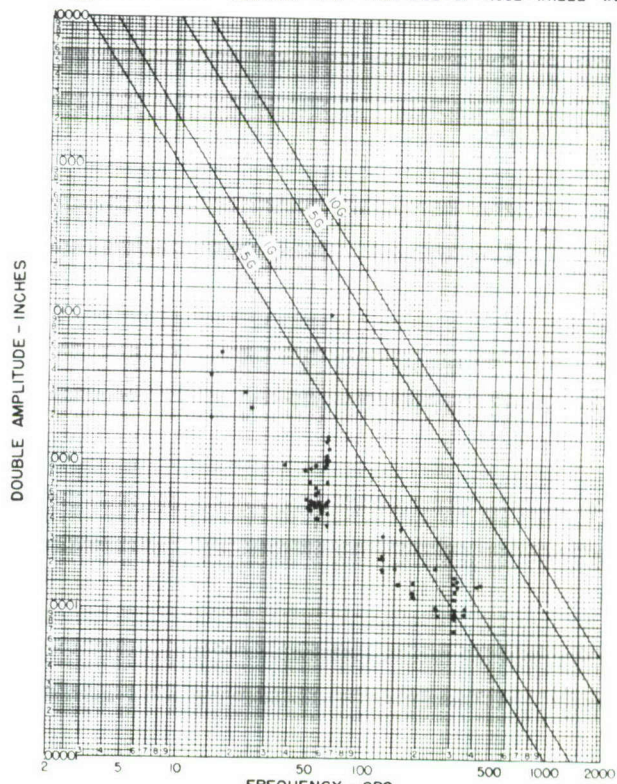


Figure 60. DIRECTION: F/A  
LOCATION: LEFT FWD SIDE OF NOSE WHEEL WELL

Figures 57 to 60. Summary Plots for Individual Vibration Pickups

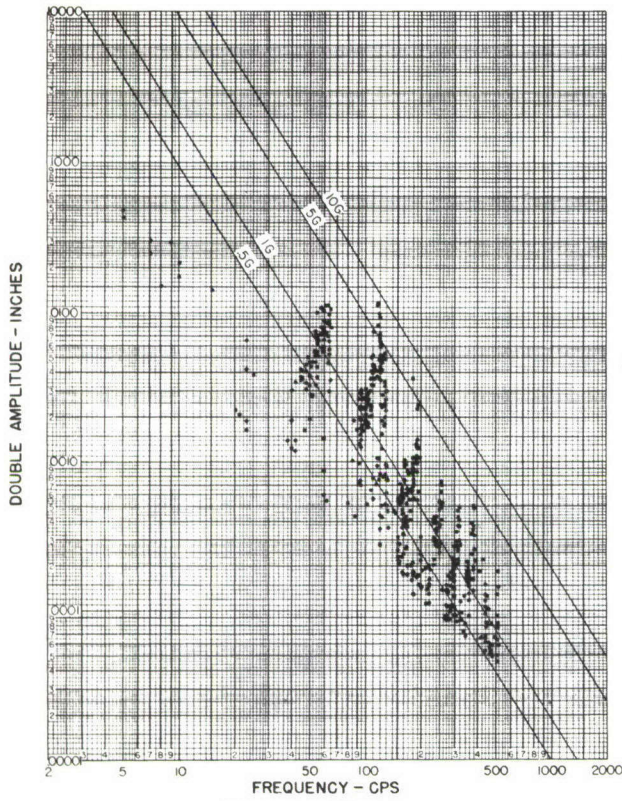


Figure 61. DIRECTION: VERTICAL  
LOCATION: TOP CENTER OF FUSELAGE AT STA. 165

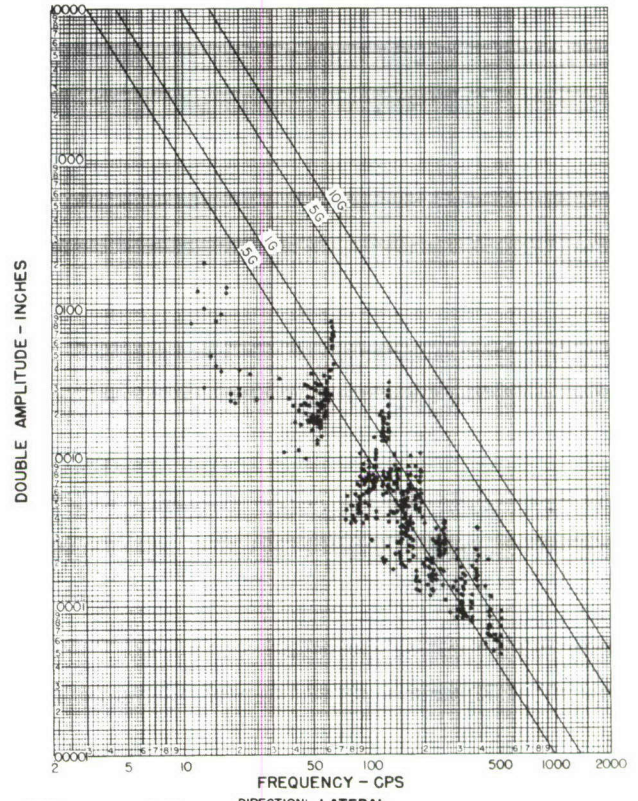


Figure 62. DIRECTION: LATERAL  
LOCATION: TOP CENTER OF FUSELAGE AT STA. 165

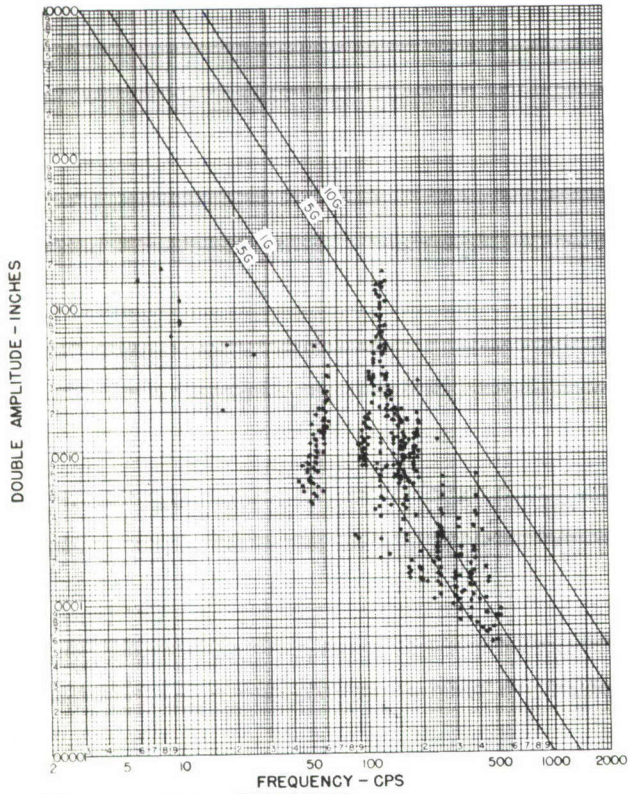


Figure 63. DIRECTION: F/A  
LOCATION: TOP CENTER OF FUSELAGE AT STA. 165

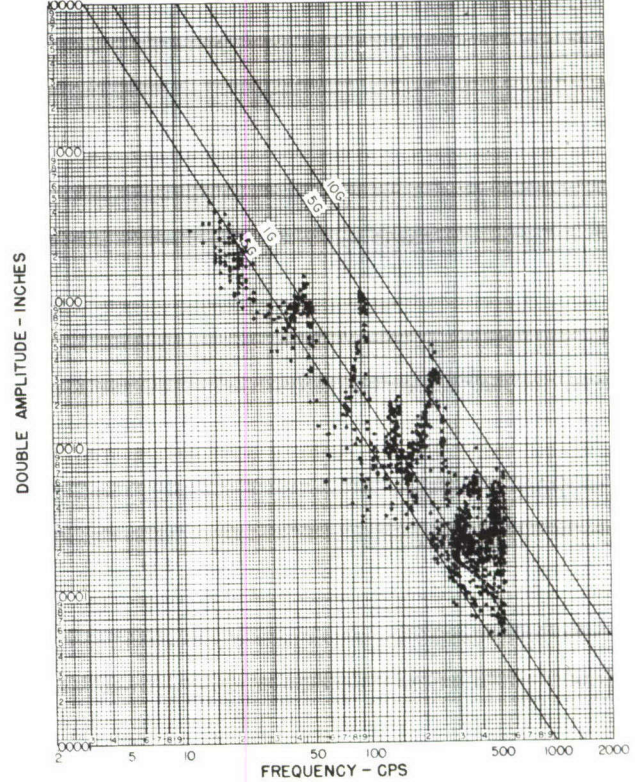


Figure 64. DIRECTION: VERTICAL  
LOCATION: ACCESSORY SECTION OF #2 ENGINE

Figures 61 to 64. Summary Plots for Individual Vibration Pickups

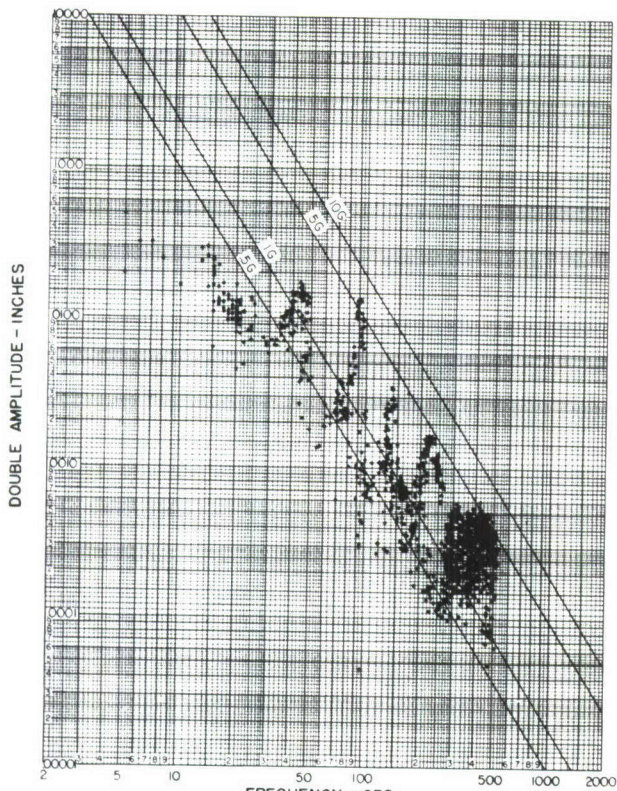


Figure 65.  
 FREQUENCY - CPS  
 DIRECTION: LATERAL  
 LOCATION: ACCESSORY SECTION OF #2 ENGINE

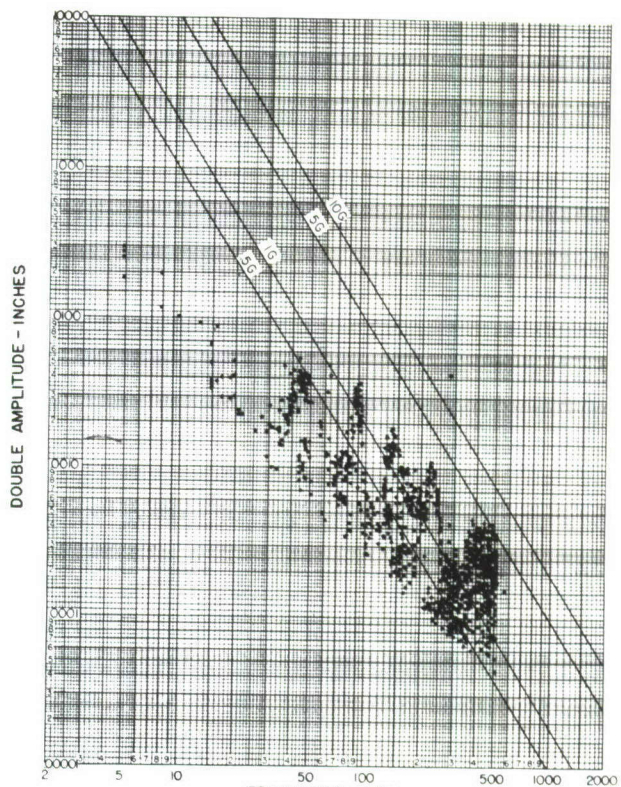


Figure 66.  
 FREQUENCY - CPS  
 DIRECTION: F/A  
 LOCATION: ACCESSORY SECTION OF #2 ENGINE

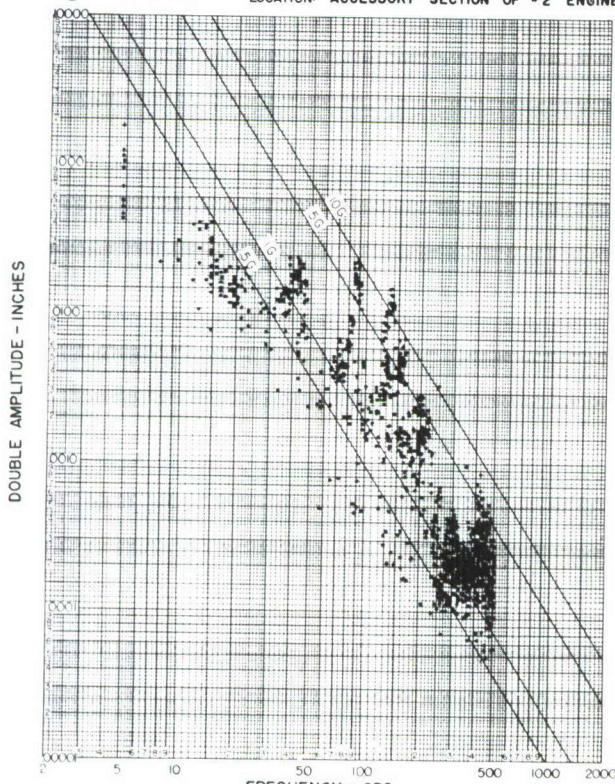


Figure 67.  
 FREQUENCY - CPS  
 DIRECTION: VERTICAL  
 LOCATION: BRUSH SECTION ON D.C. GENERATOR

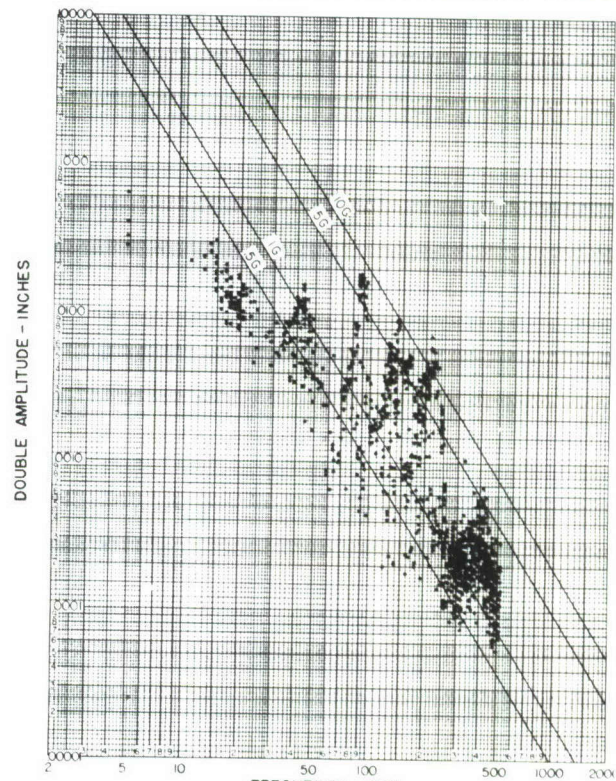


Figure 68.  
 FREQUENCY - CPS  
 DIRECTION: LATERAL  
 LOCATION: BRUSH SECTION ON D.C. GENERATOR

Figures 65 to 68. Summary Plots for Individual Vibration Pickups

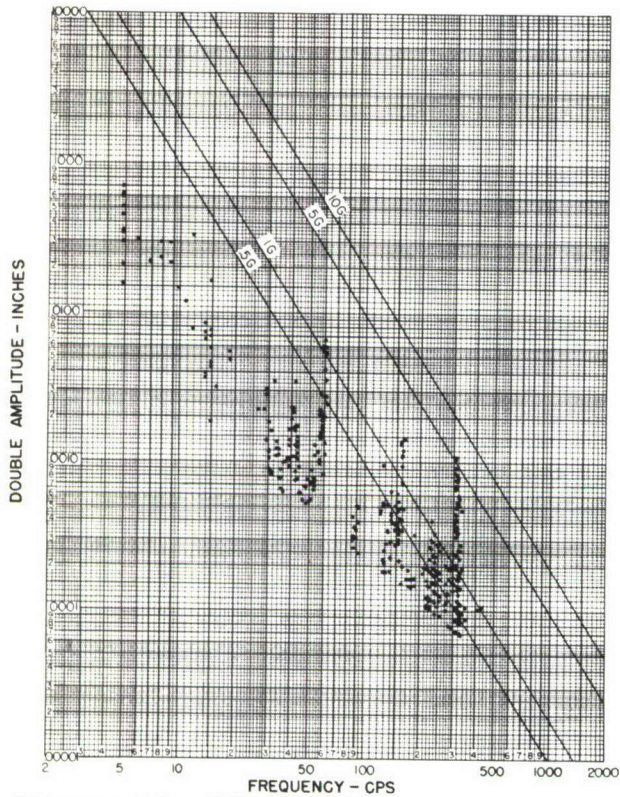


Figure 69. DIRECTION: VERTICAL  
LOCATION: RIGHT WING AT LANDING LIGHT LOCATION

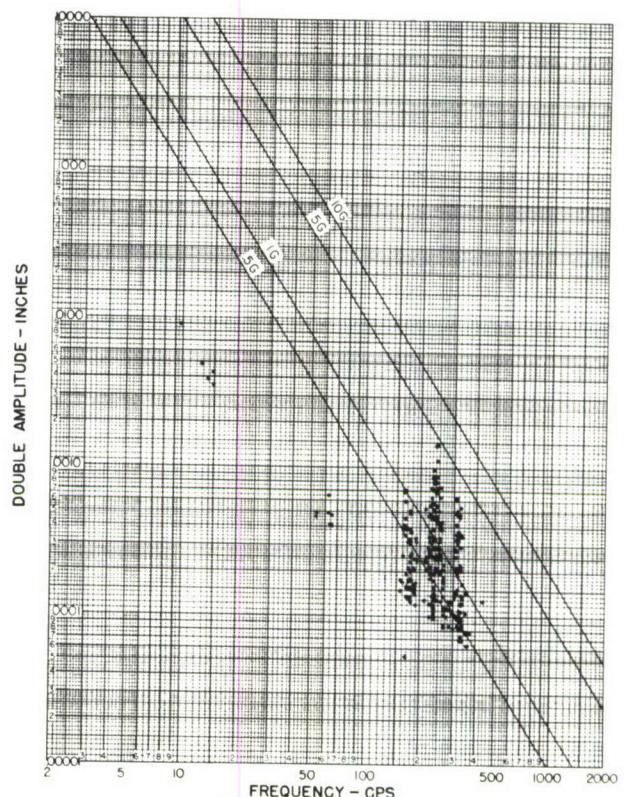


Figure 70. DIRECTION: LATERAL  
LOCATION: RIGHT WING AT LANDING LIGHT LOCATION

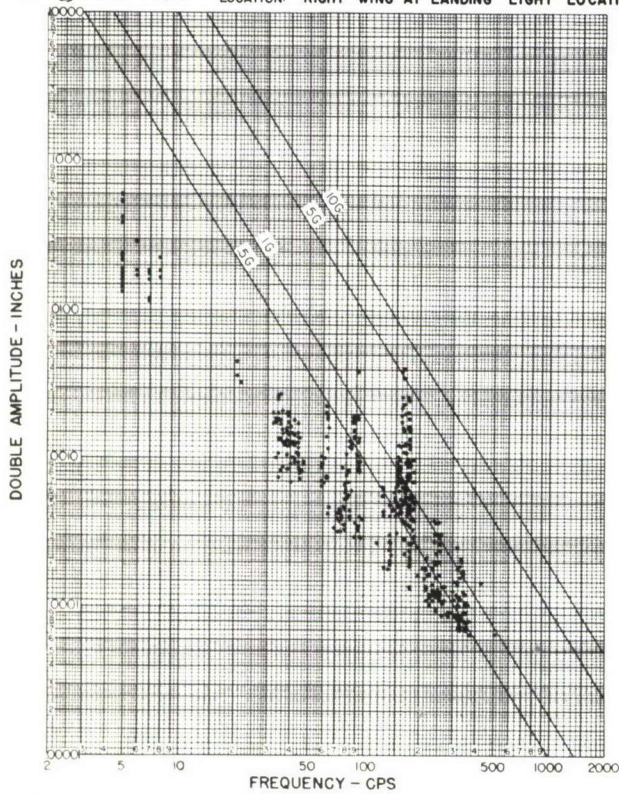


Figure 71. DIRECTION: F/A  
LOCATION: RIGHT WING AT LANDING LIGHT LOCATION

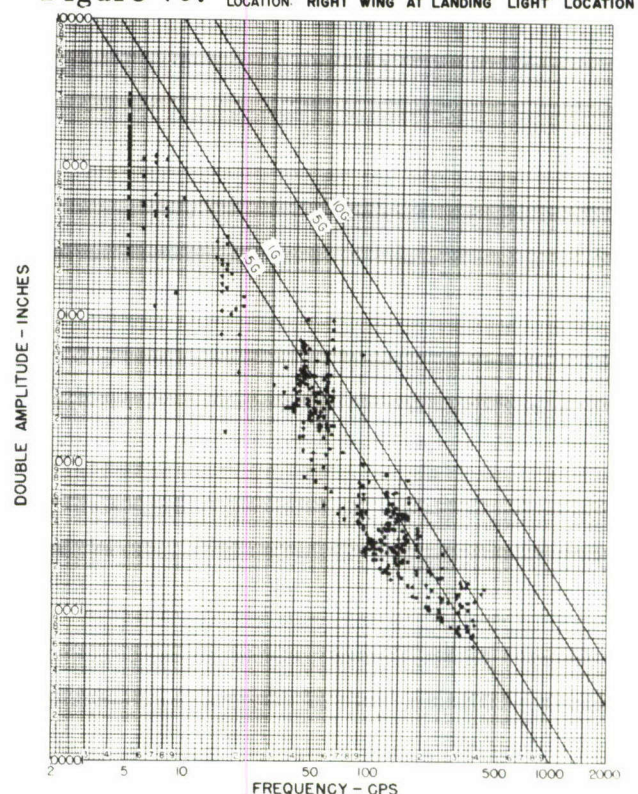


Figure 72. DIRECTION: VERTICAL  
LOCATION: STRUCTURE OF RIGHT WING TIP

Figures 69 to 72. Summary Plots for Individual Vibration Pickups

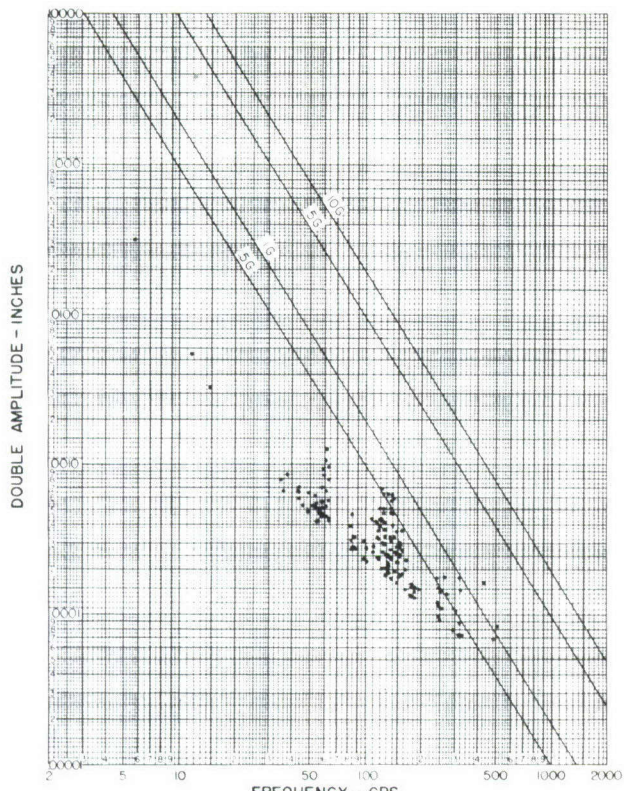


Figure 73.

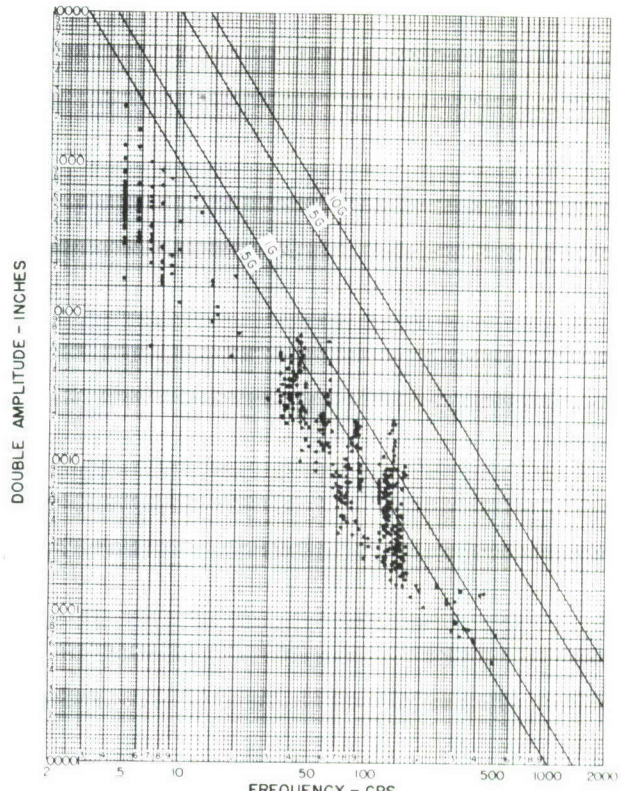


Figure 74.

Figures 73 to 74. Summary Plots for Individual Vibration Pickups