FLIGHT FLUTTER TEST PROGRAM ON CN235-100 / MPA

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Abstract

Flight flutter testing has been performed for the prototype of CN235-100 Maritime Patrol Airplane (MPA) at IPTN Flight Test Center.

The MPA modification of CN235-100 involves, big nose radome modification to accomodate search radar, ESM installed on top forward fuselage and rear fuselage, FLIR, BUBBLE WINDOW for observation and also external stores such as harpoon missile and external full tank on the wing.

Flight flutter testing was conducted to open flight envelope to suit for maritime military operation requirements, in this case, to determine whether the airplane is free from flutter up to its operational limits speed and altitude.

The airplane has been instrumented with adequate equipment for evaluation of the test result. Accelerometers and potensiometers were installed at preselected locations, to measure structural responses of the aircraft. All measured signals were recorded by on board tape recorder for later off line analysis. However some of the important signals were transmitted by telemetry for on line real time monitoring and evaluations.

The test results show that CN235-100/MPA is clear from flutter speed up to its operational limits speed and altitude therefore it is permitted to continue for further testings.

Introduction

Despite the flutter analysis method to obtain the natural frequencies and the unsteady aerodynamic of the airplane have recently been analytically satisfied but in the certain case the results of the analysis had a discrepancies between the theoretical analysis and the real flight testing condition. Therefore in order to overcome the encountered a flight flutter testing is necessary to be performed for any new airplane or a modified derivative production airplane.

On CN235-100/MPA a modified involving changes on its big radome ESM, FLIR, bubble window installations and some stored on the wings is influence airplane stiffness and the unsteady aerodynamic on its main structure (wings).

The prototype of CN235-100/MPA is fully flight test instrumented to evalute the performance and flying quality as well as flight flutter test purposed. The Onboard Data Acquisition System (OBDAS) is linked with telemetry system, hence the measured parameters and an intercom test crew hot-mike voice are able to be transmitted and monitored by the Mission Operation Control Room (MOCR) crews.

The basic CN235-100 is a high-wing airplane with cantilever mounted type and powered by 2 General Electric (GE) CT7-9C engines. The airplane is having cruising speed of 180-200 Kias and maximum certified gross weight of 15400 Kg.

Figure 1 gives an impression of CN2365-100/MPA with its wings stored configuration. As can be seen from figure 1, the external stores consists of the harpoon on the starboard and external fuel tank on the port side.

Prior to conduct flight flutter testing on the CN235-100/MPA, flutter analysis has been [1] adopted as prediction for the flutter condition which may be occured. Initial flight flutter testing was performed base on save condition for crews familiarization exercise for preparation into real flight flutter testing.

The familiarization was required in order to assure that the flight test instrumentation system was function properly and to build-up a good cooperation between flutter test engineer and crew to anticipate and able to overcome any trouble or emergency if appear.

The objective of the flight flutter testing is not to encounter flutter but rather to demonstrate by flight testing at limit speed, that the CN235-100/MPA will be safe from flutter within the test envelope, and to continue further proposed flight testing

Instrumentation

The flutter transducers used on this testing consisted of the accelerometers and the potentiometers which were installed on the strategically position to record and monitor the airframe responses due to the flight control excitation. Total of 29 flutter transducers were installed on board the airplane. All of the accelerometers were installed on the rigid structure to avoid effect of local vibration. The potentiometers were used to measure the flight control excitations that were given by the pilot. The accelerometers were utilized to pick up the airframe response signals.

The location of the CN235-100/MPA transducers are shown on figure 1.

Test Description and Test Procedure

The flight flutter testing program has been included in a wider CN235-100/MPA flight test program, by performing six scheduled flights for two different configurations MOD3C (Symmetric external store) and MOD 3D (Asymmetric external store). Several fuel quantity configurations and various flaps positions have been tested to cover CN235-100/MPA typical flight envelope conditions. The flutter program is described briefly as shown in Table 1.

The data collection of flutter flight test was initially carried out by stabilizing the airplane at desired aim speed according to the briefed test sequence.

When the airplane was stable at the desired speed and altitude, the pilot jerked or kicked the longitudinal, lateral or directional controls and leaving the airplane to reply freely to the excitaions in the eight/ten second interval.

By monitoring the airplane response via strip chart recorder after the airplane was excitated, flutter engineer could get an information of data required with related to the test instrumentation installed. If the airplane responses appeared safe then it could be decided for further test point by establishing higher speed. The test was continued until reach 220 KEAS. Therefore during one flight mission, several flutter flight test points could be obtained. The test sequence of this approach can be shown on Table 1.

This test sequence was defined based on test safety consideration and an efficiency flight test profile. Prior to conduct the test program, the test sequence has been reviewed by the Flight Test - Technical and Safety Board (TSRB) for obtaining flight test program clearance. Detail test plan is described on [2].

Data Reduction and Analysis

As it is previously mentioned the airplane responses due to the pilot's controls excitation were measured by the transducers and through the signal conditioning the measured signals were than recorded by on board tape recorder. As the test airplane was equipped with telemetry antenna as required by TSRB, a selected parameters were transmitted to Mission Operation Control Room (MOCR) for on line (real-time) monitoring.

A schematic diagram showing this data aquisition process for data reduction is given on Figure 3.

For test analysis there are two paths of signal processing analysis, which are :

- On line monitoring, to real time analysis in order to monitor the safetyness and the stabilization of the airplane during each test point. Figure 3 showed strip chart of the flight control excitation and several structure responses.
- Batch process analysis (off-line) in which it gives an information required from all flutter testing tranducers. The structural frequency and structural damping are determined in this phase hence it can define airplane structural responses or characteristics.

The evaluation and analysis of the responses data has been conducted with an extensive use of the Fast Fourier Transform (FFT) algorithm, which has been built up on the spectrum analyzer. (Le Croy Digitized Spectrum Analyzer).

An example of the result analysis from the spectrum analyzer was shown on figure 4. As can be seen from this figure, the identification of the structural frequencies can be obtained from the spectrum analyzer by picking up the top of the frequency domain graphic. On the sample plot there are several structural frequencies appreared which are indicated from the tops of the frequency domain graphic.

The determination of the structural damping value can be obtained from samples plot on figure 5 and 6 by using the time histories log decrement method. However the structural damping resulted by this method is not too accurate but it gives sufficient information and can justify the structural damping qualitatively.

Test Result

As it descibed on Table1, it gives the test description of flight flutter testing covering several airplane configuration and flight conditions. The test were carried out in the vicinity of Bandung area with the altitude test band of 8 000 ft to 14 000 ft pressure altitude.

All test point were performed in Visual Meteorological Condition (VMC) and only on daylight condition as requested by the TSRB. From real time analysis it was observed that all test points were performed in good stabilization prior the airplane was excited. The air was relatively calm and only light turbulence was encountered at few test points.

From off-line analysis by using spectrum analyzer the results are shown on Figure 7 to 10 which covering test configuration and condition as described on Table 1. From these Figures, generally the airplane's structural frequencies of the wing tip, horizontal stabilizer tip, vertical stabilizer and the engine mounting were occur at the frequencies between 3.4 Hz to 10.0 Hz. These relatively low frequencies which appeared were normal typically response of impuls excitation.

Morever it is shown that all of the structural responses were having high level of structural damping $\xi > 0.1$ (Figure 5 and 6).

From the stuctural damping results, it indicates that the airplane is having positive structural stability as no aeroelasticity instabilities were occured during covering all test points. Moreover the structural damping characteristic showed that it allowed sufficient safety margins to carry out further flight test development on CN235-100/MPA.

From the specific airplane structural responses evaluation, it dictates that the horizontal stabilizer is having the highest buffet level among others monitored main airplane structure. This was caused by the effect generated from the propeller wash down stream hit the horizontal stabilizer surface. However the buffet level was acceptable as it was well below the structural buffet limitations. For rudder excitation it were observed that the structural responses were heavily damped due to insuffient excitation energy generated by the rudder. Therefore this input was then eliminated for further flights during flutter flight test program.

Airplane fuel configuration on the left and right wings give not much influence on the airplane structural responses as these variation of configurations have not introducing significant differences on the structural frequencies and damping (see Fig 7 and Fig 8).

From the flight test technique it was found that it was difficult to generate symmetrical mode due to very small amplitudes excitation by the elevator impulse input.

Reference [3] gives detail flight test report of CN235-100/MPA in which it indicates that the airplane is free from flutter up to 220 KEAS by covering its flying envelope.

Conclusion and Recommendation

At IPTN Flight Test Center, the flutter clearance program of CN235-100 /MPA has been performed covering the typical airplane flight envelope. As expected, no aeroelastic instabilities were occured, and the characteristics behavior of damping curves showed that sufficient safety margins, were available and therefore the CN235-100/MPA could continue other flight test program covering the flight performance and flying quality as a complementary part of opening or expansion flight envelope..

Excitation by impulse metode was difficult to identify the critical modes, whether it is symmetrical or antisymmetrical mode.

Therefore for next flight flutter test program it is recommended to improve excitation system as well as analysis method and data aquicition to identify the critical mode for determination of speed margin hence the airplane will not encounter any aeroelastic instabilities.

References

1. Wing flutter characteristic of CN235-MPA, Technical Note : TN - 047 / T1400 / 05/90
2. Flight Flutter Test, Technical Document Airtec Doc ; 84 - 3207, Airplane CN235,
3. Flight Test Report CN235 - 100/MPA Development phase, Doc. No : FTRI-PMD-X1-90, Flight Test Center IPTN.

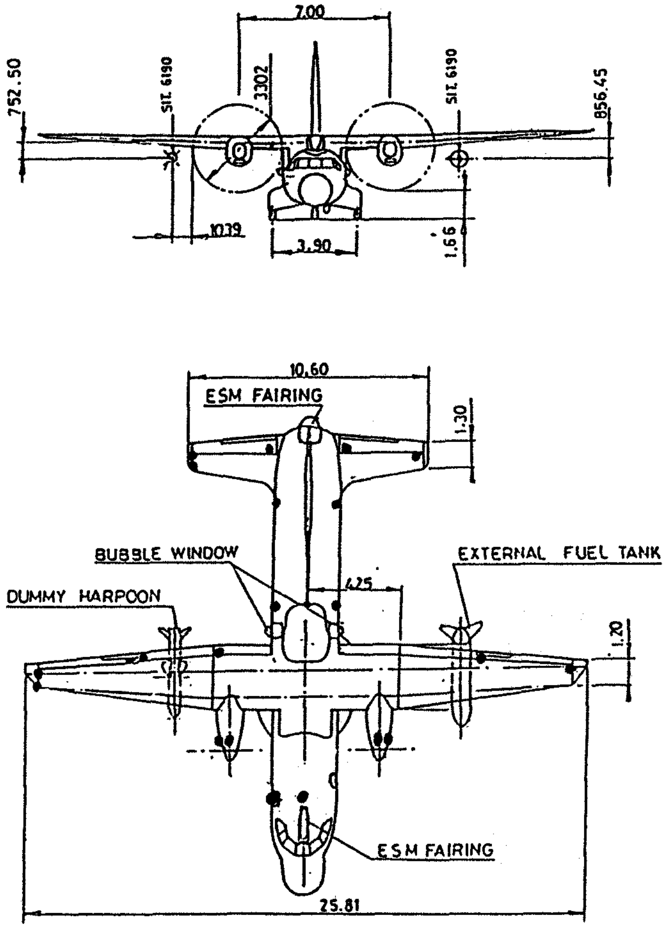


Figure 1. CN235-100/MPA MOD3C and the Flutter Transducers Location .

FL.	ALT (ft)	FUEL	FLAPS (deg)	VEL. (KEAS)
1	14000	min	0	150
1	14000	min	0	165
1	14000	min	0	180
1	8000	min	0	170
1	8000	min	0	190
2	14000	max	0	150
2	14000	max	0	165
2	14000	max	0	180
2	8000	max	0	170
2	8000	max	0	190
3	14000	max	0	190
3	14000	max	0	200
3	8000	max	0	200
3	8000	max	0	210
3	10000	max	10	135
3	10000	max	10	145
3	10000	max	10	155
4	14000	min	0	190
4	14000	min	0	200
4	8000	min	0	200
4	8000	min	0	210
4	10000	min	10	135
4	10000	min	10	145
4	10000	min	10	155
5	14000	min	0	210
5	8000	min	0	220
5	10000	min	23	130
5	10000	min	23	140
5	10000	min	23	150
6	14000	max	0	210
6	8000	max	0	220
6	10000	max	23	130
6	10000	max	23	140
6	10000	max	23	150

TABLE 1 : Flight Flutter Test for CN235-100/MPA

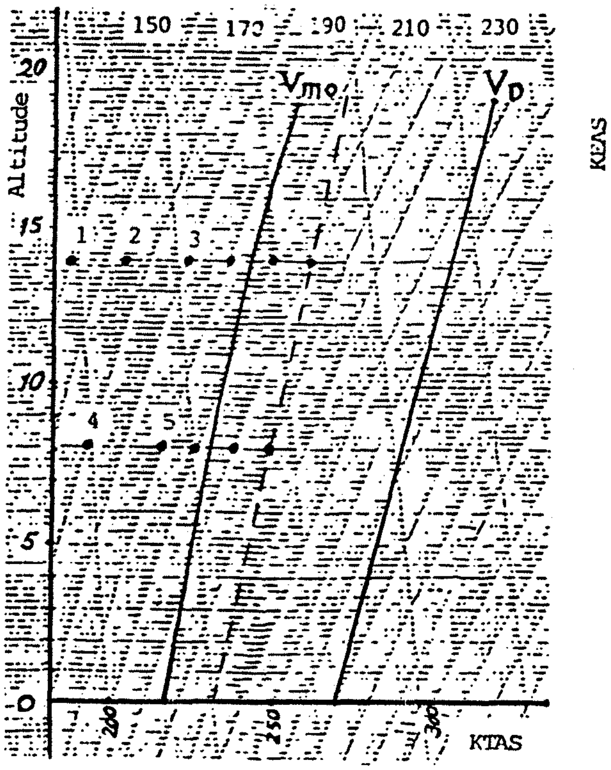


Figure 2. Flight Test Point Sequence.

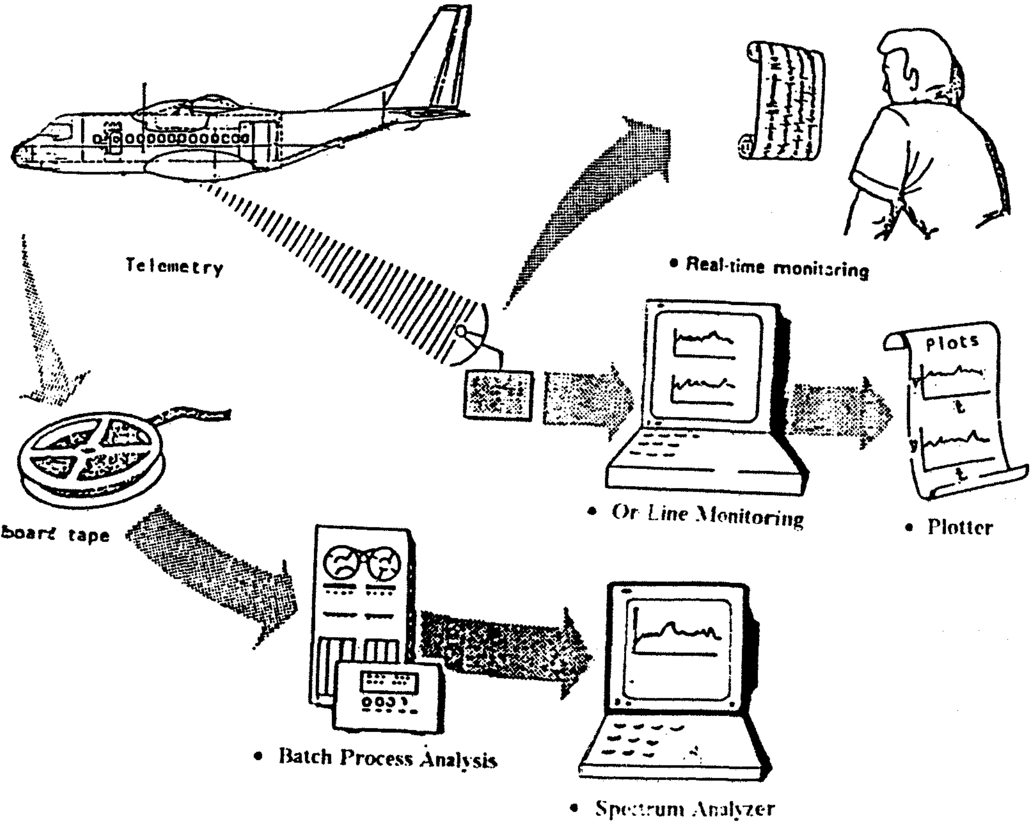


Figure 3. Data Aquisition Process.

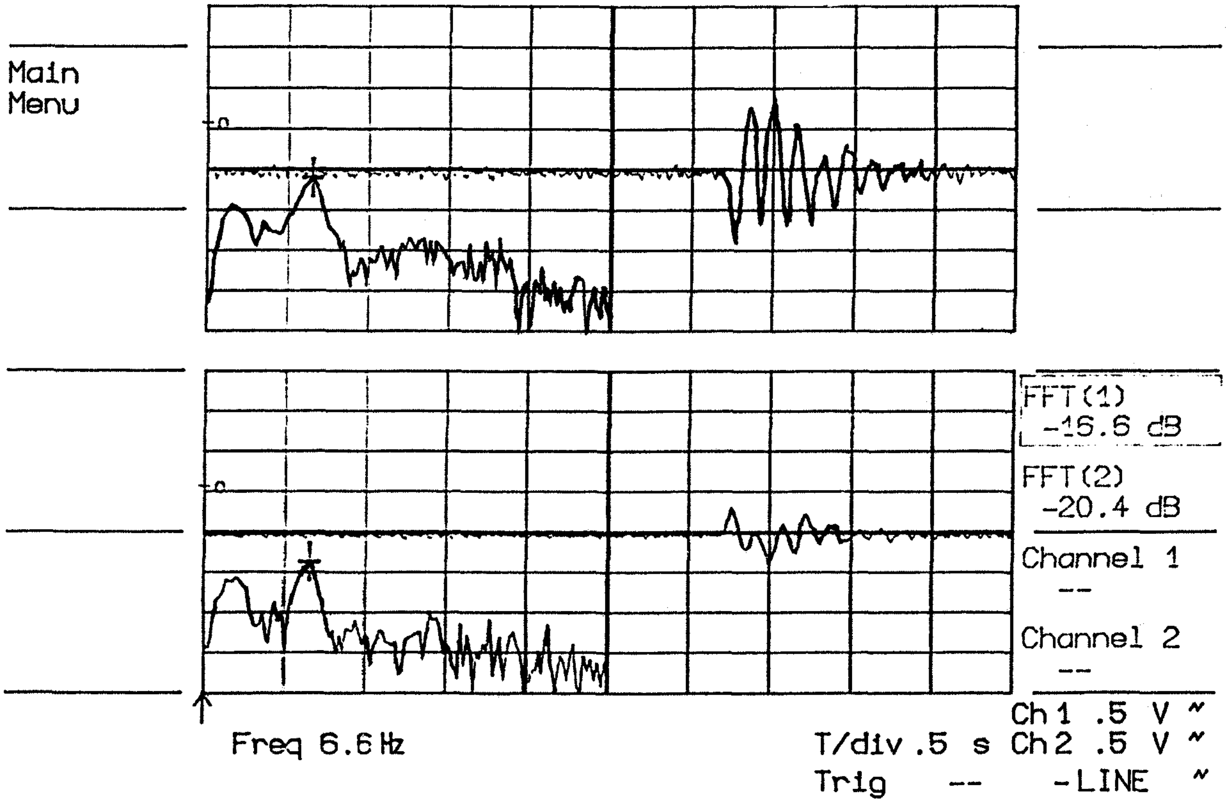


Figure 4. V = 170 KEAS, Right Aileron Excitation, Alt = 8000 Ft.

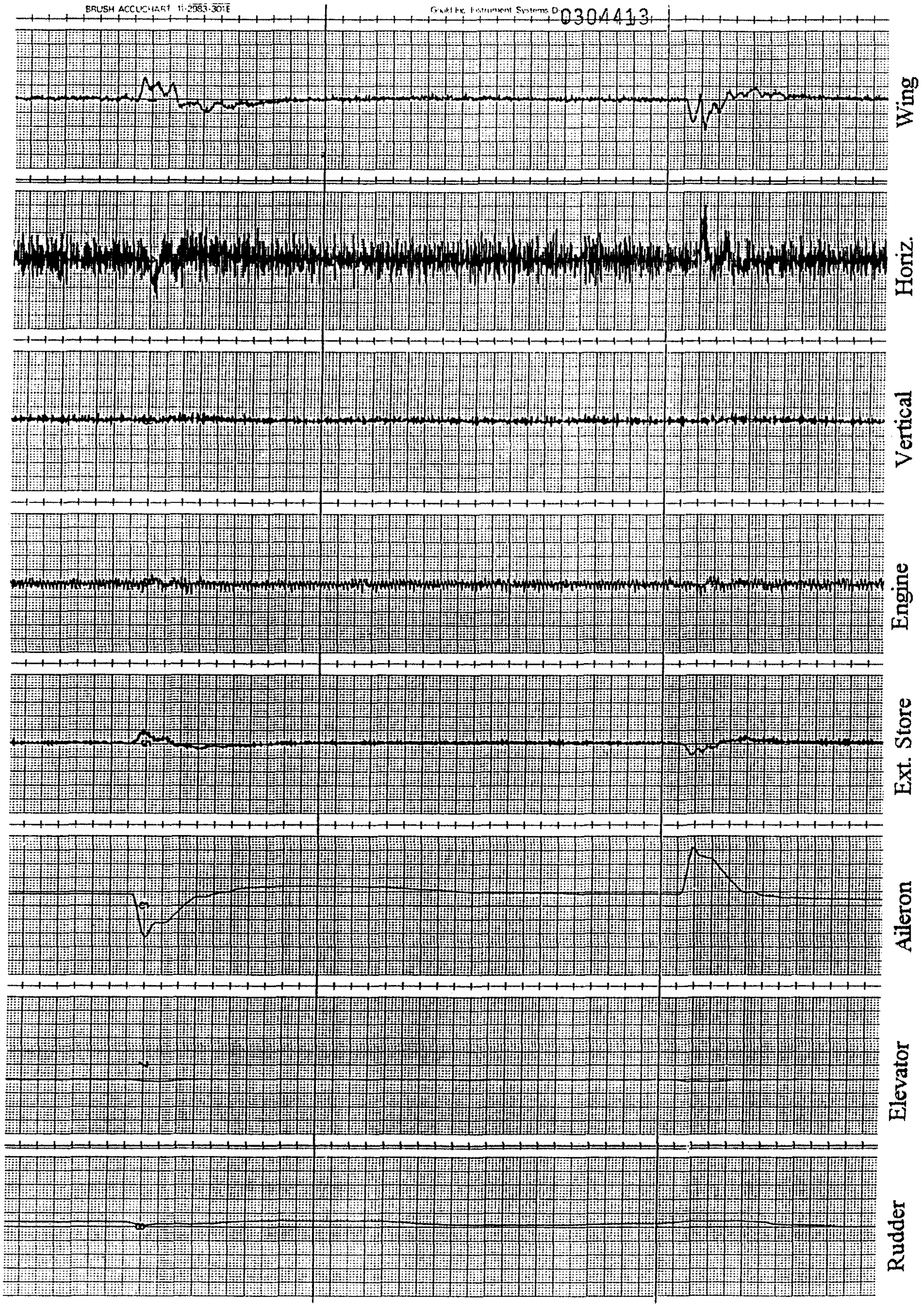


Figure 5 : Time Response and Excitation on the Aileron (V = 190 KEAS)

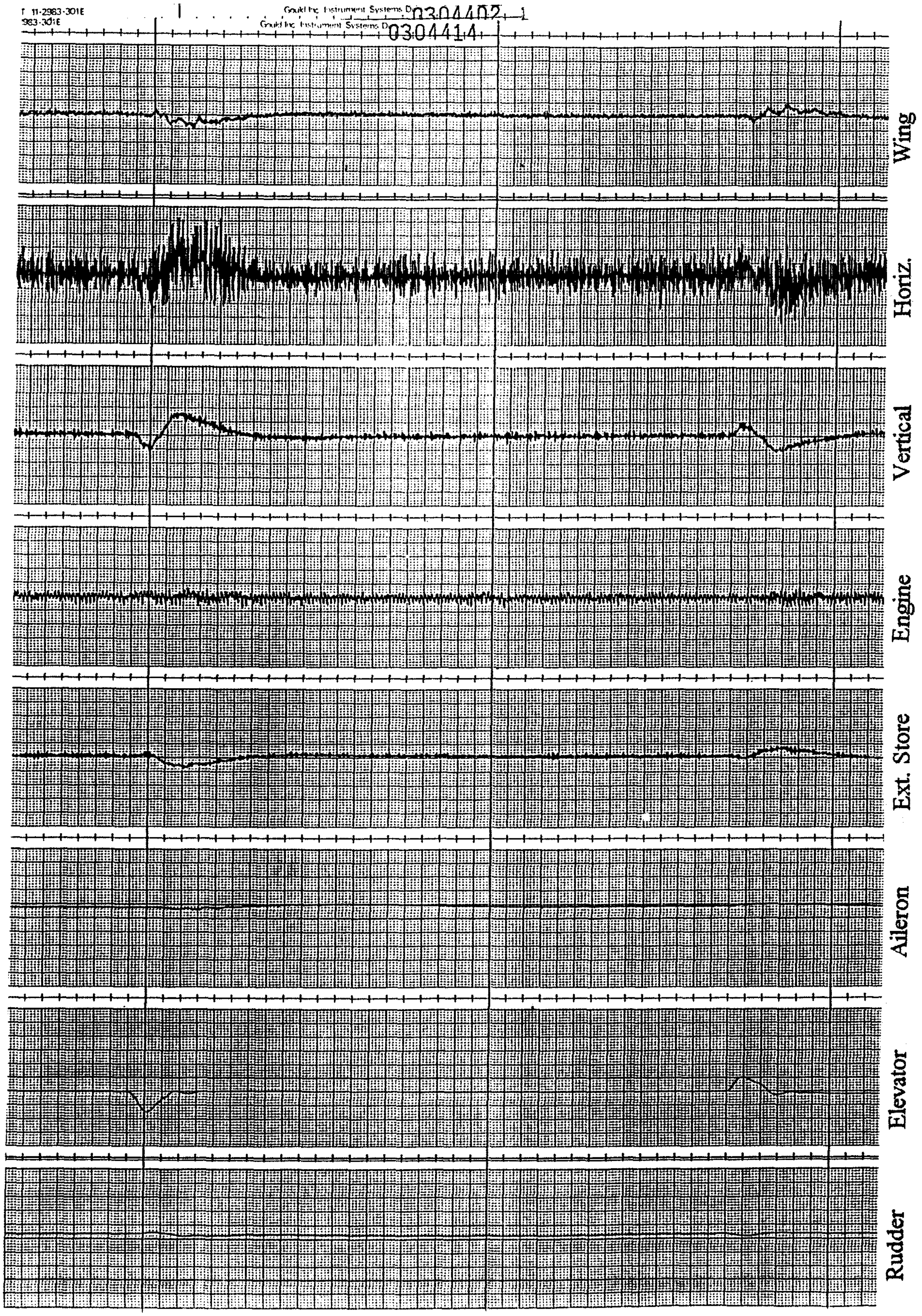
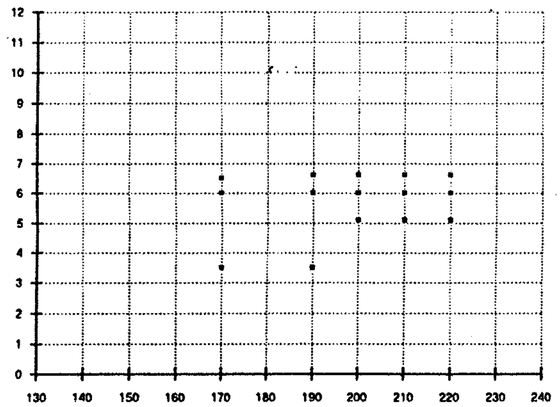
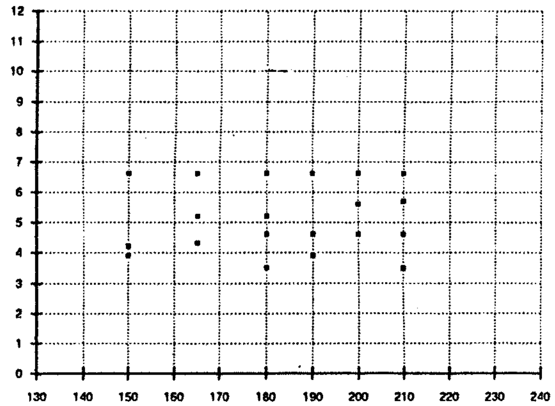


Figure 6 : Time Response and Excitation on the Elevator (V = 190 KEAS)

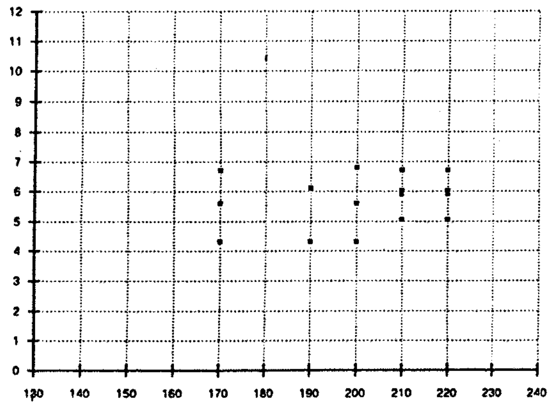
CN235-100/MPA MOD-3C MAX FUEL ALT = 8 KFT



CN235-100/MPA MOD-3C MAX FUEL, ALT = 14 KFT



CN235-100/MPA MOD-3C MIN FUEL, ALT = 8 KFT



CN235-100/MPA MOD-3C MIN FUEL, ALT = 14 KFT

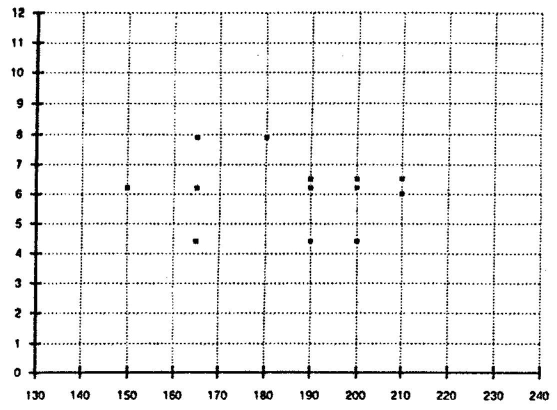
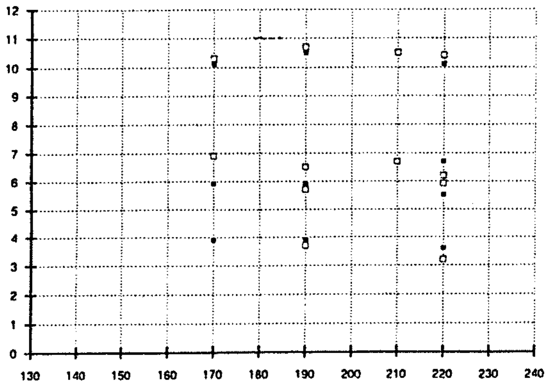
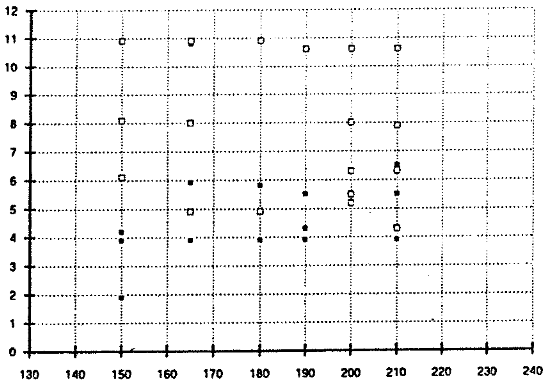


Figure 7: Engine Mount and External Store Responses (Velocity vs Frequency)

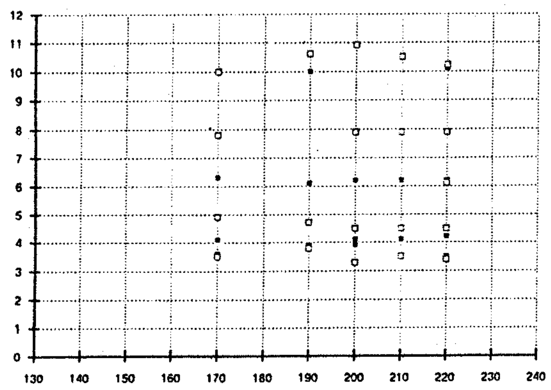
CN235-100/MPA MOD-3C MAX FUEL, ALT = 8 KFT, SYMMETRIC



CN235-100/MPA MOD-3C MAX FUEL, ALT = 14 KFT, SYMMETRIC



CN235-100/MPA MOD-3C MAX FUEL, ALT = 8 KFT, ASYMMETRIC



CN235-100/MPA MOD-3C MAX FUEL, ALT = 14 KFT, ASYMMETRIC

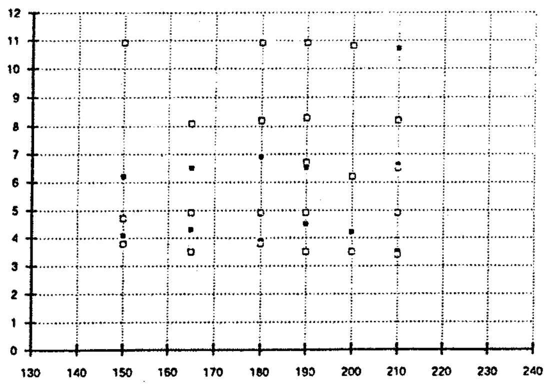
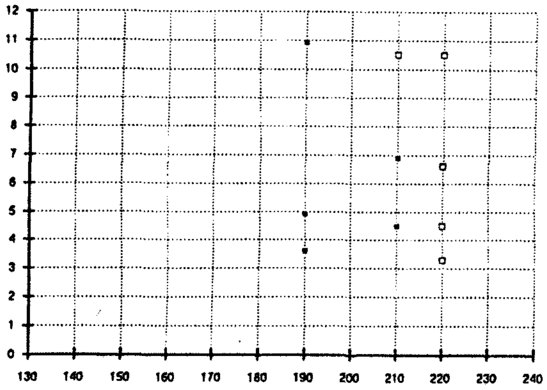
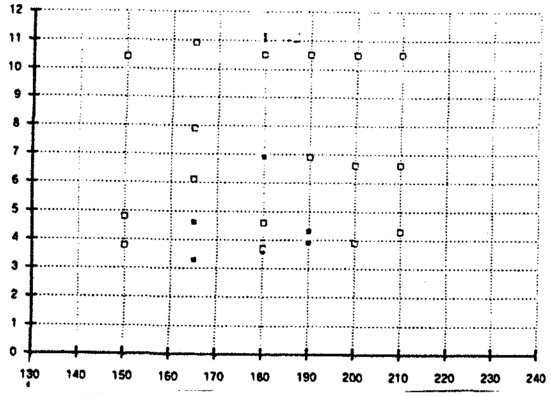


Figure 8 Wing Tip and Horizontal Tip Responses (Velocity vs Frequency)

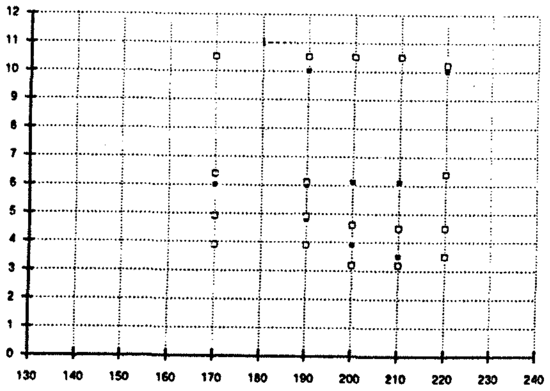
CN235-100/MPA MOD-3C MIN FUEL, ALT = 8 KFT, SYMMETRIC



CN235-100/MPA MOD-3C MIN FUEL, ALT = 14 KFT, SYMMETRIC



CN235-100/MPA MOD-3C MIN FUEL, ALT = 8 KFT, ASYMMETRIC



CN235-100/MPA MOD-3C MIN FUEL, ALT =14 KFT, ASYMMETRIC

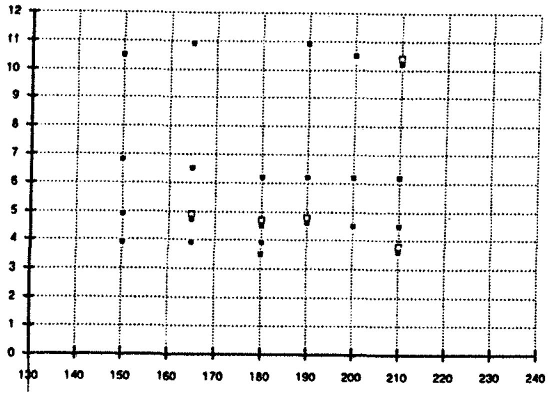
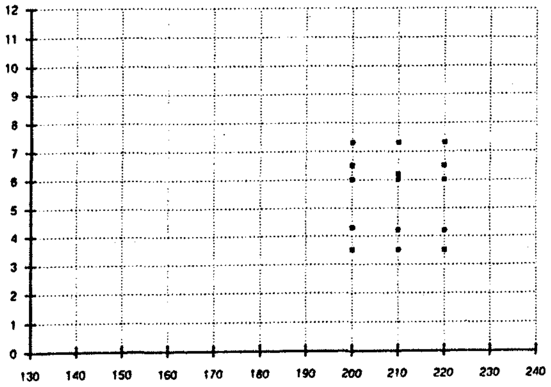


Figure 9 Wing Tip and Horizontal Tip Responses (Velocity vs Frequency)

CN235-100/MPA MOD-3D MIN FUEL, ALT = 8 KFT, SYMMETRIC



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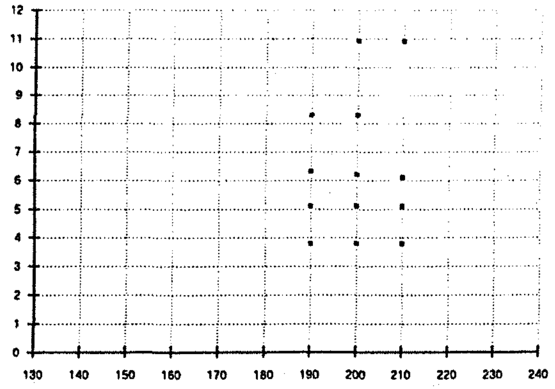

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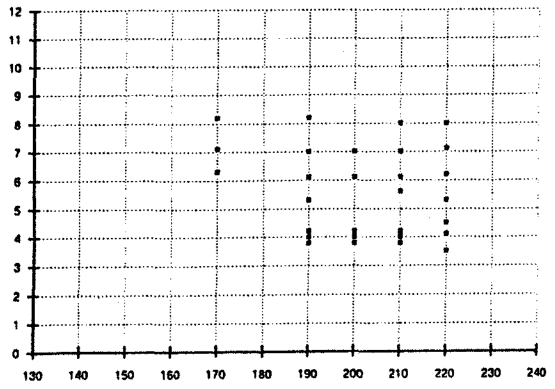

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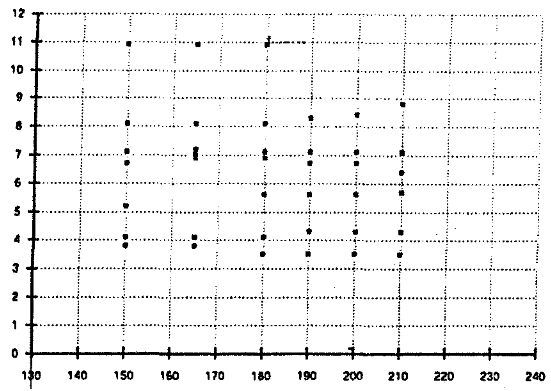

Figure 10 Wing Tip and Horizontal Tip Responses (Velocity vs Frequency)