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TECHNICAL MEMORANDUM

SX-595

for

Federal Aviation Administration
Civil Aeronautics Board
Aerospace Industries Association of America
Air Transport Association of America

SOME INFORMATION ON THE OPERATIONAL EXPERIENCES OF TURBINE-POWERED COMMERCIAL TRANSPORTS

By Joseph W. Jewel, Jr., Paul A. Hunter, and Milton D. McLaughlin

Langley Research Center
Langley Field, Va.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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ABSTRACT

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SUMMARY

This report presents a brief discussion of some information on the operational experiences noted on VGH records from six types of turbine-powered commercial transport aircraft. These flight characteristics cover oscillatory motions, maneuver accelerations, sinking speeds, placard speed exceedances, and miscellaneous or unusual flight events.

INTRODUCTION

At a meeting in Washington, D.C., on March 15, 1961, information pertaining to several aspects of turbine-powered transport operations was discussed with representatives of the Federal Aviation Administration, the Civil Aeronautics Board, the Aerospace Industries Association of America, and the Air Transport Association of America. This information was based primarily on data collected by the National Aeronautics and Space Administration with VG and VGH recorders and pertained to: airplane oscillatory motions, maneuver accelerations, sinking speeds, placard speed exceedances, and to miscellaneous or unusual flight occurrences. As a result of these discussions, copies of the figures used in the presentation are being made available to the several organizations for further study and consideration. The pertinent figures together with some explanatory remarks are presented herein.

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DISCUSSION OF VG AND VGH RECORDS

Typical examples of the records obtained from the NASA VG and VGH recorders are shown in figures 1 and 2, respectively. The characteristics and accuracies of these two recorders are given in references 1 and 2.

Results obtained from records of ten airlines are included in the program. The scope of the program is indicated in the following table:

Aircraft			Number of aircraft instrumented with -		Number of airlines
Designation	Number of engines	Type	VGH	VG	
A	4	Turbojet	6	12	3
B	4	Turbojet	8	14	5
C	4	Turbojet	5	8	3
D	4	Turboprop	7	8	4
E	2	Turboprop	2	2	1
F	4	Turboprop	1	0	1
Total			29	44	---

The VGH and VG data sample sizes in terms of flight hours and also in terms of the percent of the total commercial turbine fleet time accumulated to date are given in the following table:

	VGH	VG
Flight hours	14,571	73,000
Percent total turbine aircraft fleet time	$\frac{3}{4}$	$3\frac{1}{2}$

As shown, the VGH data represent 0.75 percent and the VG data 3.5 percent of the turbine fleet time.

The distribution of in-flight fatigue damage for a turbine-powered transport due to various sources of loads is not presented herein.

Oscillatory Accelerations

From VGH records collected on several types of commercial transports it has been observed that each type of airplane on occasion experiences oscillatory motions in the longitudinal or the longitudinal-lateral modes. These oscillations are evidenced on the VGH records primarily by the variations in the normal acceleration recorded at the center of gravity and also by variations in the airspeed and altitude. Information pertaining to the characteristics of these oscillatory accelerations is presented in tables I and II and figures 3 and 4.

The general characteristics of the oscillatory motions are summarized in table I. This table shows some of the typical acceleration wave forms, periods, and amplitudes of the oscillations recorded on the turbine-powered aircraft. The values shown for the half-amplitude of the accelerations are average maximum values rather than the maximum values which have been recorded. Maximum amplitudes of about $\pm 0.2g$ have been noted for the nearly constant-amplitude oscillations and $\pm 0.9g$ for the divergent- or convergent-type oscillations. The duration of the oscillations ranges up to about 2 minutes for the divergent-type oscillations and up to about $2\frac{1}{2}$ hours for the constant-amplitude oscillations.

The oscillations occurred primarily during the cruise portion of flight, although they have been noted occasionally during climb and descent. In general, the oscillations occur randomly and do not appear to be associated with any particular airspeed-altitude combination. The oscillations have been recorded with and without the autopilot in operation, although most of the instances apparently occurred with the autopilot engaged.

Figure 3 shows a divergent-type oscillation which has been noted a dozen or more times on both turbojet- and turboprop-powered airplanes. In these instances, the long period (approximately 20 seconds) oscillation is apparently induced by either light turbulence or buffeting. Generally, this type of oscillation continues until the airspeed is reduced.

The percentage of the total flight time during which the oscillatory acceleration occurs is given in table II for the six types of aircraft considered. Also included in the figure are the number of airlines and the number of airplanes from which the data were obtained. The percentages given in the figure are average values for each type of airplane. Individual airplanes vary widely from the average values. For example, one airplane has been observed to oscillate about 25 percent of the time.

Reported causes of the oscillations have included malfunctioning of autopilots due to such items as mismatched pitch accelerometers, vertical gyroscope malfunctions, air data computer malfunction, or improper engagement of the autopilot. Other reported causes are control-system friction and play in the control linkage.

Figure 4 illustrates the effect of maintenance on the oscillatory accelerations on one airplane. In this figure the ordinate is the percent of the total flight time during which the oscillations occurred and the abscissa is the time covered by the data sample. Each bar represents one VGH record, the width of the bar reflecting the time the record was in the aircraft. As can be seen from the figure the oscillations occurred less than about 0.2 percent of the time prior to December. Between January and March the oscillations increased to about 1 percent of the total flight time. At this time, during a maintenance inspection, excessive wear was discovered on a bearing and bolt on the elevator control linkage. The bearing and bolt were replaced and the percent flight time the oscillations occurred was reduced to about the same level as for the May to December period.

Maneuver Accelerations

A comparison between the accelerations experienced by turbojet, turboprop, and piston-powered aircraft in both operational and check flights is given in figure 5. The percent of the total flight time spent in check flights is indicated for each type of aircraft. The abscissa is the maximum acceleration expected, on the average, in 100,000 miles of total flight operations. Generally, the acceleration levels for the three types of aircraft are about the same although turboprop E shows a somewhat higher acceleration experience for both the operational and check flights.

Sinking Speed at Touchdown

The highest sinking speeds encountered in one landing out of a thousand by turbojet, turboprop, and piston engine aircraft are shown in figure 6 as a bar graph, where the length of the bar represents the sinking speed in feet per second. These results are based on sinking speeds computed by the method of reference 3 from landing impact accelerations read from VGH records. The number of landings used in establishing the distribution of sinking speeds is shown in the figure. Results similar to those shown in figure 6 have also been obtained from photographic measurements of sinking speeds.

Overspeeds

There were three phases in the program on overspeeds (that is, speeds that are in excess of operational placards): initial sample, airline visits, and subsequent sample. A brief review of these phases follows. About 18 months ago and after a study of the initial samples of VG and VGH data a marked increase in overspeeds with the introduction of turbine-powered aircraft to the airline fleets was noted. In the first quarter of 1960 a two-man team was sent from the Langley Research Center of the National Aeronautics and Space Administration to visit most of the operators of turbine transports in order to call attention to the overspeeding and point out the possible danger in such practice. In brief, the discussions with the airlines covered:

(a) A review of the basic concepts and philosophy on which current Civil Air Regulations governing minimum structural design requirements and flying qualities are based

(b) The interdependence of the design requirements and operating practices

(c) A review of VG and VGH data which indicated that turbine-powered airplanes were being operated above placard speeds

(d) Emphasizing that operations above placard limit speeds were potentially unsafe and should be avoided in normal operations.

Subsequent samples of VG and VGH data taken during the latter part of 1960 indicate that no overall improvement in the overspeed problem has been achieved. An analysis of the initial overspeed data has been reported in reference 4.

Miscellaneous Events or Unusual Occurrences

From VGH records it has been observed that the turbine transports experience unusual flight situations more frequently than did the piston transports. Figures 7 to 12 illustrate some of the unusual occurrences which have been recorded for four-engine turbine-powered aircraft. A brief description of these figures follows:

Figure 7 shows an abrupt maneuver during climbout. The aircraft experienced a +0.5g increment in acceleration as it climbed from 4,500 feet to 7,000 feet. At this time a pushover of -0.6g increment initiated a 15° descent to approximately 5,500 feet. Again, a positive acceleration of 0.6g increment established the aircraft in a climb.

This flight situation may have resulted from a collision-avoidance maneuver although no information is available concerning this incident.

Figure 8 shows a positive acceleration experienced shortly after take-off, possibly as a result of a collision-avoidance maneuver. The peak value of acceleration was 2.7g or a positive increment of 1.7g. No information was available concerning this particular unusual occurrence.

Figure 9 shows a large loss in altitude soon after take-off. After take-off, the airplane climbed normally to 1,500 feet. At this point, the acceleration trace showed a positive increase as the aircraft entered a turn. During the turn, the altitude dropped back to approximately 500 feet as the airspeed continued to increase. At this position, a positive acceleration plus a possible leveling of the wings put the aircraft into a steep climb. From integrations of the acceleration trace, it appears that the aircraft turned approximately 180° with an angle of bank in excess of 45°.

Figure 10 shows an extremely low airspeed during cruise flight. Information obtained from the operator indicated that the pilot concerned reported experiencing moderate turbulence during the flight. The record shows the aircraft slowing down to 100 knots as it descended from 29,000 to 23,000 feet. Possibly, this was an overshoot on a slowdown maneuver. The stall speed was estimated to be 98 knots for the particular flight condition and weight.

Figure 11 shows an aircraft entering the buffet boundary during cruise flight. In this case, the airplane was at too high an altitude for its weight. A study of the airspeed trace indicated a slow gain of indicated airspeed until a Mach number of 0.85 was reached at which time a high positive acceleration was experienced. The altitude then increased several thousand feet and the airspeed decreased. The slowing maneuver following the high positive acceleration could have been the result of the pilot purposely slowing the aircraft or it may have been a mild pitch-up. A number of instances similar to that shown in the figure have been recorded.

The acceleration trace in figure 12 indicates oscillatory accelerations of ± 0.4g increment in the final portion of a landing approach. (Although the altitude trace suggests the aircraft touched down before going around, the original altitude trace indicated the aircraft did not touch down but came to within 180 feet of the ground before going around.) In the second approach, the oscillatory accelerations were still present but were not as high in magnitude as during the first approach. Oscillatory accelerations during landing for this type of aircraft are unusual and it is suspected that the pilot may have gone around on the first approach because of them.

CONCLUDING REMARKS

This report presented a brief discussion of some unusual flight characteristics noted on VGH records from six types of turbine-powered commercial transport aircraft. These flight characteristics covered oscillatory motions, maneuver accelerations, sinking speeds, placard speed exceedances, and miscellaneous or unusual flight events.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., June 22, 1961.

REFERENCES

1. Richardson, Norman R.: NACA VGH Recorder. NACA TN 2265, 1951.

2. Taback, Israel: The NACA Oil-Damped V-G Recorder. NACA TN 2194, 1950.

3. Dreher, Robert C., and Batterson, Sidney A.: The Estimation of the Statistics of Vertical Velocity From Landing Accelerations and Airplane Weight. NASA TM X-238, 1960.

4. Coleman, Thomas L., Copp, Martin R., and Walker, Walter G.: Airspeed Operating Practices of Turbine-Powered Commercial Transport Airplanes. NASA TN D-744, 1961.

TABLE I

SAMPLE OSCILLATORY ACCELERATIONS

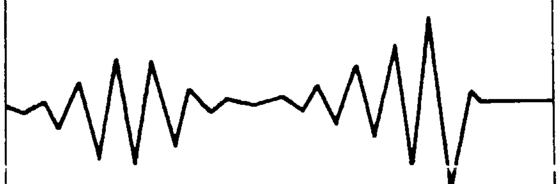
Oscillations	Period, sec	Half-amplitude, g	Aircraft types
	7 to 12	0.3	B, D, and E
	9 to 30	.2	A, B, and C
	4 to 12	.2	B and E
	7 to 17	.8	A, B, D, and F
	15 to 20	.2	B
	15 to 30	.2	A
	2 to 20	.2	E

TABLE II

PERCENT FLIGHT TIME OSCILLATIONS OCCUR

Aircraft type	Number of airlines	Number of aircraft	Percent time
A	3	6	0.5
B	4	7	8.5
C	1	2	2.3
D	3	6	1.9
E	1	2	7.6
F	1	1	.2

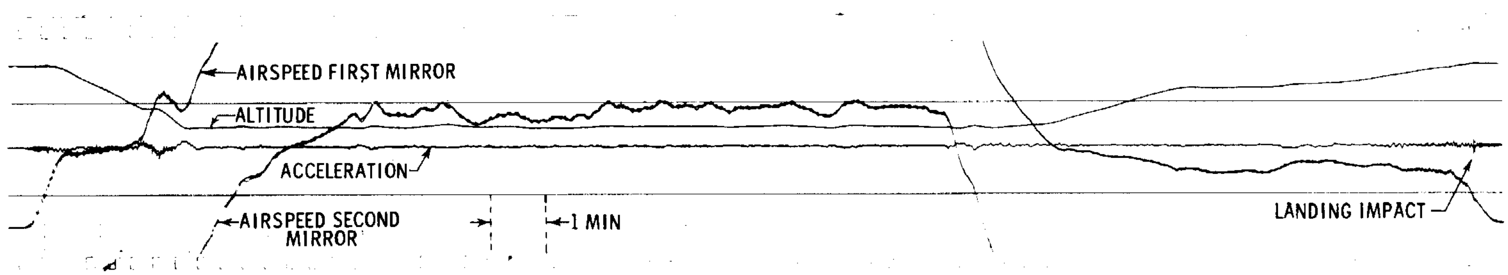


Figure 1.- Example of VGH record.

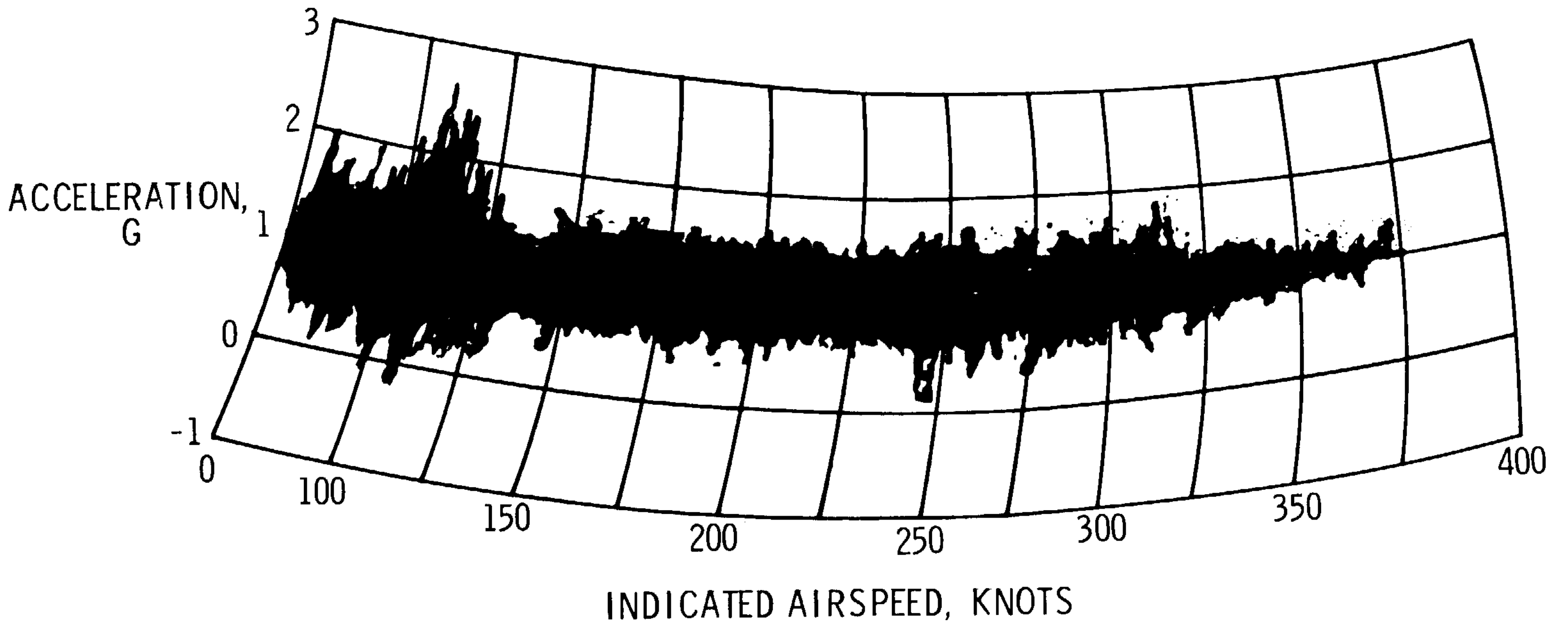


Figure 2.- Example of VG record.

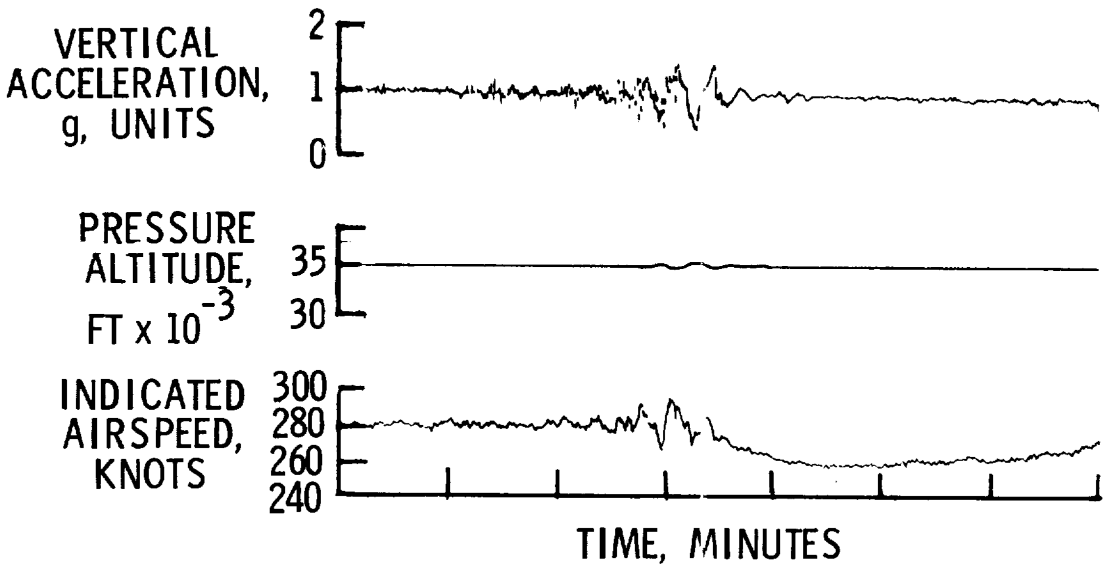


Figure 3.- Divergent-type oscillation.

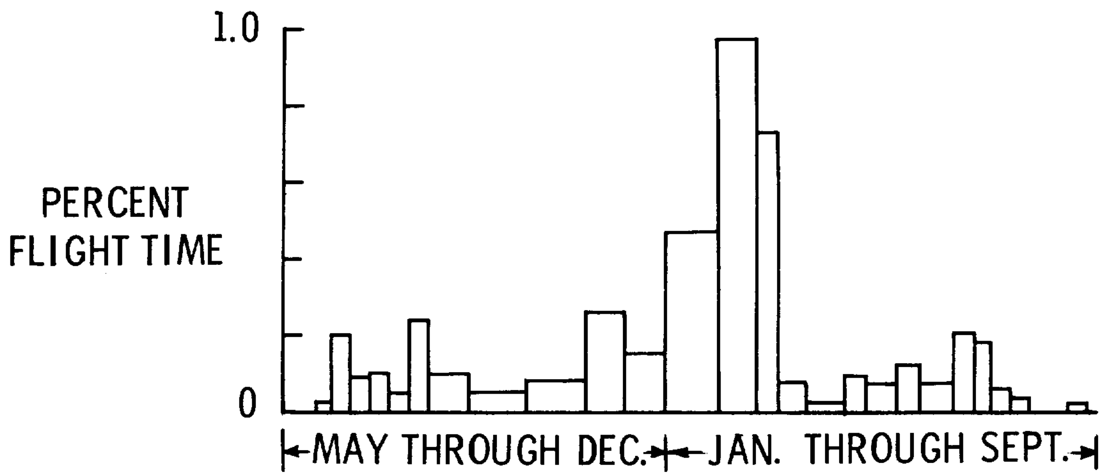


Figure 4.- Effect of maintenance on oscillations.

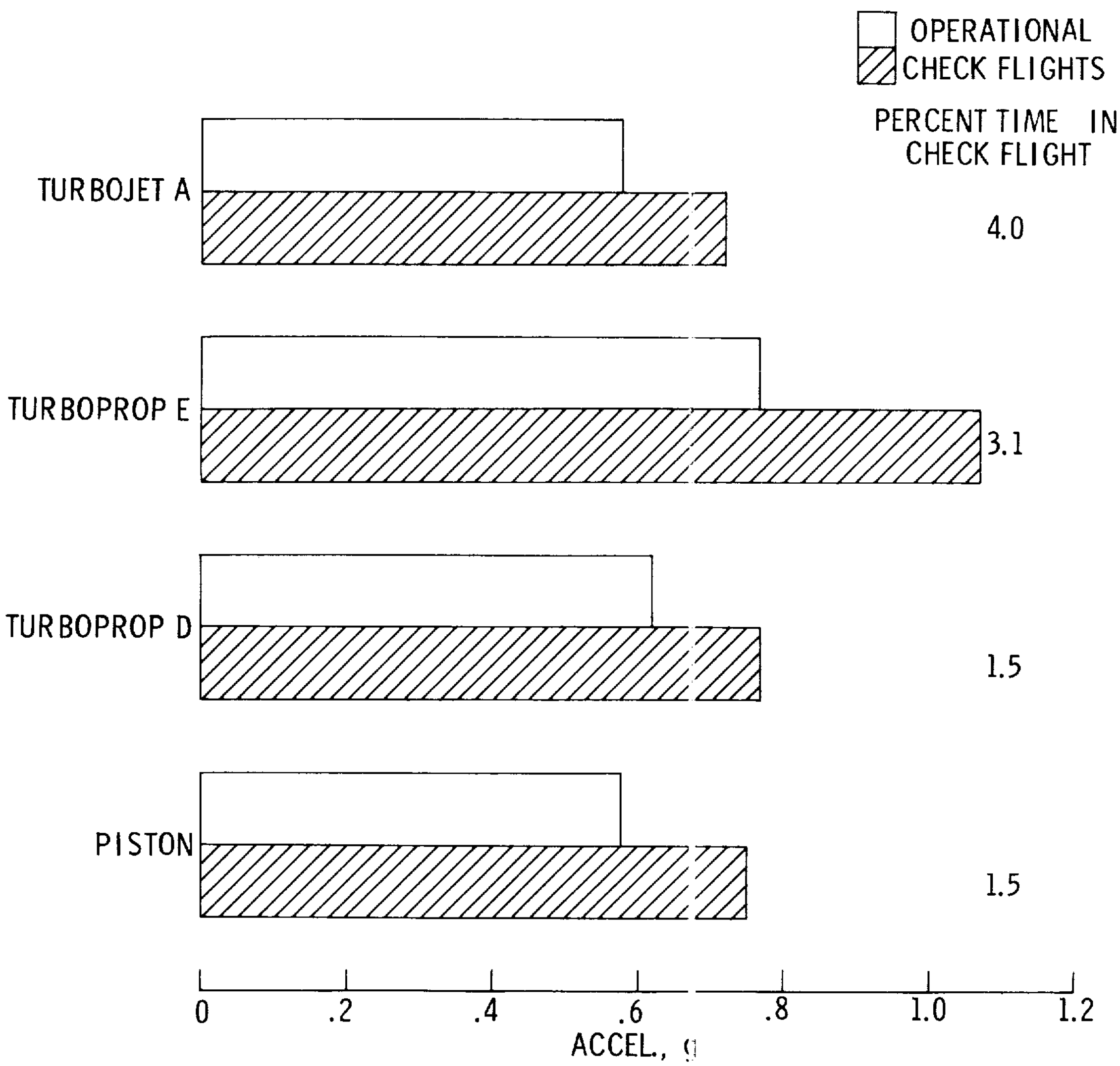


Figure 5.- Maneuver acceleration experience.

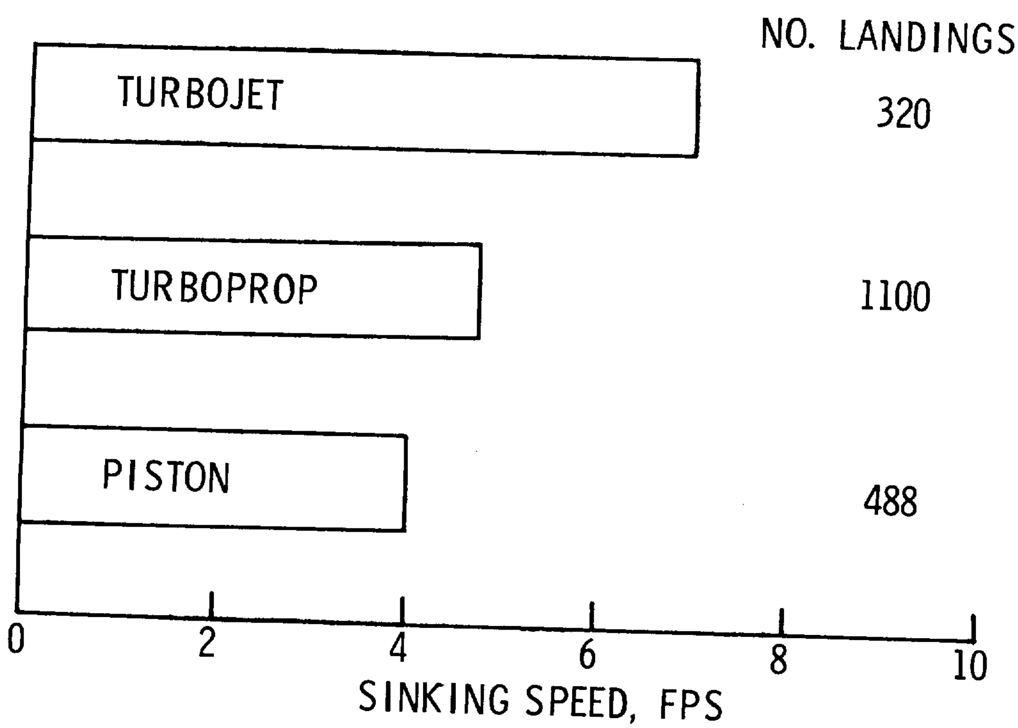


Figure 6.- Sinking speed at touchdown. One landing in 1,000.

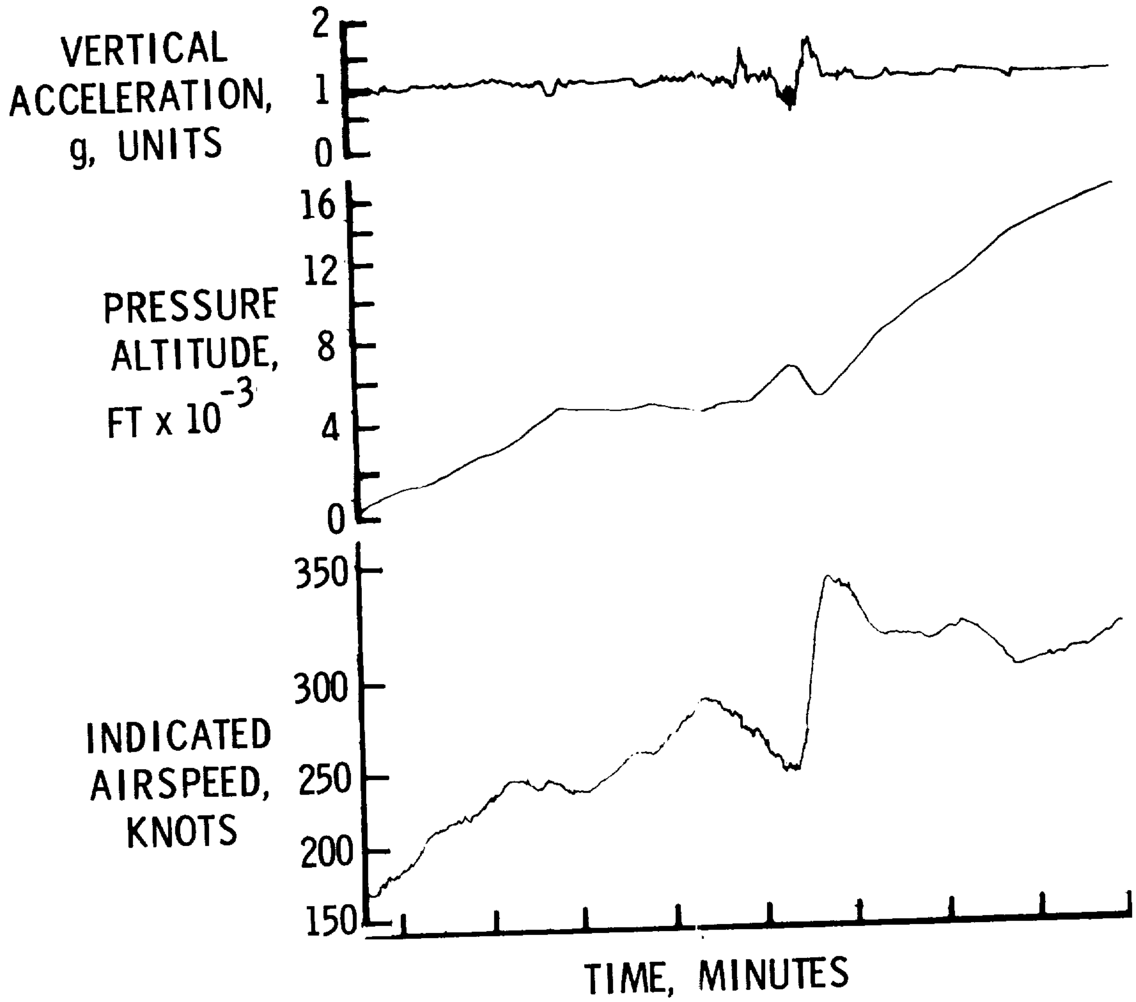


Figure 7.- Abrupt maneuver during climbout.

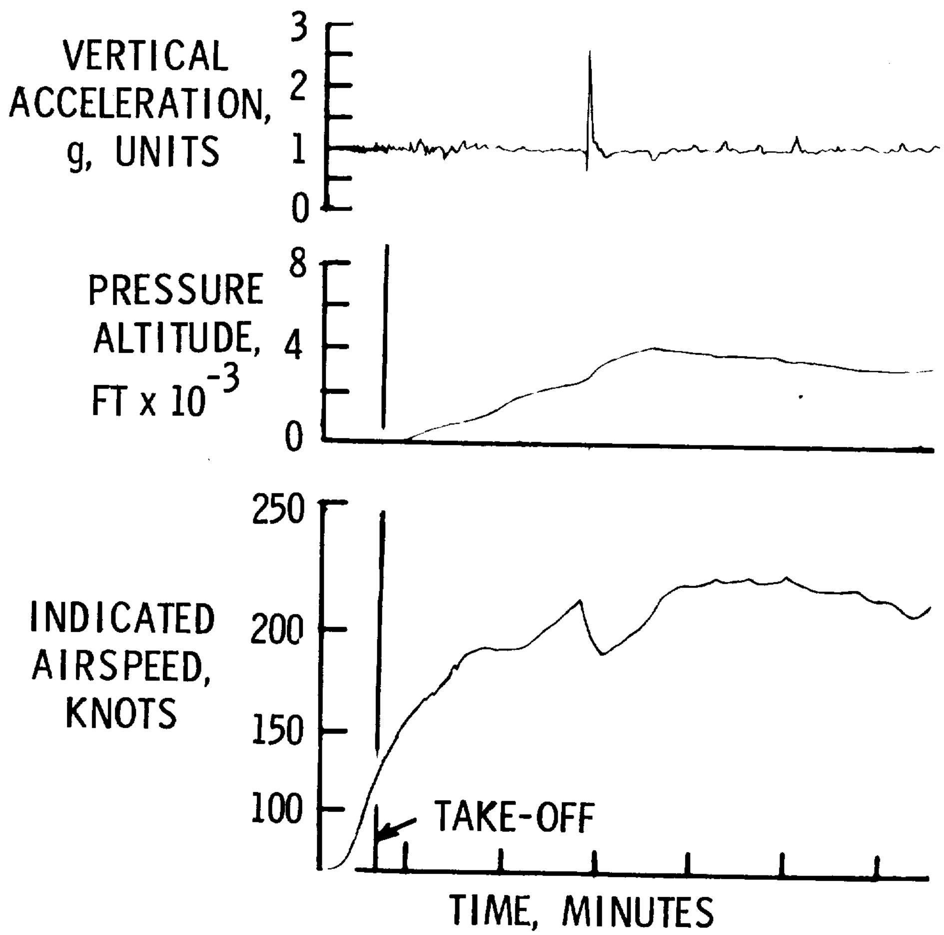


Figure 8.- Collision avoidance.

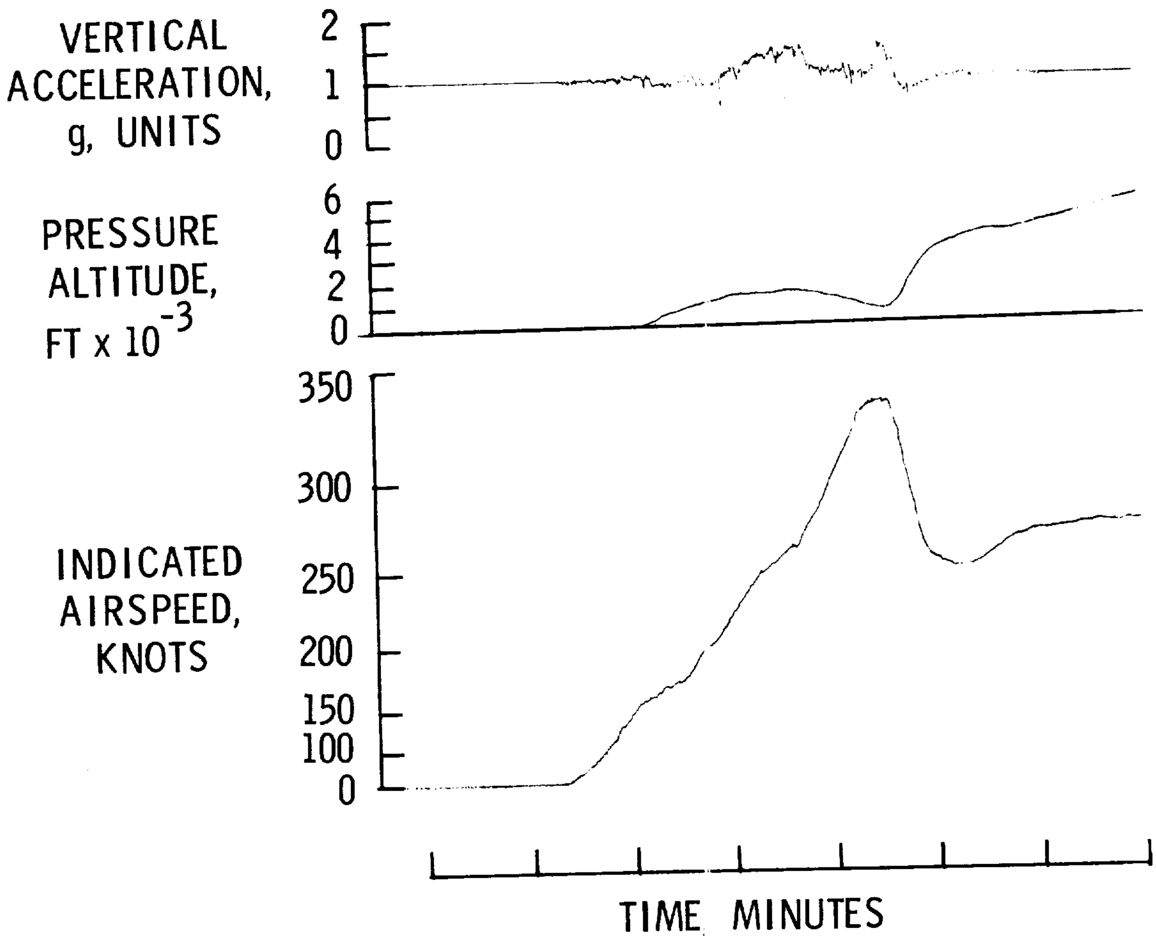


Figure 9.- Altitude loss following take-off.

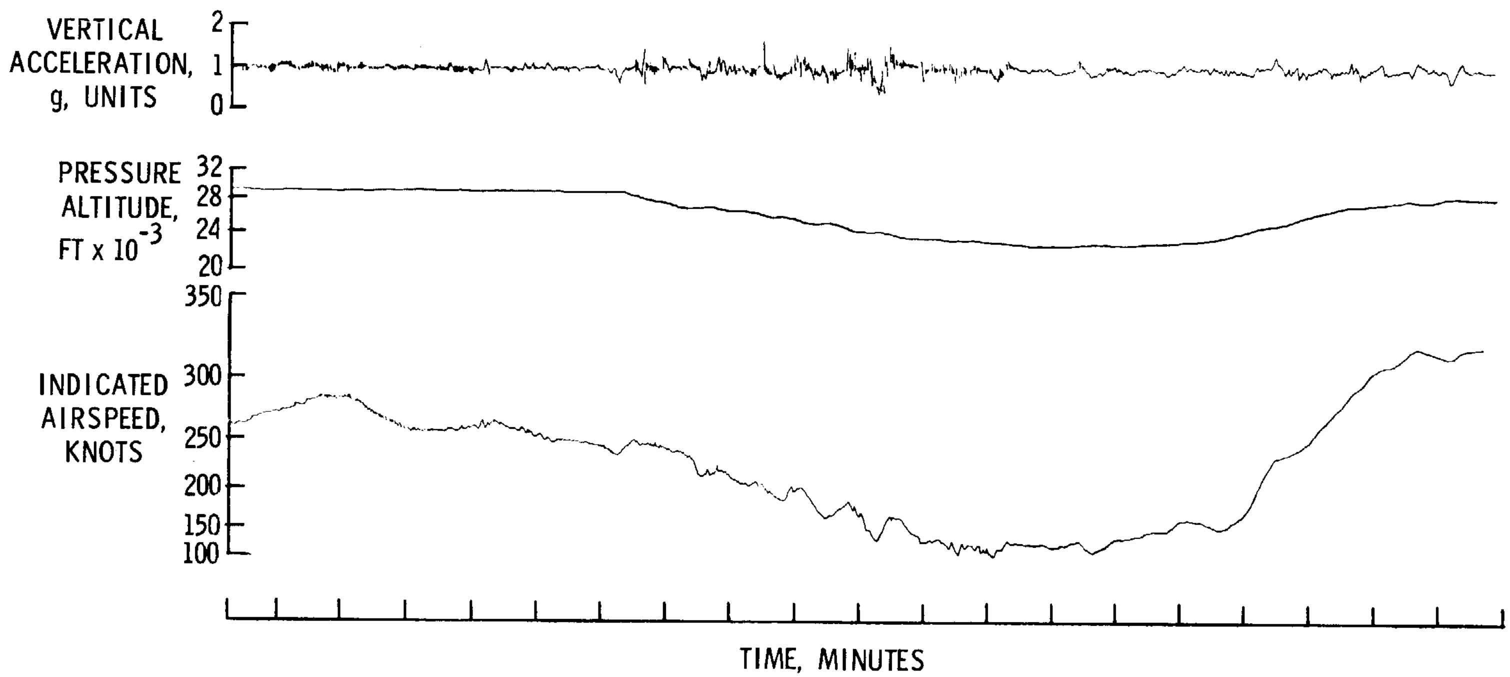


Figure 10.- Low airspeed during cruise.

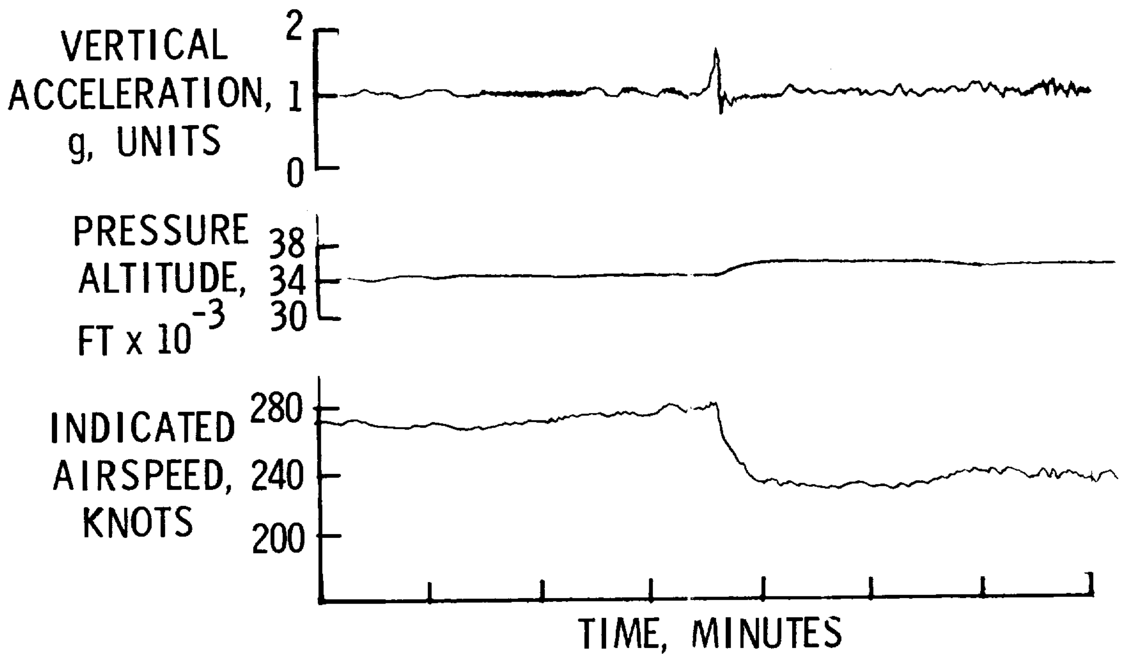


Figure 11.- High-speed buffet.

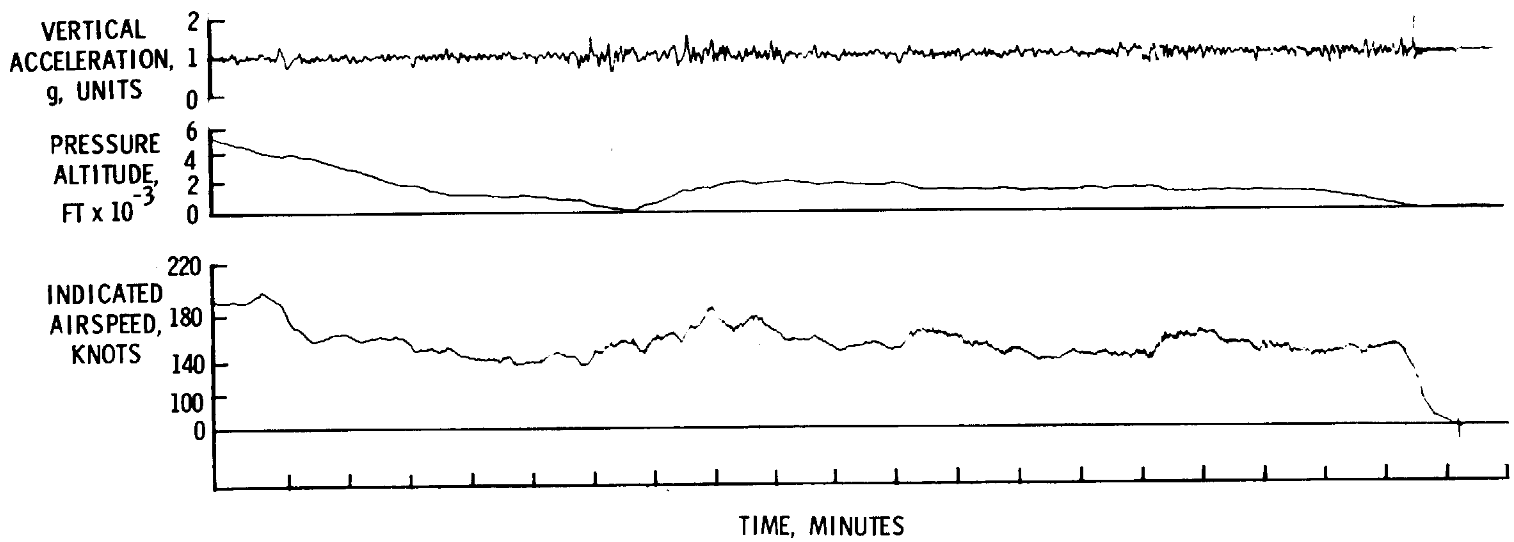


Figure 12.- Oscillations during landing approach.