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FLIGHT EXPERIENCE WITH THE DECELERATING NOISE ABATEMENT APPROACH

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INTRODUCTION

Major advances in developing low-noise aircraft propulsion systems have been made in recent years. Some of these low-noise engines are being used on the new wide-body jets, such as the Boeing 747, McDonnell Douglas DC-10, and Lockheed L-1011. It has taken many years and huge sums of money to develop these relatively quiet aircraft engines, and further advances will require more time and money. However, the wide-body jets account for only a small portion of the take-offs and landings at our airports today; so, in order to lessen the airport noise problem, methods of reducing the noise of the older aircraft must also be found.

The noise of older aircraft can be reduced in two principal ways: retrofitting the aircraft with a quiet propulsion system, and changing the flight operational procedures used in flying the aircraft. The former approach has already proved to be expensive, time consuming, and difficult to implement even though low-noise propulsion system technology exists. The latter method seems to hold promise of being less expensive and easier to implement.

One operational technique which might reduce the noise beneath the landing approach path is the decelerating approach. This technique requires intercepting the 3° approach path at a relatively high speed with the aircraft in the cruise configuration, then reducing the thrust to idle and allowing the aircraft to decelerate along the 3° approach path. As the appropriate airspeed is achieved, the landing flaps and landing gear are deployed for a normal flare and landing. Because the engines, which are the predominant noise source on landing approach, are at idle thrust, a significant reduction in the noise beneath the approach path should be realized.

A series of standard and decelerating landing approaches was flown at the Flight Research Center with a small jet transport aircraft, and measurements were made of the noise on the ground beneath the flightpath. This paper compares the noise levels for the different approach techniques and shows time histories of the approach profiles and rates of deceleration.

SYMBOLS

D	duration correction, $10 \log \frac{t_i}{15}$
EPNL	effective perceived noise level, EPNdB
PNLM	maximum perceived noise level
t_i	duration time for i^{th} flight (see p. 5)
VASI	visual approach slope indicator

TEST AIRCRAFT

The Lockheed Jetstar aircraft (fig. 1) used in these tests is a four-engined, medium-range, jet transport. In the standard configuration the aircraft accommodates 8 to 10 passengers in its pressurized cabin, and has a crew consisting of a pilot and copilot. The JetStar is powered by Pratt & Whitney JT12A-6 turbojet engines. The maximum takeoff weight is 18,562 kilograms.

INSTRUMENTATION AND DATA REDUCTION

The placement of the microphone used in these tests is shown in the diagram of figure 2. The microphone was mounted on a tripod 1.22 meters high along one edge of runway 15 on Rogers Dry Lake. The lakebed has a smooth, hardpacked, sandy-clay surface capable of supporting very large aircraft.

A condenser-type microphone with a 2.54-centimeter diameter was used. It was oriented with the diaphragm parallel to the ground surface.

The data signal from the microphone was driven through a cable by an amplifier to an instrument van. Electrical power for the microphone and line-driving amplifier was supplied by batteries through an inverter. The cable from the microphone was terminated at the van with a line-isolation transformer, and the signal was routed to an amplifier and recorded on an instrumentation-type magnetic tape recorder. The frequency response of the microphone and recording system was flat within ±1 decibel over the frequency range of 50 hertz to 10,000 hertz. The time of day provided by a time-code receiver was also recorded so that the acoustic data could be correlated with the aircraft position. The microphone system was calibrated with a piston-phone in the field before and after the tests.

The data were reduced by using a computer-controlled, real-time, one-third-octave-band analyzer. The data were scaled, frequency corrections were applied if necessary, and overall sound pressure and perceived noise levels were calculated.

The time constant used for data reduction was 1 second. The data were corrected to standard-day conditions; however, no correction for ground reflection was made.

TEST PROCEDURES AND CONDITIONS

It was planned to fly the aircraft on a 3° glide slope approach at several different rates of deceleration. In addition a single-segment, 6° glide slope approach was to be flown to compare the noise levels between the standard 3° approach and the 6° approach. The primary constraints on the 3° glide slope tests were that the aircraft had to be at normal handbook approach speed and over the microphone position at FAR, Part 36 conditions (ref. 1), that is, an altitude of 112.8 meters and an approach glide slope angle of 3°. The rate of deceleration of the aircraft for the different engine power settings and aircraft configurations was not known, thus preliminary flights were made on a trial-and-error basis to determine the initial speed and altitude required for the aircraft to be in the landing configuration and at landing speed over the noise measurement point. On the basis of these data, intercept altitudes and speeds for the different approaches were plotted on tracking radar display maps. These maps and information were then used by an air controller in the Flight Research Center control room to determine the initial aircraft position and speed. After intercepting the glide slope, the pilot maintained the slope by using the visual approach slope indicator (VASI) light located on the runway. Backup glide slope information was supplied by the air controller from the tracking radar.

Table 1 summarizes the aircraft operating schedule during the landing approach tests. Flights 1 and 2 were made by intercepting the glide slope at the reference landing speed with the aircraft in the landing configuration. The engine thrust was then adjusted to maintain the glide slope and the reference speed. The aircraft continued down the glide slope until it was approximately 500 meters to 1000 meters beyond the microphones, at which time the aircraft configuration and engine power were changed to allow the aircraft to go around for another approach.

The decelerating approaches, flights 3 and 4, were made by intercepting the glide slope at the predetermined altitude and speed with the aircraft in the cruise configuration. On the basis of the aircraft speed, the air controller notified the pilot to retard the throttles just before the glide slope was intercepted. Then the aircraft was allowed to decelerate until the maximum speed for takeoff flap extension was reached, at which time the takeoff flaps were extended. When the maximum speed for gear and landing flap extension was reached, the landing gear and flaps were lowered. The approach was continued so that the aircraft speed over the noise measuring point was approximately the same as on flights 1 and 2. After passing the noise measuring point, the aircraft made a go-around without actually landing.

Figure 3 shows the wind conditions between the ground and the maximum test altitude approximately 4 hours before the flight tests. These data were not available at a time closer to the flights; however, since no significant changes in the weather occurred during this period, these data are believed to be representative of the winds during the flight tests.

The surface temperature during the tests was 21.1° C, and the relative humidity was 35 percent.

RESULTS AND DISCUSSION

Aircraft Profiles

The elevation, velocity, and deceleration profiles for the landing approaches are presented in figure 4. These data were obtained from the tracking radar; thus the velocity plotted is with respect to the ground, and the accelerations were obtained by differentiating the ground speed with respect to time.

The elevation and velocity profiles for the constant-speed, 6° approach (flight 1) are shown in figure 4(a). The aircraft ground speed was approximately constant at 79 meters per second, and the aircraft passed over the microphone position at an altitude of 229 meters, which is about twice that specified in FAR, Part 36 for noise certification of aircraft. This means that the aircraft noise level would be 6 decibels less than the 3° glide slope noise level because of the greater distance of the aircraft from the measuring station.

The elevation and velocity profiles for the standard 3° approach (flight 2) are shown in figure 4(b). The velocity decreased somewhat on this approach, from 82 meters per second to 76 meters per second, even though it was supposed to remain constant. The altitude over the noise measuring position was 120 meters, which was approximately as planned.

Figure 4(c) presents the elevation, velocity, and deceleration profiles for the 3° glide slope approach at idle power (flight 3). The planned altitude of the aircraft over the noise measuring point was 120 meters; however, the velocity decreased to about 67 meters per second. As shown in figure 4(c), the aircraft initially decelerated rather slowly. When the landing gear and landing flaps were extended at an altitude of 1500 meters to 2000 meters before the microphone location was reached, the deceleration increased about 2 meters per second squared as the aircraft passed over the noise measuring position.

It should be noted that it is difficult to obtain a desired velocity precisely at a point on the flightpath unless specialized information is displayed to the pilot. In fact, this particular approach was the fourth attempted on the day of the tests. The three previous attempts were aborted because the aircraft decelerated to an unacceptable speed before passing over the noise measuring point. Each attempted approach was initiated at a lower altitude until the profile shown in figure 4(c) was flown. It is believed that the previously established initial altitude and velocity conditions did not permit the aircraft to pass over the noise measuring point at the prescribed conditions because on the day the initial conditions were established the tailwind component was larger than on the test day. Thus it appears that any guidance information given to the pilot for a decelerating approach should include wind effects.

The decelerating approach on flight 4 resulted in the elevation, velocity, and deceleration profiles shown in figure 4(d). The engines were throttled to provide

about one-half the thrust required for a standard 3° approach. Over the noise measuring station, the aircraft altitude was approximately 120 meters and the velocity was 69 meters per second. The deceleration profile was significantly different for flight 4 than for the other flights for several reasons. The deceleration was initially rather slow until an altitude profile correction was made about 4000 meters from the microphone position; this caused the deceleration to decrease to zero. With the extension of the landing gear and the landing flaps, the deceleration did not decrease as rapidly as on flight 3 because of the thrust generated by the engines. However, over the noise measuring station, the deceleration was about the same on flights 3 and 4—approximately 2 meters per second squared.

Acoustic Results

Time histories of the perceived noise levels measured during the landing approaches are shown in figure 5. To calculate an effective perceived noise level, a duration time, t_i, was defined as the time interval during which the perceived noise level was within 10 decibels of the maximum perceived noise level. These times are shown in figure 5 for the landing approaches. The duration correction was then calculated by using the equation

$$D = 10 \log \frac{t_i}{15}$$

This correction, which accounts for the effects of the noise time history and duration, was used to calculate the effective perceived noise level with the following equation:

$$EPNL = PNLM + D$$

It should be noted that for spectra with no discrete tones, as in this study, the perceived noise level equals the tone-corrected perceived noise level.

As shown in figure 5, the shortest duration time measured was on the standard 3° approach (flight 2), and the longest duration time was on the 6° approach (flight 1). The longer duration time was the penalty for a 6° glide slope approach. However, the peak perceived noise level was reduced significantly. The idle-power decelerating approach on flight 3 also had a relatively long duration time compared to that of the standard approach; whereas, the partial-power approach showed little increase in duration time but a large reduction in peak perceived noise level.

The sound pressure level spectra at the time of maximum perceived noise level for each landing approach are shown in figure 6. All the spectra are characterized by prominent dips at 80 hertz and 200 hertz. The dips are caused by destructive interference between the incident sound wave and the wave reflected by the ground surface.

To properly evaluate the results of this study, they must be compared with a standard such as the approach noise criterion in FAR, Part 36 (ref. 1). This

comparison is shown in figure 7. The approach noise criterion for the JetStar aircraft at its maximum takeoff weight is 102 EPNdB. The noise level at the approach noise measuring point for a standard 3° approach is 106.8 EPNdB. The approach noise measured under a single-segment 6° approach is 98.6 EPNdB, or a reduction of approximately 8 EPNdB from the standard approach noise level. As previously mentioned, 6 decibels of this noise reduction are attributed to the fact that the aircraft altitude over the noise measuring point was twice as great for the 6° approach as for the 3° approach. The remaining 2-decibel reduction is a result of the decreased thrust required on the 6° approach. The approach noise is reduced further on the idle-power 3° approach. The noise measured on this approach is 90.7 EPNdB, which is a reduction of 16.1 EPNdB from the noise generated on a standard approach.

The crosshatched area in figure 7 represents the probable level of nonpropulsive aerodynamic noise discussed in reference 2. Unpublished results of power-off landings at the Flight Research Center with the JetStar aircraft confirm that the nonpropulsive noise level of the aircraft in a landing configuration is about 90.7 EPNdB under these test conditions. Thus it appears that 16.1 EPNdB is the maximum noise reduction achievable for the JetStar on landing approach.

The noise level of 97.7 EPNdB measured beneath the landing approach path for the partial-power 3° approach is also a significant reduction in approach noise. Thus it seems that a partial-power decelerating approach can be just as effective in reducing approach noise as a 6° approach.

CONCLUDING REMARKS

A preliminary flight-test program evaluated the potential noise reduction that could be achieved through the use of a decelerating landing approach. The noise, measured at the FAR, Part 36 noise measurement station for approaches, was compared with the noise for a standard 3° glide slope approach and a 6° approach. The following observations can be made:

(1) Reductions in approach noise of as much as 16.1 EPNdB for the JetStar aircraft can be achieved through the use of the decelerating approach. For this aircraft the lower limiting noise level on approach with idle thrust is the nonpropulsive airframe noise.

(2) Decelerating approaches cannot be flown consistently without some onboard guidance system that accounts for the effects of wind on the deceleration of the aircraft.

(3) Decelerating approaches at power levels between standard approach power and idle power can result in significant reductions in approach noise levels.

Flight Research Center,
National Aeronautics and Space Administration,
Edwards, Calif., Jan. 4, 1974.

REFERENCES

1. Anon.: Federal Aviation Regulations. Part 36—Noise Standards: Aircraft Type Certification, Appendix B. FAA, Dec. 1969.

2. Blumenthal, V. L.; Streckenbach, J. M.; and Tate, R. B.: Aircraft Environmental Problems. AIAA Paper No. 73-5, Jan. 1973.

TABLE 1.—SUMMARY OF AIRCRAFT OPERATING SCHEDULE DURING LANDING APPROACHES

Flight number	Glide slope, deg	Intercept altitude, m	Intercept calibrated airspeed, m/sec	Calibrated airspeed at microphone position, m/sec	Engine speed, percent
1	6	975	74.6	74.6	76
2	3	640	74.6	74.6	84
3	3	884	118.3	69.4	Idle
4	3	579	102.9	69.4	69

Figure 1. Test aircraft.

E-21742

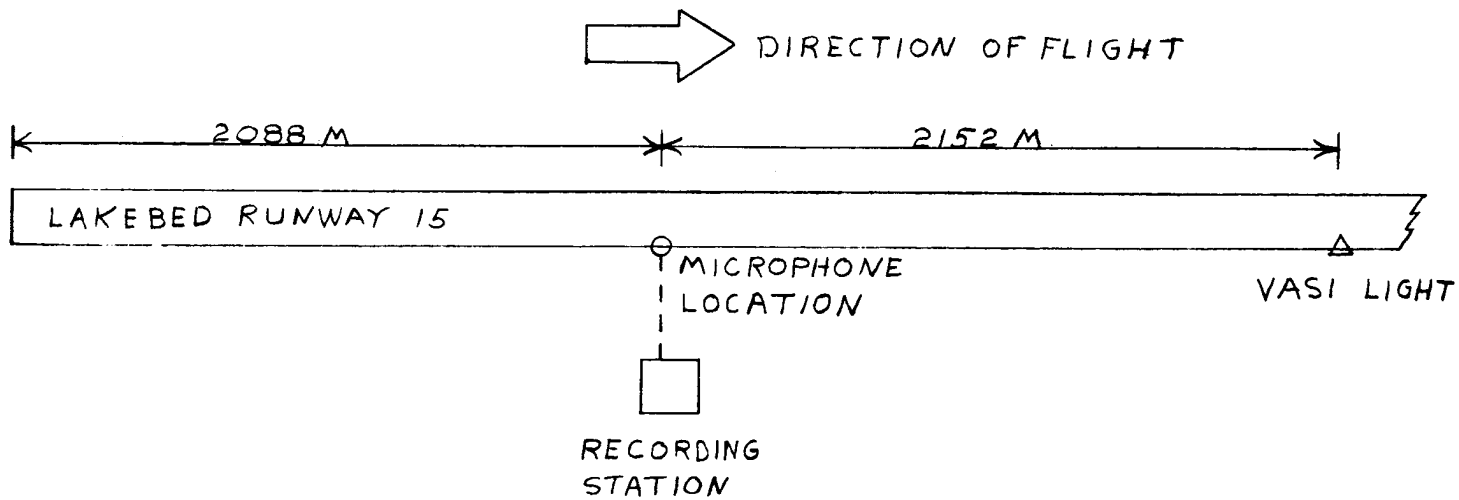


Figure 2. Schematic diagram of microphone location in relation to the approach ground track and VASI light.

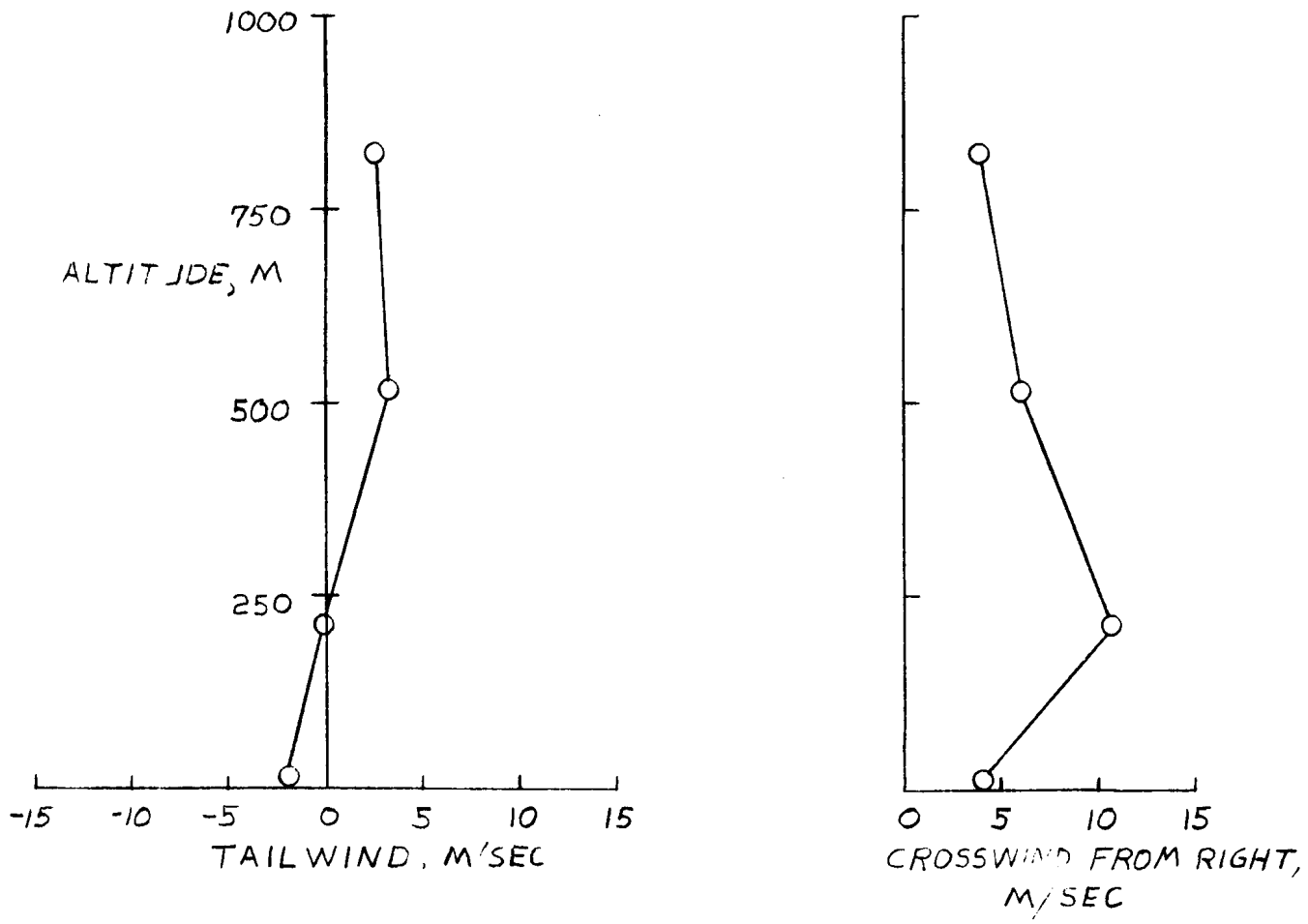
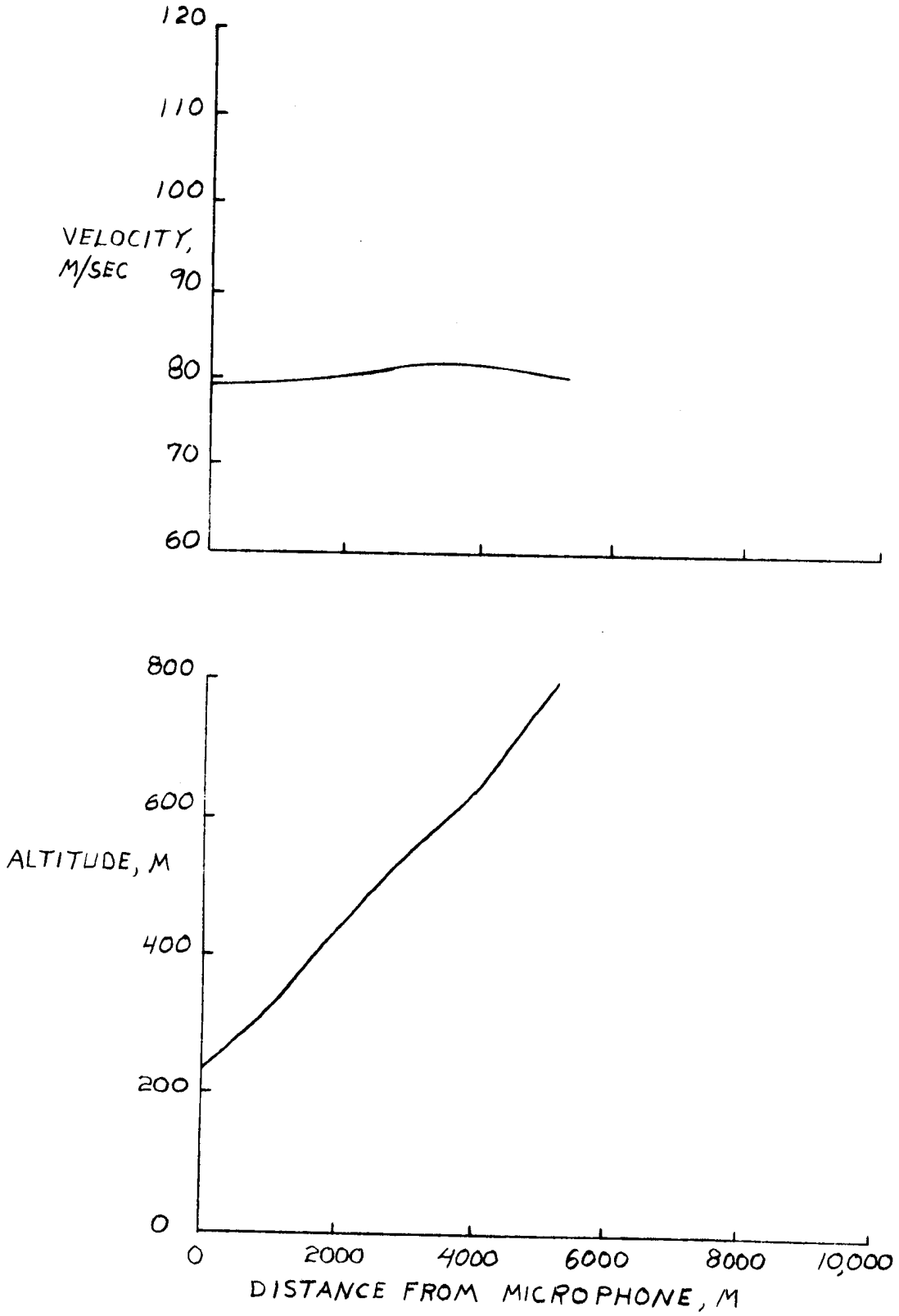
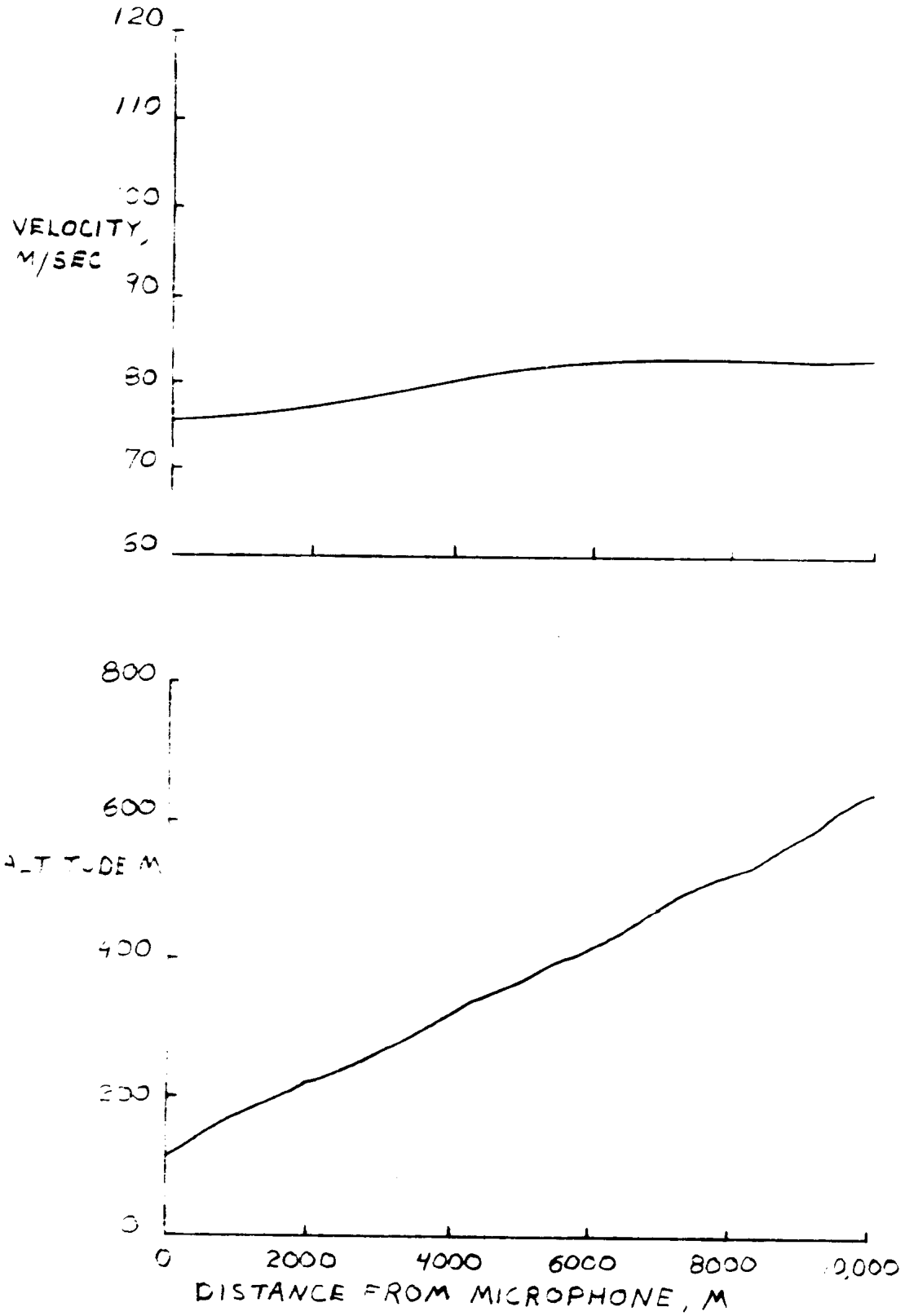


Figure 3. Wind conditions between the ground and the maximum test altitude approximately 4 hours before the flight tests.



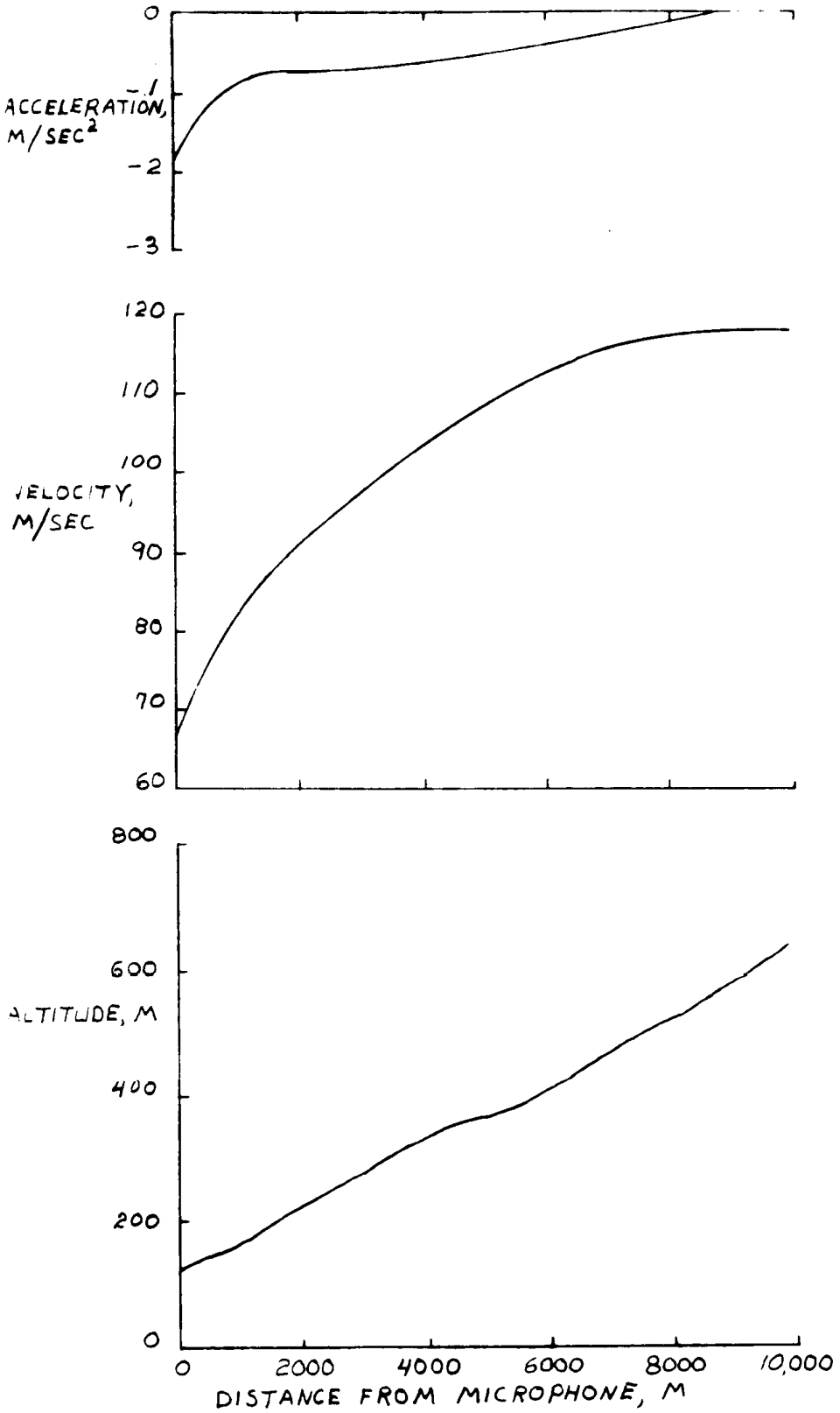
(a) Elevation and velocity profiles for 6° approach (flight 1).

Figure 4. Aircraft elevation, velocity, and acceleration profiles during landing approaches.



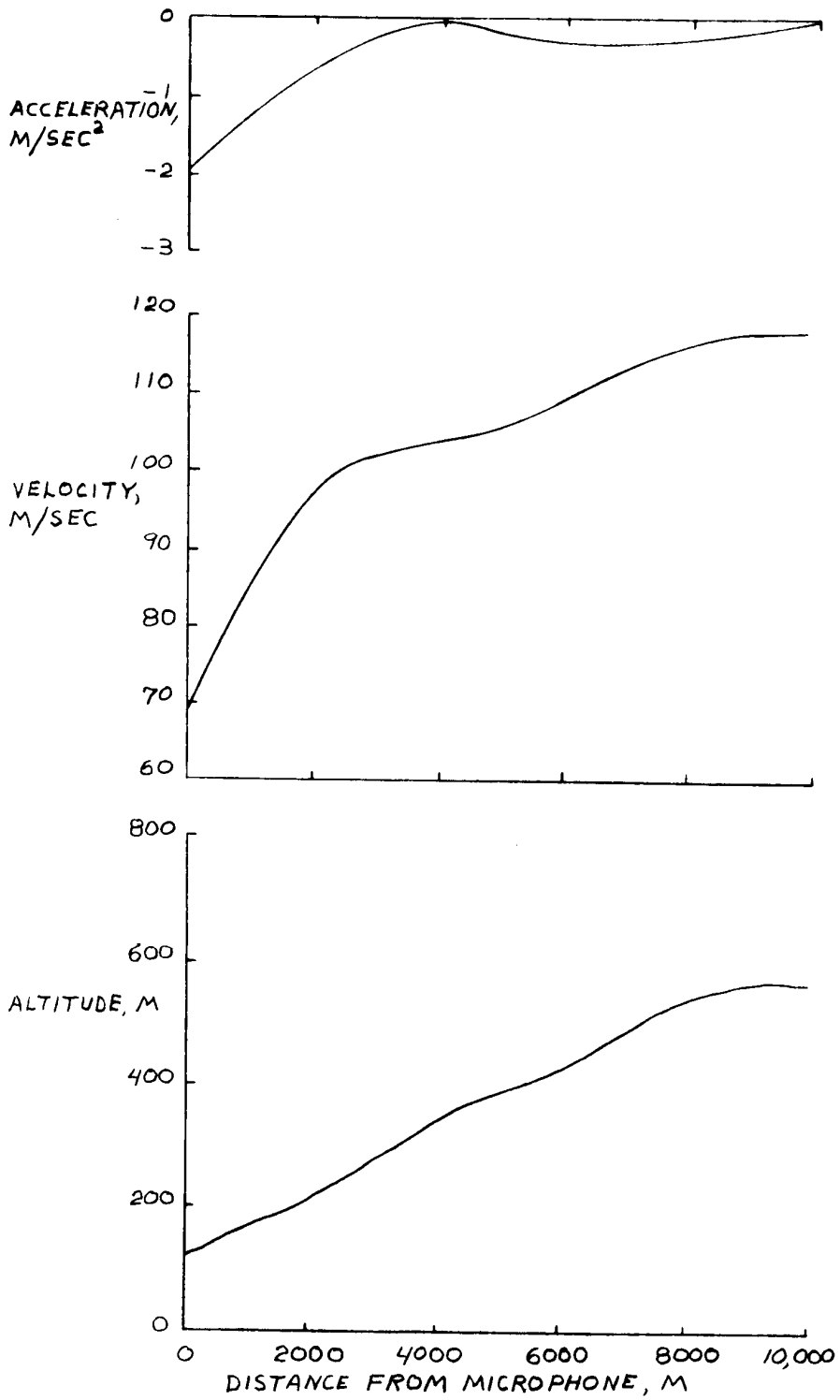
(b) Elevation and velocity profiles for standard 3° approach (flight 2).

Figure 4. Continued.



(c) Elevation, velocity, and acceleration profiles for idle-power 3° approach (flight 3).

Figure 4. Continued.



(d) Elevation, velocity, and acceleration profiles for partial-power 3° approach (flight 4).

Figure 4. Concluded.

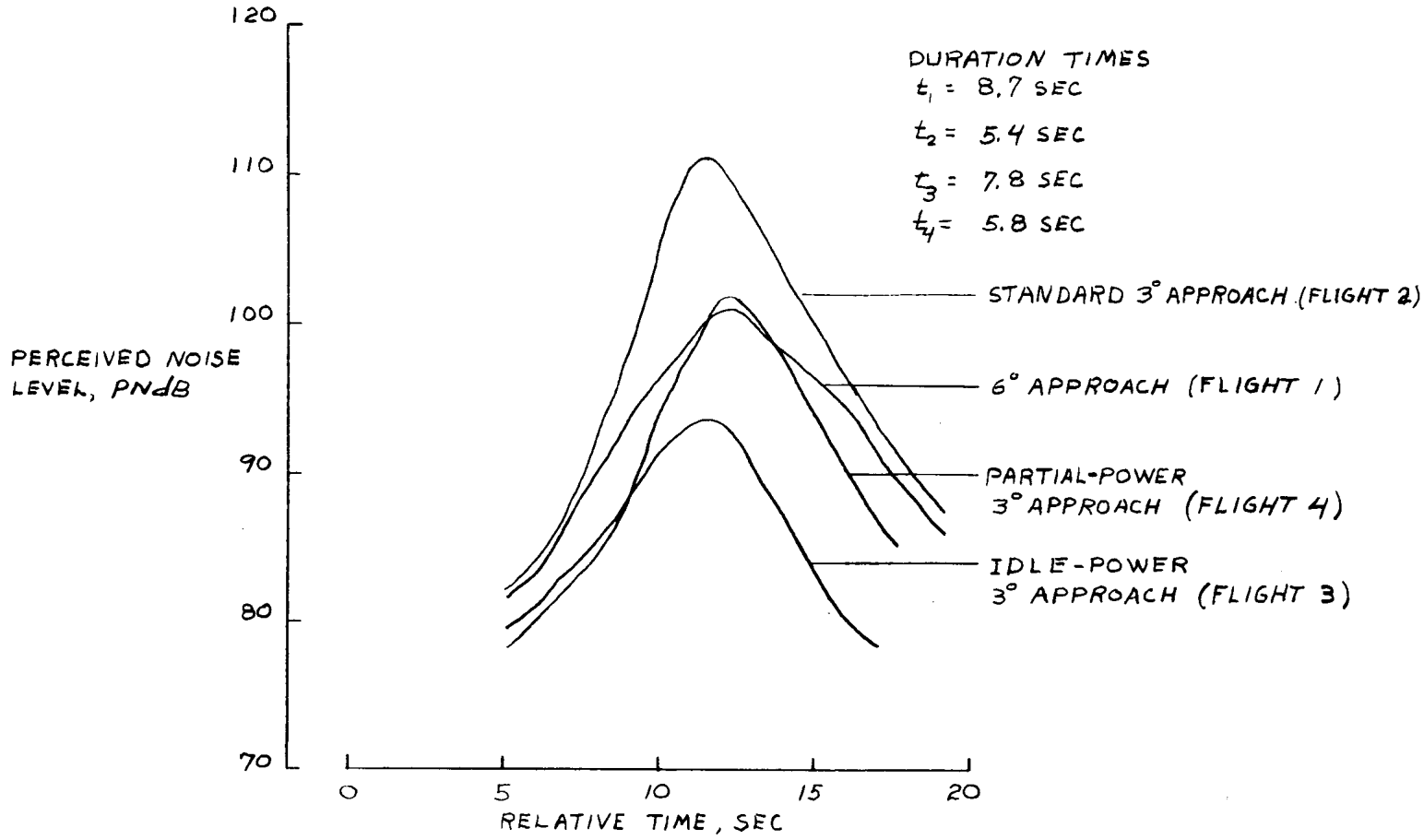


Figure 5. Time histories of perceived noise levels during the landing approaches.

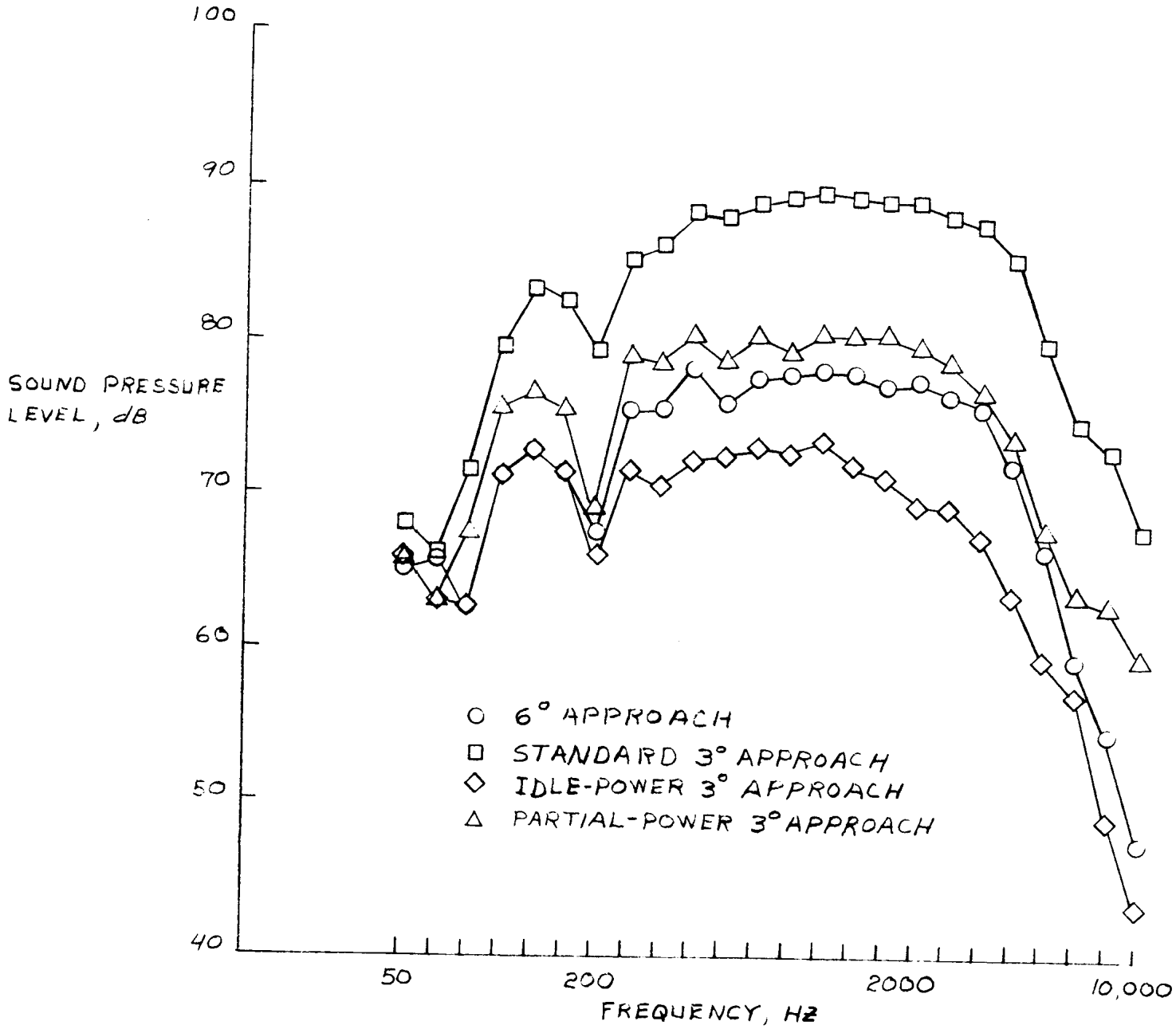


Figure 6. Noise spectra at the time of maximum perceived noise level for the landing approaches.

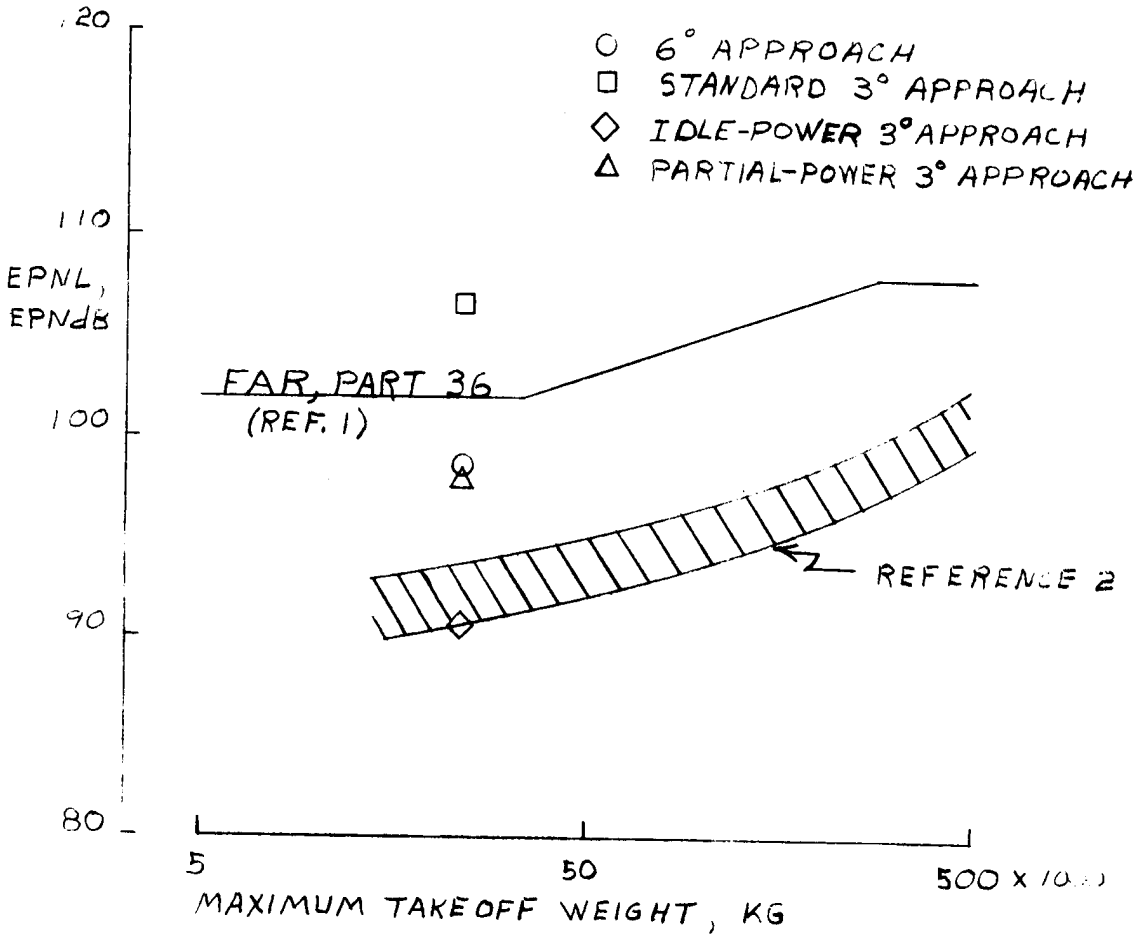


Figure 7. Comparison of present results with FAR, Part 36 criterion for approach noise.