General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

NASA TECHNICAL MEMORANDUM

NASA TM X-72760

BASELINE MEASUREMENT OF THE NOISE GENERATED BY A SHORT-TO-MEDIUM RANGE JET TRANSPORT FLYING STANDARD ILS APPROACHES AND LEVEL FLYOVERS

By

Earl C. Hastings, Jr.; Robert E. Shanks;

and

Arnold W. Mueller

August 4, 1975

1. Report No. TM X-72760	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Baseline Measurement of the Noise Generated by a Short-to-Medium Range Jet Transport Flying Standard ILS Approaches and Level Flyovers		5. Report Date August 4, 1975
		6. Performing Organization Code
7. Author(s) Earl C. Hastings, Jr.; Robert E. Shanks; and Arnold W. Mueller		8. Performing Organization Report No.
9. Performing Organization Name and Address NASA Langley Research Center Hampton, VA 23665		10. Work Unit No. 513-52-01-04
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		13. Type of Report and Period Covered* High Number TMX
		14. Sponsoring Agency Code

15. Supplementary Notes

Interim release, to be converted to a formal publication by 1976.

16. Abstract

The results of baseline noise flight tests are presented for an experimental short-to-medium range commercial jet aircraft flying standard ILS approaches. Data are given for a point 1.85 kilometers (1.0 nautical mile) from the runway threshold. Experimental results of level flyover noise at altitudes of 122 meters (400 feet) and 610 meters (2,000 feet) are also shown for several different power levels. The experimental data are compared with data from other sources and reasonable agreement is noted. A description of the test technique, instrumentation, and data analysis methods is also included.

17. Key Words (Suggested by Author(s)) (STAR category underlined) Environment Polution Noise measurements, flight tests, noise measuring systems	18. Distribution Statement Unclassified Limited		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 60	22. Price* $4.25

1   SUMMARY

2   The results of baseline noise flight tests are presented for an

3   experimental short-to-medium-range commercial jet aircraft flying

4   standard ILS approaches. Data are given for a point 1.85 kilometers

5   (1.0 nautical mile) from the runway threshold. Experimental results

6   of level flyover noise at altitudes of 122 meters (400 feet) and

7   610 meters (2,000 feet) are also shown for several different power

8   levels. The experimental data are compared with data from other

9   sources and reasonable agreement is noted. A description of the

10   test technique, instrumentation, and data analysis methods is also

11   included.

12

13

14

15

16

17

18

19

20

21

22

23

24

25

NASA-Langley Form 22 (Apr 69)

INTRODUCTION

One of the broad objectives of the NASA Terminal Configured Vehicle (TCV) Program is the reduction of terminal area noise by operational procedures. In order to accomplish this, and other program objectives, NASA has recently acquired a research configured, short to medium range jet aircraft. The aircraft is equipped with advanced avionics equipment and a research cockpit located in the passenger compartment of the aircraft. Additional details of the test aircraft experimental systems are given in reference 1.

This research aircraft will be utilized in all of the noise experiments in this program. Therefore, an objective of the first noise test series was to determine baseline 3-degree approach noise for this aircraft, using the noise instrumentation and data analysis methods which will be common to all these experiments. Another objective of the first test series was to obtain flight noise measurements for use in developing improved aircraft noise prediction methods. This required level flyovers at several altitudes and thrust levels as well as the baseline approach data.

This paper describes the test procedures and instrumentation used in making the measurements and the analysis methods used in reducing the data. The baseline 3-degree approach data and the level flyover data are presented and compared with pertinent data from other sources.

NOMENCLATURE

dBA	A-weighted sound pressure level, dB	
EPR	Engine Pressure Ratio	
$EPNL_{TEST}$	Effective perceived noise level for test conditions, dB	
$EPNL_{REF}$	Effective perceived noise level for reference conditions, dB	
F_N	Net thrust, newtons	
GMT	Greenich Mean Time	
ILS	Instrument Landing System	
KIAS	Indicated airspeed, knots	
OASPL	Overall sound pressure level, dB	
PNL	Perceived noise level, dB	
PNLT	Tone corrected perceived noise level, dB	
PNLTM	Maximum tone corrected perceived noise level, dB	
P_o	Atmospheric pressure, newtons/meter^2	
RH	Relative humidity, percent	
t	Time, sec	
T	Temperature, deg K	
V_{cw}	Cross wind velocity, knots	
V_s	Stall speed, KIAS	
V_w	Wind velocity, knots	
W	Weight, newtons	
Y	Lateral distance from extended centerline	
Z	Vertical distance above reference point	
δ	Atmospheric pressure ratio.	
θ_w	Wind direction, degs	

NASA-Langley Form 22 (Apr 69)

DESCRIPTION OF AIRPLANE AND DATA SYSTEMS

Airplane

The test aircraft is the twin-engine jet transport shown in figure 1. Equipped with triple-slotted trailing-edge flaps, leading-edge slots, and Krueger leading flaps, this vehicle was designed for short-haul operations into existing small airports with short runways. Vehicle longitudinal control and trim are achieved by the elevator and movable stabilizer, respectively, while lateral control is obtained by a combination of ailerons and spoilers. The spoilers also function as speed brakes when so selected by the pilot. A single-surface rudder provides directional control of the aircraft. Aircraft dimensions and design data are presented in table I.

The only geometrical difference between the test aircraft used in these tests, and the 737-200 aircraft used for comparison of level flyover data is that the 737-200 fuselage is 1.93 meters (76") longer than that of the test aircraft. Both aircraft used in the comparisons have P & W JT8D-7 engines.

Data Systems

The primary data systems used in support of these tests are summarized below:

-4-

	Data System				
Type of Test	Noise Measurement	Meteorological	Position	Sim ILS Guidance	Aircraft Performance
Level Flyovers	Yes	Yes	Yes	No	No
3-degree Approaches	Yes	Yes	Yes	Yes	Yes

The location of the groundbased systems at the Wallops Flight Center airfield are shown in figure 2. These groundbased systems and the onboard data system are described in detail in the following subsections:

Noise Measurement System. - The noise measuring system consisted of a 1/2-inch condenser type pressure microphone, cables, signal conditioning, and recording equipment necessary to obtain flyover data in accordance with reference 2. The system incorporated field proven, commercial hardware from recognized manufacturers.

The data acquisition system block diagram for a typical microphone channel is shown in figure 3. Principal system components were the 1/2-inch pressure microphone with an accessory windscreen and pre-amplifier, variable-gain amplifier, and an FM tape recorder. An oscillograph was used for in-field data verification and to establish optimum recording levels. The microphones were configured with the standard grid cap. The noise measurements discussed herein were made with the microphones mounted 1.2 meters above ground level with their longitudinal axes parallel to the ground, and generally perpendicular to the vertical projection of the flight path. Free-field frequency

1 response corrections were applied to the microphones fitted with

2 windscreens. The corrections were taken from the manufacturers

3 literature and are tabulated in Table II.

4   The tape recorder was operated 76 cm/sec (30 in/sec) for all

5 measurements. The time code (modulated 1,000 Hz) signal was recorded

6 on magnetic tape with the microphone data on each run. Voice information

7 was also recorded. The power supply to the preamplifier incorporated

8 24 volt dc batteries. The signal leads were hard-wired through the

9 power supply chassis and routed to the variable-gain amplifiers. The

10 other elements of the system were powered by a remotely located, gas

11 powered generator.

12   Prior to the conduct of field measurements, extensive system

13 calibration and testing were conducted to verify proper system operation

14 and to document system performance. All system components were

15 individually calibrated in accordance with the manufacturer's recommended

16 procedures, or an alternate method developed by NASA. General calibration

17 policies and procedures were as recommended by the Navy Standard

18 Laboratory Information Manual. All test measurements were made with

19 instruments whose calibration is traceable to the National Bureau of

20 Standards. In the case of microphones, an electrostatic calibration

21 was performed to determine frequency response. Microphone sensitivity

22 was determined using a commercially available pistonphone.

23   The system was assembled and the critical parameters of

24 frequency response, distortion, linearity, and noise floor were

25 documented. System level tests are summarized in Table III. A

1 typical system frequency response plot is shown in figure 4. The roll-off

2 at high frequencies exhibited by the frequency response plot is a function

3 of the low-pass filter in the tape recorder reproduce electronics. The

4 slight rise in the frequency range from 20 Hz to 60 Hz of figure 4 was

5 characteristic of the sound level meter electronics. As the deviation

6 in this range is on the order of tenths of a dB and in the low frequency

7 range of the frequency range guidelines of reference 2, no corrections

8 for this condition were made to the acquired data.

9 Before, during, and at the end of the tests, end-to-end system

10 sensitivity was determined using a commercially available calibration which

11 produced a 124 dB acoustic signal at 1 KHz. This calibration was

12 recorded on magnetic tape.

13 Measurements for the 3-degree approach flights were made with a

14 microphone located at a site approximately 1.85 kilometers (1.0 nautical

15 mile) from the threshold of runway 04. The precise position of the

16 microphone was determined by survey and found to be 2,007.1 meters (6,585.5

17 feet) from the threshold, 14.5 meters east of the extended runway centerline

18 at an elevation of 10.7 meters (35 feet) above mean sea level. For the level

19 flyovers, the microphone was deployed on the airfield near the threshold

20 of runway 35 as shown in figure 2.

21 Figure 5 is a photograph of the noise site location used for the 3°

22 approaches showing a mobile van containing the recording equipment with

23 the runway threshold in the background. The microphone was located in

24 the open field in the center of the photograph. Traffic on the secondary

25 road in the foreground was infrequent and posed no background noise

26 problems during these tests.

NASA-Langley Form 22 (Apr 69)

1 Meteorological Measurement System. - The primary meteorological site for

2 these tests was located near the end of WFC runway #10 as shown on

3 figure 2. A backup site, located slightly northwest of the threshold

4 of runway #04, is also shown.

5   The facilities at the primary site are shown in figure 6 and

6 consisted of the following:

7   1. A hygrothermograph which measured and recorded surface

8 temperature and relative humidity, and a microbarograph which measured

9 the atmospheric pressure. These were located in the instrument shelter

10 shown in the center of the photograph.

11   2. An anemometer (left center, figure 6) which measured wind

12 direction and wind velocity, 10 meters above ground level.

13   3. Radiosondes to measure relative humidity and temperature

14 through the test altitude range. The sonde release site was located

15 about 100 meters northeast of the anemometer location (right background,

16 figure 6).

17   4. Theodolites to measure the position of the radiosondes during

18 ascent.

19   "Temperature" sondes and "humidity" sondes were alternately released

20 at 30 minute intervals during the flight testing. Sonde, anemometer,

21 and theodolite data were recorded in the mobile van (right center, figure 6).

22 The theodolite data were later used to determine wind velocity and

23 direction in the test altitude range.

24   The facilities at the backup site consisted of the hygrothermograph

25 and the 10 meter anemometer. Surface conditions from these measurements

-8-

1 were recorded and displayed in real time in the WFC Weather Bureau

2 Office in the Range Control Center. This facility provided full time

3 monitoring of surface conditions during the tests.

4 <u>Aircraft Position Measurement System.</u>- The primary source of aircraft

5 position data, displayed and monitored in real time in the Range Control

6 Center, was the FPQ-6 radar located about 11.1 Km (6 n. mi.) south of

7 the airfield. The AN/GSN-5 radar at the airfield (figure 2) was used

8 primarily to provide precision guidance during approaches, but also

9 provided a backup source of position data.

10   After the tests, the radar tapes were processed to provide X, Y,

11 and Z position data at 1 second intervals. For approaches, position

12 data were referenced to the extended centerline and to a projected

13 touchdown point 305 meters (1,000 feet) from the runway threshold. For

14 level flyovers, the position data were referenced to the noise site

15 location at the runway threshold centerline.

16 <u>Aircraft Performance Measurements.</u>- The aircraft parameters of primary

17 interest in these tests were engine pressure ratio (related to net thrust),

18 airspeed, flap deflection, landing gear position, and aircraft weight.

19 During the 3° approaches all of these parameters, except weight, were

20 recorded onboard on a wide-band magnetic tape recorder. Other data

21 (Table IV) were also recorded during the approaches. Correlation of

22 these data with ground measurements was provided by an onboard time code

23 generator syncronized with WFC range time at the start of the tests.

24 Aircraft weight was determined by an on-board observer by adding the fuel

25 weight from the fuel quantity gages to the weight of the aircraft

26 without fuel.

-9-

1   During the level flyovers the onboard recording system was

2 inoperative. For these tests, the onboard observer recorded values

3 of engine pressure ratio from the EPR gage, and checked airspeed,

4 flap, and gear indicator values against the test values specified

5 in the Plan of Test prior to each run. Weight values were determined

6 in the same manner as in the approaches.

7

8

9

·10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

25

NASA-Langley Form 22 (Apr 69)

TEST CONDITIONS AND PROCEDURES

Test Conditions

The test conditions for the five 3° approach runs are given in Table V. Gear and flap position, thrust, airspeed, and weight are from data obtained onboard the aircraft. Altitude and time over the station are from radar data, wind velocity data are from the 10 meter anemometer at the primary meteorological site, and temperature, relative humidity and static pressure are from data recorded at the backup meteorological site.

Table VI presents the test conditions for each of the level flyover runs. Since airspeed was not recorded in this case, this parameter is given in terms of the test value specified in the Plan of Test. The pilot and on-board observer noted that the actual airspeeds were within ± 3 kts of these values on all of the level flyover runs.

It may be noted from Table V that on the day when the 3° approach tests were made, all of the meteorological conditions were within the limits given in ref. 2 for noise testing, with the exception of a 1 kt. deviation in cross wind on the first run. For the level flyovers, all of the meteorological surface conditions were within the test specifications of ref. 2 at all times.

Table VII presents the radiosonde data taken during the approach tests. The data show that, within the limited altitude range of interest for these tests (surface to about 150 meters), there was very little variation in temperature, relative humidity, or wind velocity or direction.

NASA-Langley Form 22 (Apr 69)

1   Radiosonde data taken during the level flyovers are given in

2 Table VIII. Over most of the test period, there were no atmospheric

3 anomolies. Data in Tables VIII(g), and VIII(i) however, show that a

4 weak temperature inversion occurred near the end of the test period,

5 between altitudes of about 122 meters (400 ft) and 213 meters (700 ft.).

6 Although surface conditions were constantly monitored, the existence

7 of this anomaly at altitude was not known at the time and four of the

8 610 meter altitude runs were made during this period. This anomaly was

9 found to have had no discernable effect on the noise measurements, and

10 is discussed in more detail in a later section of this report.

11   Test Procedures

12 3° Approaches.- The flight test procedure for the 3° approaches required

13 that the test aircraft fly simulated ILS approaches, over the length of the acoustic

14 range, toward a projected touchdown point 305 meters (1000 feet) from the

15 threshold of runway 04. Real time position information was transmitted

16 to the test aircraft using the system shown schematically in figure 7. Aircraft

17 position data from the AS/GSN-5 radar were recorded during each approach

18 and compared with the desired coordinates of the flight path using a

19 computer. Glide slope and localizer deviations were computed and transmitted

20 to the test aircraft in real time. This information was displayed in standard format

21 on the aircraft's Altitude Direction Indicator. Figure 8 shows the glide

22 slope and localizer geometry used in the computer program.

23   The pilots ability to fly a 3° glide slope using the simulated ILS

24 information is shown by the data in figure 9. It can be noted in this

25 figure that vertical and horizontal deviations from the nominal were small.

NASA-Langley Form 22 (Apr 69)

1   In these runs, the simulated glide slope signal was acquired

2 about 16.78 km (9 n. mi.) from the touchdown point, and the aircraft

3 configuration and test conditions were established by 9.24 km (5 n. mi.)

4 from the threshold. In order to maintain the desired test airspeed,

5 the pilot deployed the aircraft's speed brakes as necessary. The run

6 was broken off after manually flying the aircraft to the threshold

7 using the transmitted guidance information. Six runs were made for the

8 3° approach condition to gather comparative data. However, data from

9 the sixth run was questionable and is not presented in this report.

10 Level Flyovers.- Since the microphones for the level flyovers were

11 located at the threshold of runway 35, the flight procedure for these

12 runs was for the aircraft to approach the threshold, holding the

13 desired altitude until approximately 1.85 km (1 n. mi.) past the

14 station and then break off the run. The real time data display from

15 the FPQ-6 radar was used to voice vector the RSFS onto and along the

16 proper flight path until the runway was in sight. The test configurations

17 were usually established by about 5.5 km (3 n. mi.) from the site. In

18 order to maintain the desired test airspeed and thrust, the speed brakes

19 were deployed as required during the level flyovers. Three runs were

20 made for each of the five level flyover conditions.

21   Figure 10 shows recorded tracking data for typical level flyovers.

22 The data show that horizontal and vertical deviations from the nominal

23 flight paths were small using this technique.

24

25

1

2   Figure 11 shows, schematically, the basic elements in the acoustic data

3 reduction system. The analog tapes from the recorder in the van were

4 processed through the third octave-band analyzer (with reference to the

5 microphone system calibration level) to yield digitized sound pressure

6 levels in the third octave bands between 25 Hz and 20,000 Hz with a

7 resolution of 0.25 dB. These data, determined at 0.5 second intervals,

8 were entered in the computer which corrected for system frequency

9 response, sound level meter dynamic response, microphone windscreen

10 effects, and ambient noise levels. Following these operations, the

11 corrected third octave-band sound pressure levels were then reprocessed

12 by the computer to obtain the noise parameters OASPL, dBA, PNL, PNLT,

13 and EPNL discussed in this report.

14   Overall sound pressure level (OASPL) at a given time increment was

15 determined by summing the corrected third octave band sound levels on the

16 basis of their squared pressures (see reference 3) between the frequency

17 bands from 25 Hz to 20,000 Hz. The parameter dBA was determined in a

18 similar manner except that an "A" weighting correction function was

19 applied to the sound levels in each third octave band prior to the

20 summation process. This method of analysis is also described in

21 reference 3. The methods used for the computation of the PNL and PNLT are

22 described in reference 2.

23   The Effective Perceived Noise Level for the test conditions (EPNL$_{TEST}$)

24 was also calculated in accordance with reference 2 by an analysis of

25 the PNLT time history. An important parameter in this analysis was

26 the duration time. Reference 2 defines this term as the time interval

1 between points on the PNLT history that are 10 dB less than PNLTM.

2 (The 90 db PNLT duration cutoff, also described in reference 2, was

3 not used in this analysis.) The effect of the duration parameter on

4 the data taken during these tests is discussed in a later section of

5 this report.

6   In order to provide a comparison of EPNL data on a standard

7 reference basis, the parameter $EPNL_{REF}$ was also determined by taking

8 into account the effects of differences between the test conditions and

9 a set of reference conditions. The 3° approach data were corrected to

10 the reference conditions specified in reference 2 using the methods given

11 in that reference (with the exception of the atmospheric attenuation

12 correction which was made using the method of reference 4).

13   The conditions to which the approach data were corrected were:

14   Surface temperature - 77^OF

15   Surface Relative Humidity - 70%

16   Maximum Landing Weight - $89,700^{\#}$

17   Noise Site Location - 1.85 Km (1.0 nautical mile) from threshold

18   Height over Station - 113 meters (370 ft.)

19 In addition, these 3° approaches were all normalized to an approach speed

20 of 1.3 V_s + 10 KIAS. For the 40° flap configuration at the above weight,

21 this airspeed was 136 KIAS.

22   For the level flyovers, atmospheric attenuation, position, and airspeed

23 corrections were applied to allow a direct comparison with the data in

24 reference 5. These references values were:

25   Temperature - 77^OF

1   Relative Humidity - 70%

2   Airspeed - 160 KIAS

3   Heights over noise site - 122 m (400 ft.) and 610 m (2,000 ft.)

4   During the 15 level flyovers, all ground based systems operated

5 satisfactorily and the data analysis was straightforward. However,

6 during analysis of the 3^0 approach data, it was found (by a correlation

7 of events and times from radar, onboard, and noise data) that the time

8 code placed on the noise tapes were in error. Thus, the location of

9 the aircraft at the time of PNLTM (required to apply the atmospheric

10 attenuation correction to $EPNL_{REF}$) had to be estimated.

11   Other test data were then examined. During this test series, six

12 approaches had been made at 4^0. These data, though not included herein,

13 indicated that three of these runs appeared to have reasonable time

14 codes on the noise data tapes. These data indicated that PNLTM occured one

15 second after the aircraft was directly overhead (time interval = +1 second).

16 An examination of the level flyover data also indicated that, for the runs

17 at 122 meters with power levels corresponding to the 3^0 approach value,

18 the time interval was about +1 second.

19   Since +1 second appeared to be a reasonable value, a sensitivity

20 test was performed to evaluate the effect of errors in this assumed

21 value. Intervals of zero seconds (PNLTM directly overhead) and +2 seconds

22 were used, the atmospheric attenuation due to these slant ranges were

23 calculated and the results were compared with the assumed 1 second value.

24 The results showed that an error of only ± 0.25 db resulted from a ± 1

25 second error in the assumed value.

NASA-Langley Form 22 (Apr 69)

1   On the basis of these considerations, an assumed time interval of

2 +1 second was used in the analysis of $EPNL_{REF}$ for the 3° approaches. It

3 should be noted that this assumption does not influence any of the other

4 3° approach noise parameters since they do not include the atmospheric

5 attenuation correction. Since the time code generator operated satis-

6 factorily during the level flyovers, measured values were used in

7 determining those $EPNL_{REF}$ values.

8

9

10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

25

3^0 Approaches

Figures 12(a) through (c) are PNLT histories of the 3^0 approach runs. For these data, the times of PNLTM (in GMT) were determined by adding 1 second to the overhead time, as discussed earlier. These plots indicate the repeatability of the measurements. Figure 13 shows a typical (run 1) spectra at the time of PNLTM for a 3^0 approach. The data shows the predominance of high frequency noise at these conditions.

Table IX presents maximum values of dBA and OASPL, PNLTM, $EPNL_{TEST}$ and $EPNL_{REF}$, for each run. The data are quite consistent and show little deviation from the average. The difference between the $EPNL_{TEST}$ and $EPNL_{REF}$ values results primarily from the atmospheric attenuation correction.

The average value of the $EPNL_{REF}$ data in Table IX is 110.4 dB. Unpublished noise data from certification tests of the same type of aircraft show a value of 107.9 dB at the same reference conditions. This difference is not unreasonable, considering possible differences in terrain where the measurements were made, normal data recording, reduction, and analysis errors, and the time code generator problem noted earlier.

Level Flyovers

Typical PNLT histories (runs 1.1, 2.1, 3.1, 4.1, and 5.1) are presented in figures 14 through 18, and Table X presents maximum values of OASPL and dBA, PNLTM, $EPNL_{TEST}$, and $EPNL_{REF}$ for all of the level flyovers.

An examination of the data in Table X shows that the agreement in noise data between the various runs was quite good, and that the effect

-18-

1 of differences between test and reference conditions ($EPNL_{TEST}$ and

2 $EPNL_{REF}$) was small.

3   The effect of the weak temperature inversion can be seen by a

4 comparison of the maximum dBA data in this Table. Runs 5.1, 5.2,

5 and 5.3 were identical except that 5.3 was performed when the weak

6 inversion was present and runs 5.1 and 5.2 were conducted before it

7 developed. Since the dBA parameter does not involve spectral corrections

8 for temperature or humidity, the effect of the inversion is present in

9 these values. The agreement between the data prior to, and during the

10 inversion is quite good and indicates that the effect of the weak

11 inversion was negligable.

12   The effect of duration time on $EPNL_{TEST}$ is also shown by these data.

13 For all of the 122 meter (400 foot) passes, where duration time was

14 short (i.e. figs. 14, 15, and 16), $EPNL_{TEST}$ was about 5 dB lower than

15 PNLTM. At 610 meters (2,000 feet) however, the duration times are long

16 (i.e., figs. 17 and 18) and $EPNL_{TEST}$ had about the same value as PNLTM.

17   A typical (Run 1.1) low altitude level flyover spectra, at the time

18 of PNLTM, is shown in figure 19. This spectra shows the same general

19 frequency characteristics as the 3° approach data in figure 13. The

20 typical (Run 4.1) high altitude level flyover spectra shown in figure 20,

21 however, does not show the predominance of high frequency noise shown by

22 these low altitude data because of the attenuation of the high frequency

23 at the larger propagation distance involved.

24   Data showing the effect of thrust and altitude on noise level of

25 the 737-200 aircraft are given in reference 5 and compared with data from

-19-

1 these tests in figures 21 and 22. Both sets of data are for the aircraft

2 with JT8D-7 engines. It should be noted however, that where these flight

3 data are from direct measurements at both altitudes, the reference 5

4 data at 610 (2,000 ft.) meters was extrapolated from low altitude

5 flyover test results.

6   The dBA data are compared in figure 21 and shows reasonable agree-

7 ment at both altitudes and at all five thrust levels. The effect of the

8 differences in the reference test conditions between the data in figure 21

9 was estimated to be less than 0.5 dbA.

10   Figure 22 compares these flight data with reference 5 in terms of

11 EPNL. The data show that the agreement at the low altitude and low

12 power settings remains reasonable but a significant difference appears at

13 the higher altitude. This discrepency was not evident in the dBA comparison

14 of figure 21. Since the reference 5 data were extrapolated to the higher

15 altitude and (as shown earlier) the duration time has a large effect on

16 EPNL, the difference at 610 meters (2,000 feet) is attributed to the values

17 of this term used in the extrapolation to this altitude. This discrepancy

18 would not be expected to appear in the dBA comparison (figure 21) since

19 this noise parameter does not involve duration time.

20

21

22

23

24

25

CONCLUDING REMARKS

1

2   Baseline 3-degree approach noise data have been determined for

3 a short-to-medium-range jet transport aircraft using noise

4 instrumentation, test procedures, and analysis methods compatible with

5 the requirements of reference 2. These 3-degree approach data have been

6 determined for reference noise test conditions at a point 1.85 kilometers

7 (1.0 nautical miles) from the runway threshold.

8   Flight measurements correlating noise with thrust were also

9 made during level flyovers at altitudes of 122 meters (400 feet) and

10 610 meters (2,000 feet) and referenced to standard conditions for

11 purposes of comparison.

12   The data from these flight tests has been compared with pertinent

13 data from other sources and reasonable agreement was noted.

14

15

16

17

18

19

20

21

22

23

24

25

NASA-Langley Form 22 (Apr 69)

REFERENCES

1. New Design and Operating Techniques and Requirements for Improved
    Aircraft Terminal Area Operations: Reeder, John P., Taylor, Robert T.,
    and Walsh, Thomas M.:   NASA TM X-72006.

2. Federal Aviation Regulation - Part 36:   Appendices A, B, and C;
    December 1, 1969.

3. Handbook of Noise Ratings: Pearsons, Karl S. and Bennett, Ricarda L.:
    NASA CR-2375, April, 1974.

4. Standard Values of Atmospheric Absorption as a Function of Temperature
    and Humidity for Use in Evaluating Aircraft Flyover Noise;
    SAE ARP 866, August, 1964.

5. Aircraft Noise Definition, Individual Aircraft Technical Data,
    Model 737; FAA-EQ-73-7, 4; December, 1973.

TABLE I.- AIRCRAFT DIMENSION AND DESIGN DATA

General:
  Length, m (ft) 28.65 (94)
  Height to top of vertical fin, m (ft) 11.28 (37)

    :
  Area, m^2 (ft^2) 91.04 (980)
  Span, m (ft) 28.35 (93.0)
  Mean Aerodynamic chord, m (ft). 3.41 (11.2)
  Incidence angle, deg. 1.0
  Aspect ratio 9.07
  Dihedral, deg 6
  Sweep, deg 25
  Flap deflection (max), deg 40
  Flap area, m^2 (ft^2) 14.94 (160.8)
  Aileron deflection (max), deg . . . . $\pm$20
  Spoilers deflection, deg:
    Inboard 60
    Outboard 40

Stabilizer:
  Area, m^2 (ft^2). 28.98 (312)
  Span, m (ft). 10.97 (26)
  Stabilizer deflection, deg 12
  Elevator deflection (max), deg . . . .$\pm$21

Vertical tail:
  Total area, m^2 (ft^2) 20.9 (225)
  Span, m (ft) 6.15 (20.16)
  Rudder area, m^2 (ft^2) 5.22 (56.2)
  Rudder deflection, deg . . . .$\pm$24

Weight:
  Maximum takeoff gross weight, N (lb). . . . . 4.35 X 10^5 (97,800)
  Maximum landing weight, N (lb). . . . . 3.98 X 10^5 (89,700)
  Empty weight (zero fuel), N (lb). . . . . 2.82 X 10^5 (63,500)

Moment of inertia for 4.00 X 10^5 N (90,000 lb) condition:
  I_{xx}, kgm^2 (slug-ft^2) . . . . 5.89 X 10^7 (375,000)

  I_{yy}, kgm^2 (slug-ft^2) . . . . 1.37 X 10^8 (875,000)

  I_{zz}, kgm^2 (slug-ft^2) . . . . 1.88 X 10^8 (1,2000,000)

Center of gravity:
  Percent of mean aerodynamic chord 20.0

TABLE II

Increments to Free-Field Correction Curves at 90° Incidence Due to
Windscreen 1/2 Inch Condenser Microphones

Frequency Hz	Correction dB
500	0.1
630	0.1
800	0.1
1000	0.2
1250	0.3
1600	0.5
2000	0.6
2500	0.7
3150	0.8
4000	0.2
5000	-0.5
6300	-0.3
8000	-0.4
10,000	-1.0

TABLE III

SUMMARY OF SYSTEM LEVEL TESTS

TEST	PROCEDURE	TEST RESULTS
Frequency Response[1] (45 Hz to 11.2 KHz)	Apply oscillator signal at preamplifier input. Record system frequency response through tape recorder output.	+2 dB -1 dB
Distortion	Apply signal at microphone using acoustic calibrator. Check system distortion through tape recorder output.	<2%
Linearity	Apply oscillator signal at preamplifier input. Check system linearity at tape recorder output over expected range settings of variable-gain amplifier.	±1.0% of full scale tape recorder deviation
Noise Floor (Ref. 2×10^{-5} N/m^2)	Short circuit preamplifier input and monitor system noise level at tape recorder output.	40-61 dB

[1] With respect to the calibration signal at 250 or 1000 Hz.

TABLE IV

TEST AIRCRAFT DATA LIST

Total Air Temperature
Airspeed
Radar Altitude
Flap Position
Gear Position
Speed Brake Position
Engine Pressure Ratio
Throttle Position

Angle of Attack
Pitch Altitude
Yaw Altitude
Roll Altitude

Pitch Rate
Roll Rate
Yaw Rate

Rudder Position
Aileron Position
Spoiler Position
Stabilizer Position
Elevator Position
Pedal Position

Column Force
Wheel Force

TABLE V

TEST CONDITIONS

(3° Approaches)

Run No.	Configuration				Meteorological Conditions					Conditions Over Station		
	Flap[1] pos. (deg)	Gear pos.	F_N/δ N/eng (lb./eng)	Weight, N (lb.)	V_w, Kts	V_{cw}, Kts	Temp, K^O (^{O}F)	Rel. Hum., percent	p_o, N/m^2 (lb./in^2)	Time GMT	Z m (ft.)	KIAS
1	40	Down	25,899 (5820)	396,990 (89,200)	8	6	279.0 (43.0)	51.0	102,961 (14.94)	13:02:00	119.9 (393)	134
2	40	Down	23184 (5210)	390,265 (87,700)	5	3	279.5 (43.9)	48.5	102,961 (14.94)	13:15:32	110.7 (363)	127
3	40	Down	24564 (5520)	389,035 (86,300)	8	2	279.8 (44.5)	46.5	102,961 (14.94)	13:28:57	125.1 (410)	132
4	40	Down	23184 (5210)	377,805 (84,900)	8	3	280.2 (45.2)	45.5	102,961 (14.94)	13:42:03	115.9 (380)	134
5	40	Down	23184 (5210)	373,355 (83,900)	7	4	280.5 (45.7)	44.0	102,961 (14.94)	13:52:24	118.3 (388)	129

1   All leading edge flaps fully extended.

TABLE VI

Test Conditions
(Level Flyovers)

Run No.	Configuration				Meteorological Conditions					Conditions Over Station		
	Flap[1] pos. (deg)	Gear pos.	F_N/δ N/eng. (lbs./eng)	Weight N (lb.)	V_w, knots	V_{cw}, knots	Temp, ^oK (^oF)	Rel. Hum., percent	Po n/m^2 (lb./in^2)	Time GMT	Z m (ft.)	KIAS
1.1	10	Up	19,046 (4,280)	400,055 (89,900)	6	4	296.2 (74)	65	101,283 (14.70)	19:56:01	121.4 (398)	145
1.2	10	Up	19,046 (4,280)	400,500 (90.000)	3	1	295.1 (72)	69	101,283 (14.70)	20:58:57	122.6 (402)	145
1.3	10	Up	19,046 (4,280)	400,500 (90,000)	0	0	294.0 (70)	73	101,283 (14.70)	22:01:08	123.2 (404)	145
2.1	30	Up	24,075 (5,410)	392,045 (88,100)	0	0	296.8 (75)	62	101,283 (14.70)	18:46:49	109.8 (360)	150
2.2	30	Up	24,075 (5,410)	383,145 (86,100)	4	1	296.8 (75)	62	101,283 (14.70)	18:56:12	108.6 (356)	150
2.3	30	Up	24,075 (5,410)	376,915 (84,700)	2	2	296.8 (75)	63	101,283 (14.70)	19:16:29	114.4 (375)	150
3.1	30	Up	28,569 (6,420)	381,810 (85,800)	2	1	296.8 (75)	62	101,283 (14.70)	19:06:28	113.8 (373)	150
3.2	30	Up	28,569 (6,420)	388,485 (87,300)	6	3	295.7 (73)	66	101,283 (14.70)	20:15:51	112.0 (400)	150
3.3	30	Up	28,569 (6,420)	383,590 (86,200)	4	2	295.7 (73)	67	101,283 (14.70)	20:24:55	120.2 (394)	150

[1] All leading edge flaps fully extended.

TABLE VI (concluded)

Test Conditions

(Level Flyovers)

	Configuration				Meteorological Conditions					Conditions Over Station		
Run No.	Flap[1] pos. (deg)	Gear pos.	F_N/δ N/eng. (lbs./eng)	Weight N (lb.)	V_w, knots	V_{cw}, knots	Temp, $^\circ$K ($^\circ$F)	Rel. Hum., percent	P_0 n/m^2 (lb./in^2)	Time GMT	Z m (ft.)	KIAS
4.1	40	Down	46,725 (10,500)	388,485 (87,300)	4	3	295.1 (72)	69	101,283 (14.70)	12:18:1.	610.9 (2,003)	165
4.2	40	Down	46,725 (10,500)	381,810 (87,300)	2	0	294.5 (71)	70	101,283 (14.70)	21:27:35	609.4 (1,998)	165
4.3	40	Down	46,725 (10,500)	395,605 (88,900)	0	0	294.0 (70)	74	101,283 (14.70)	22:09:45	610.9 (2,003)	165
5.1	40	Down	56,960 (12,800)	393,825 (88,500)	5	3	296.8 (75)	62	101,283 (14.70)	18:38:24	613.1 (2,010)	160
5.2	40	Down	56,960 (12,800)	393,825 (88,500)	7	3	296.2 (74)	65	101,283 (14.70)	20:06:07	637.2 (2,089)	160
5.3	40	Down	56,960 (12,800)	394,270 (88,600)	5	1	295.1 (72)	69	101,283 (14.70)	21:08:21	631.1 (2,069)	160

[1] All leading edge flaps fully extended.

TABLE VII.- RADIOSONDE DATA - 3° APPROACHES

(a) Relase Time - 13:09:xx GMT

Δt, Sec	Alt., m (ft)	V_w, Kts	θ_w, deg	T, °C
15	80.2 (263)	11.9	357.1	5.5
30	154 (505)	13.2	0.8	4.5
45	193 (632)	9.2	357.8	4.0
60	276 (907)	20.6	349.2	3.8
75	309 (1013)	25.6	348.1	3.5
90	383 (1257)	20.6	352.7	3.0

(b) Release Time - 13:40:xx GMT

Δt, Sec	Alt., m (ft)	V_w, Kts	θ_w, deg	Rel. Hum., percent
15	53 (173)	9.1	346	36
30	112 (368)	9.7	351	38
45	164 (537)	10.0	345	39
60	278 (912)	16.5	339	40
75	326 (1068)	18.1	348	42
90	413 (1356)	12.4	0.5	39

(c) Release Time - 14:10:xx GMT

Δt, Sec	Alt., (Ft)	V_w, Kts	θ_w, deg	T, °C
15	54 (178)	9.4	334	4.1
30	92 (301)	10.1	345	3.7
45	168 (551)	12.3	334	3.0
60	211 (693)	14.0	328	2.5
75	284 (933)	11.2	337	2.1
90	338 (1110)	11.1	338	1.6

(d) Release Time - 14:40:xx GMT

Δt, Sec	Alt., (ft)	V_w, Kts	θ_w, deg	Rel. Hum., percent
15	37 (122)	3.7	315	32
30	69 (227)	4.7	324	32
45	122 (401)	7.0	353	33
60	179 (587)	6.4	357	34
75	243 (798)	8.9	345	35
90	299 (980)	7.8	335	35

TABLE VIII.- RADIOSONDE DATA - LEVEL FLYOVERS

(a) Release Time - 18:30:xx GMT

Δt, sec.	Alt., m (ft.)	V_w, Kts.	θ_w, deg	T, °C
15	44 (144)	4.1	190	25.1
30	86 (281)	5.1	185	24.6
45	133 (435)	6.3	193	23.9
60	181 (594)	6.3	197	23.7
75	234 (769)	6.2	192	23.2
90	280 (918)	7.2	198	22.9
105	323 (1061)	7.1	208	22.8
120	365 (1199)	7.4	228	22.4
135	416 (1365)	8.4	243	21.8
150	476 (1561)	9.9	249	21.5
165	545 (1788)	8.6	245	20.7
180	622 (2042)	5.0	265	19.9
195	691 (2267)	4.3	324	19.3
210	773 (2535)	5.8	357	18.5

TABLE VIII.- CONT.

(b) Release Time - 19:00:xx GMT   (c) Release Time - 19:30:xx GMT

Δt, Sec	Alt., m (ft)	V_w, Kts.	θ_w, deg	Rel. Hum., percent
15	37 (123)	5.0	168	50
30	75 (247)	5.6	183	51
45	109 (356)	5.8	179	53
60	149 (488)	5.7	181	54
75	192 (630)	5.6	191	55
90	240 (788)	5.6	197	56
105	288 (944)	5.2	199	56
120	341 (1118)	5.5	192	57
135	399 (1310)	2.8	209	56
150	455 (1493)	4.8	295	58
165	511 (1677)	9.0	292	57
180	563 (1848)	9.2	292	53
195	613 (2010)	9.4	300	53
210	650 (2133)	9.6	305	56
225	703 (2305)	8.5	311	56

Δt, Sec	Alt., m (ft.)	V_w, Kts.	θ_w, deg	T, °C
15	38 (124)	3.8	165	24.1
30	62 (205)	4.6	168	24.1
45	98 (323)	5.8	175	23.7
60	127 (416)	5.2	179	22.9
75	161 (528)	4.9	184	22.5
90	196 (644)	5.2	194	22.0
105	237 (776)	5.2	210	21.8
120	277 (910)	5.1	225	21.7
135	321 (1052)	5.5	227	20.7
150	364 (1194)	5.9	221	20.3
165	410 (1344)	6.8	212	19.6
180	452 (1483)	6.2	217	19.6
195	494 (1622)	5.8	240	18.3
210	535 (1755)	6.1	252	18.6
225	574 (1884)	5.8	259	17.9
240	612 (2008)	5.6	273	17.5
255	656 (2151)	5.6	285	17.0

TABLE VIII.- Cont.

(d)   Release Time - 20:00:xx GMT   (e)   Release Time - 20:30:xx GMT

Δt, Sec	Alt., m (ft)	V_w, Kts.	θ_w, deg	Rel. Hum., percent
15	51 (167)	3.5	257	42
30	105 (343)	5.4	272	43
45	154 (506)	6.5	258	45
60	222 (729)	7.5	245	46
75	300 (983)	7.6.	247	47
90	383 (1258)	7.2	272	49
105	482 (1581)	7.2	287	51
120	570 (1869)	7.8	292	52
135	667 (2187)	9.5	295	53
150	758 (2487)	10.2	299	55

Δt, Sec	Alt., m (ft)	V_w, Kts.	θ_w, deg	T, °C
15	43 (142)	4.0	168	25.1
30	84 (277)	4.1	166	24.5
45	119 (392)	4.1	161	23.9
60	155 (510)	4.1	183	23.7
75	202 (662)	5.6	209	23.3
90	242 (794)	5.7	216	23.3
105	292 (959)	3.1	238	23.3
120	346 (1136)	3.3	300	23.1
135	397 (1302)	5.8	311	22.8
150	454 (1491)	7.2	307	22.4
165	511 (1677)	7.8	306	21.5
180	563 (1848)	8.9	310	21.1
195	616 (2022)	9.7	309	20.6
210	657 (2156)	11.2	310	20.1
225	700 (2298)	12.9	309	19.6

TABLE VIII.- CONT.

(f) Release Time - 21:00:xx GMT

Δt, Sec	Alt., m (ft)	V_w, Kts.	θ_w, deg	Rel. Hum. percent
15	81 (267)	7.6	158	60
30	156 (511)	5.6	196	59
45	245 (804)	4.3	272	57
60	330 (1084)	5.1	291	56
75	417 (1367)	4.6	297	57
90	499 (1637)	3.8	321	57
105	585 (1918)	5.2	330	60
120	652 (2139)	9.1	326	60
135	725 (2380)	10.6	333	59

(g) Release Time - 21:32:xx GMT

Δt, Sec	Alt., m (ft)	V_w, Kts.	θ_w, deg	T, °C
15	40 (130)	3.3	159	18.2
30	74 (242)	4.9	159	17.5
45	106 (348)	5.7	158	17.2
60	137 (451)	4.3	152	17.0
75	164 (538)	1.6	132	17.0
90	192 (631)	0.6	-	17.8
105	221 (725)	1.6	-	18.2
120	251 (822)	2.5	341	17.6
135	282 (925)	3.9	340	17.0
150	310 (1016)	5.2	346	16.7
165	338 (1109)	6.2	343	16.3
180	359 (1178)	7.0	344	16.2
195	391 (1284)	7.2	344	16.1
210	416 (1364)	7.5	335	16.0
225	440 (1442)	7.5	329	15.8
240	465 (1527)	7.1	330	15.5
255	484 (1587)	7.5	334	15.3
270	507 (1662)	8.6	330	15.1
285	536 (1759)	8.5	323	14.9

TABLE VIII.- Concluded.

(h) Release Time - 22:05:xx GMT

Δt, Sec	Alt., m (ft)	V_w, Kts.	θ_w, deg	Rel. Hum. percent
15	100 (328)	3.6	159	70
30	200 (656)	1.8	319	64
45	299 (980)	6.8	339	54
60	422 (1385)	8.6	347	53
75	509 (1670)	11.2	342	52
90	631 (2071)	13.8	342	50
105	721 (2365)	13.8	350	49

(i) Release Time - 22:30:xx GMT

Δt, Sec	Alt., m (ft)	V_w, Kts.	θ_w, deg	T, °C
15	91 (297)	3.0	162	20.0
30	175 (573)	1.0	331	20.4
45	265 (869)	4.4	342	20.3
60	358 (1175)	7.6	345	19.8
75	450 (1477)	11.0	346	19.1
90	543 (1780)	13.1	343	18.5
105	633 (2076)	13.8	348	17.6
120	725 (2377)	14.3	355	17.1
135	813 (2668)	14.0	359	16.4

TABLE IX.- NOISE DATA

3° Approaches

Run No.	Maximum OASPL	Maximum dBA	PNLTM	EPNL TEST	EPNL REF.
1	100.7	98.4	115.2	109.0	110.3
2	100.5	98.3	114.7	108.0	109.4
3	100.3	98.4	116.2	108.0	110.6
4	100.4	98.5	115.4	108.5	110.7
5	99.4	97.9	113.9	108.5	111.1
Avg.	100.3	98.3	115.1	108.4	110.4

TABLE X.- NOISE DATA

Level Flyovers

Run No.	Maximum OASPL	Maximum dBA	PNLTM	$EPNL_{TEST}$	$EPNL_{REF}$
1.1	97.7	97.3	112.8	107.3	106.7
1.2	97.2	96.8	112.5	106.8	106.2
1.3	97.2	96.7	112.7	107.1	106.6
Avg	98.0	96.9	112.7	107.1	106.5
2.1	99.6	98.6	114.9	109.0	107.8
2.2	99.5	98.6	114.7	109.2	107.8
2.3	99.8	99.2	115.4	109.6	108.9
Avg	99.6	98.8	115.0	109.3	108.2
3.1	101.5	99.7	116.6	111.4	110.7
3.2	100.7	98.8	115.5	110.3	109.9
3.3	101.2	99.7	116.4	111.0	110.4
Avg	101.1	99.4	116.2	110.9	110.3
4.1	93.1	86.2	100.3	102.5	102.5
4.2	93.6	89.0	100.9	100.9	100.8
4.3	93.2	87.8	100.0	100.6	100.5
Avg	93.3	87.7	100.4	101.3	101.3
5.1	99.7	94.2	106.1	105.0	105.0
5.2	99.0	91.5	104.7	104.8	104.8
5.3	98.5	92.4	104.6	105.1	105.1
Avg	99.1	92.7	105.1	105.0	105.0

Figure 1. - Photograph of test aircraft.
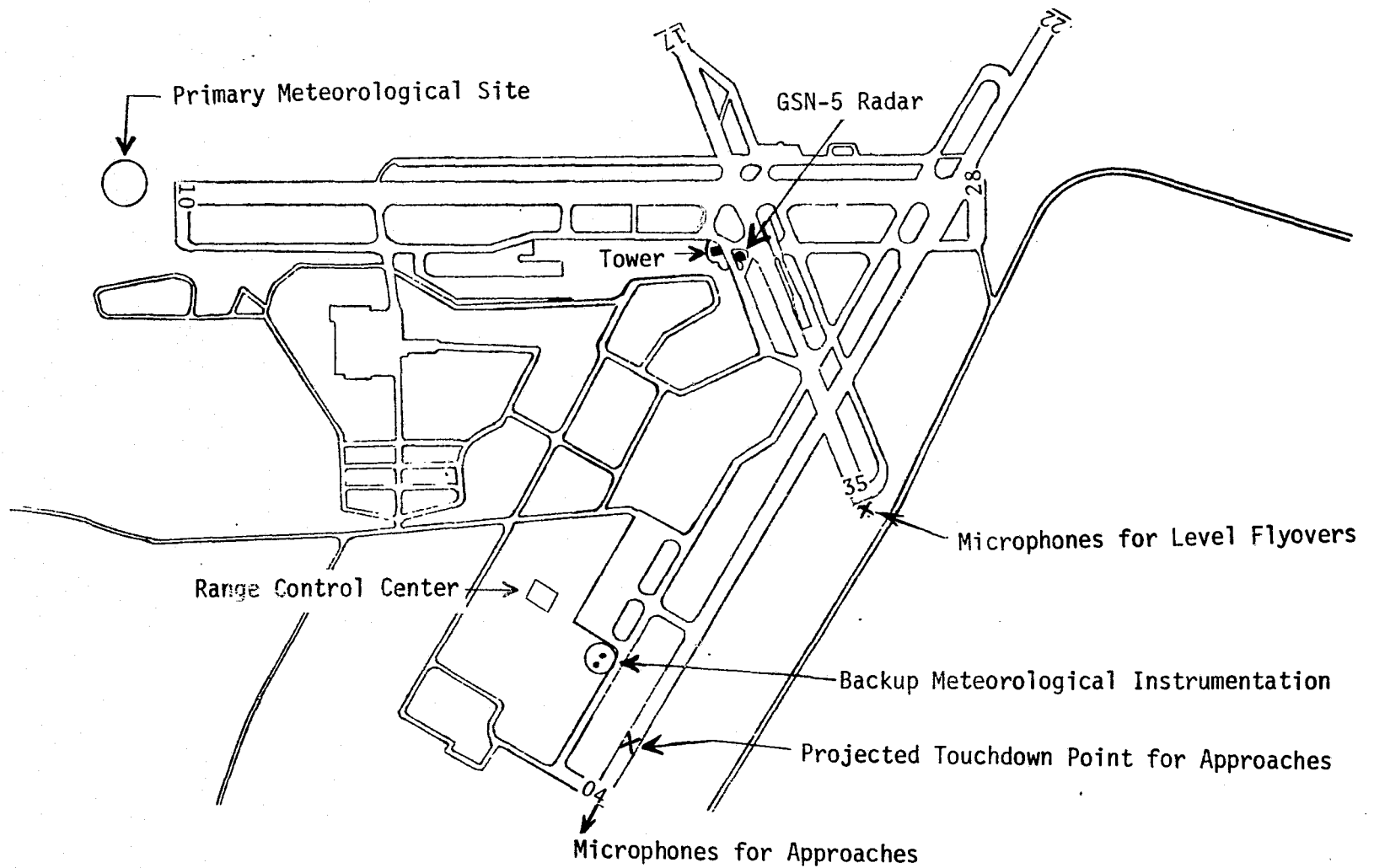
Figure 2.- Location of ground support systems on the WFC airfield(Not to Scale).
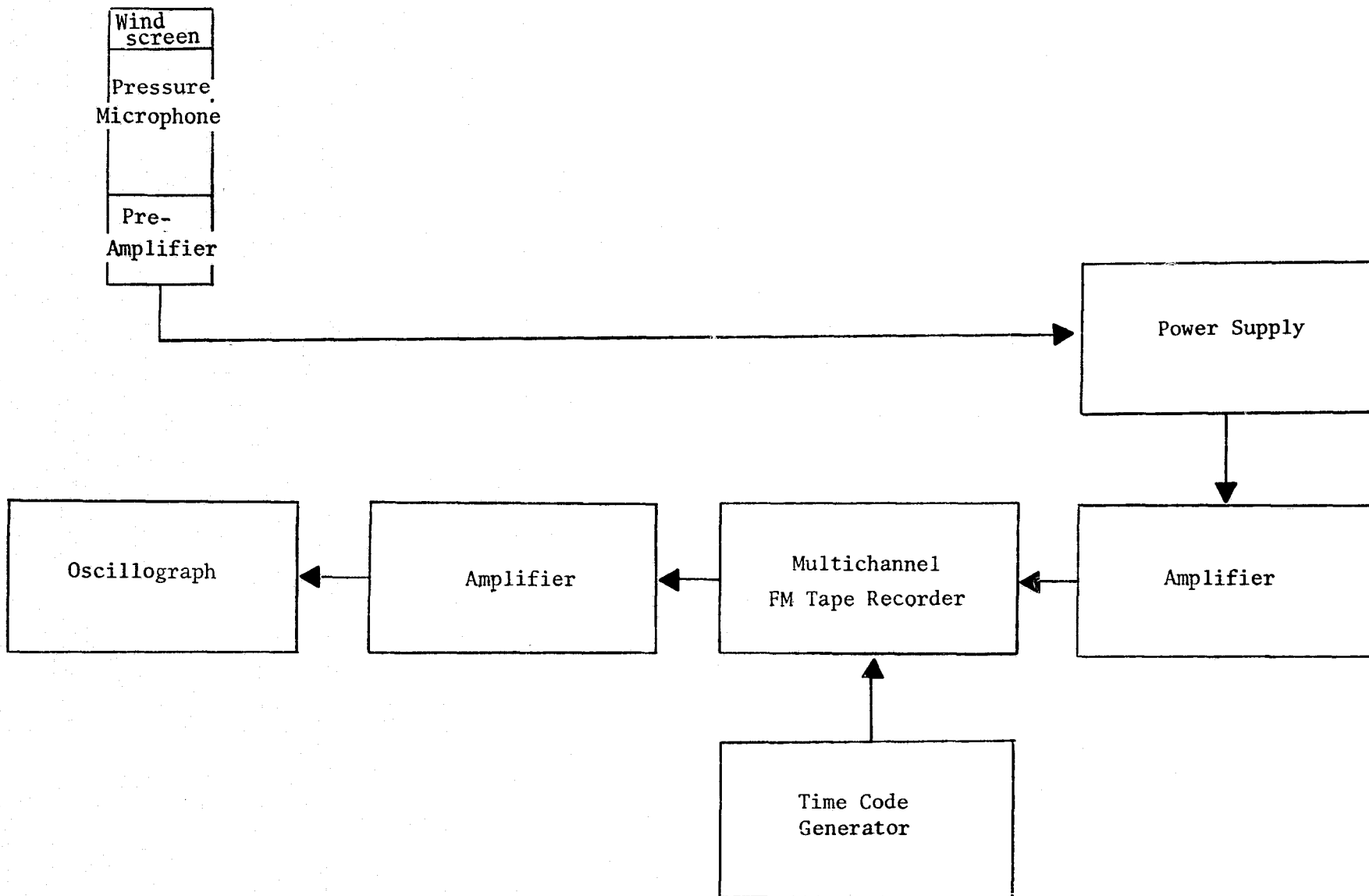
Figure 3.- Acoustic instrumentation block diagram.
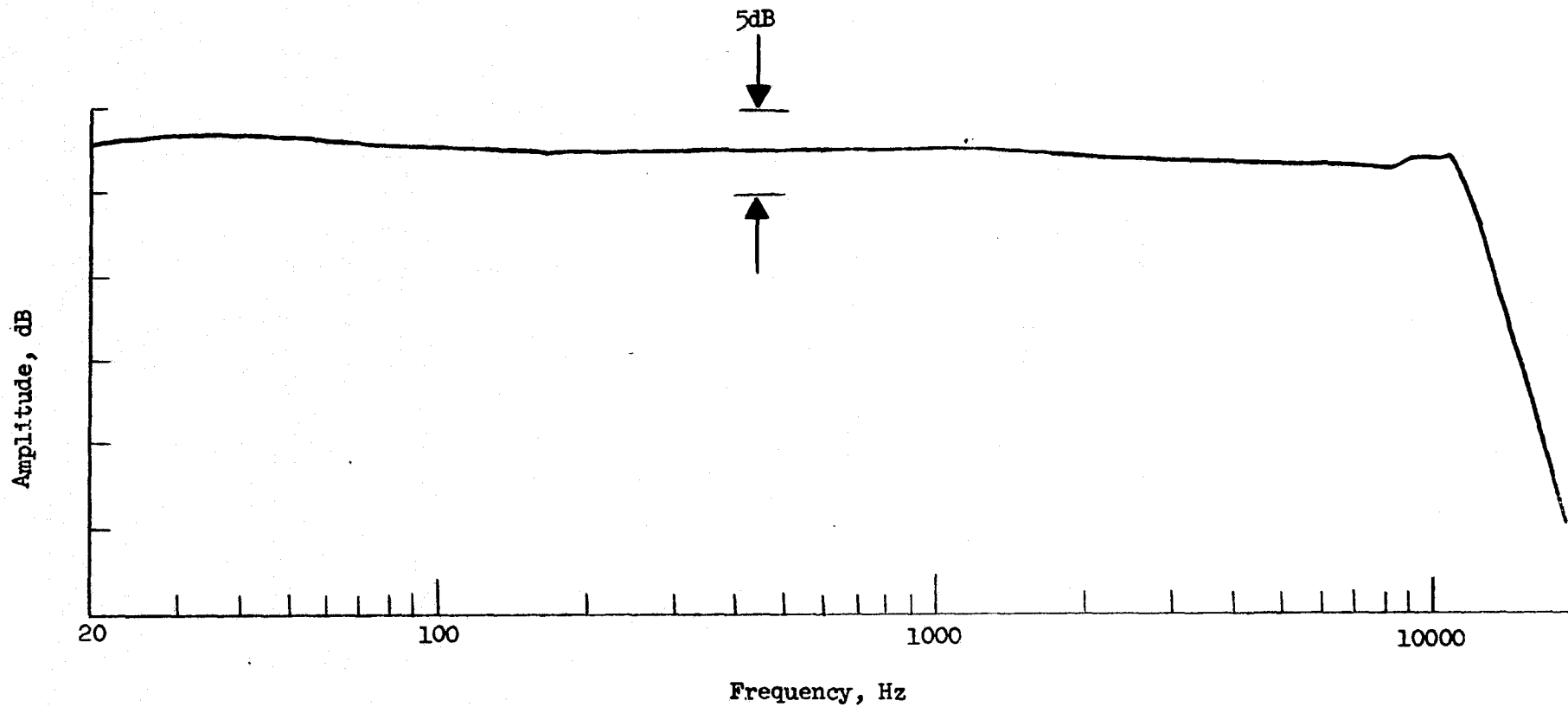
Figure 4.- Typical microphone channel frequency response.

Figure 5.- Photograph of site for approach noise measurements.
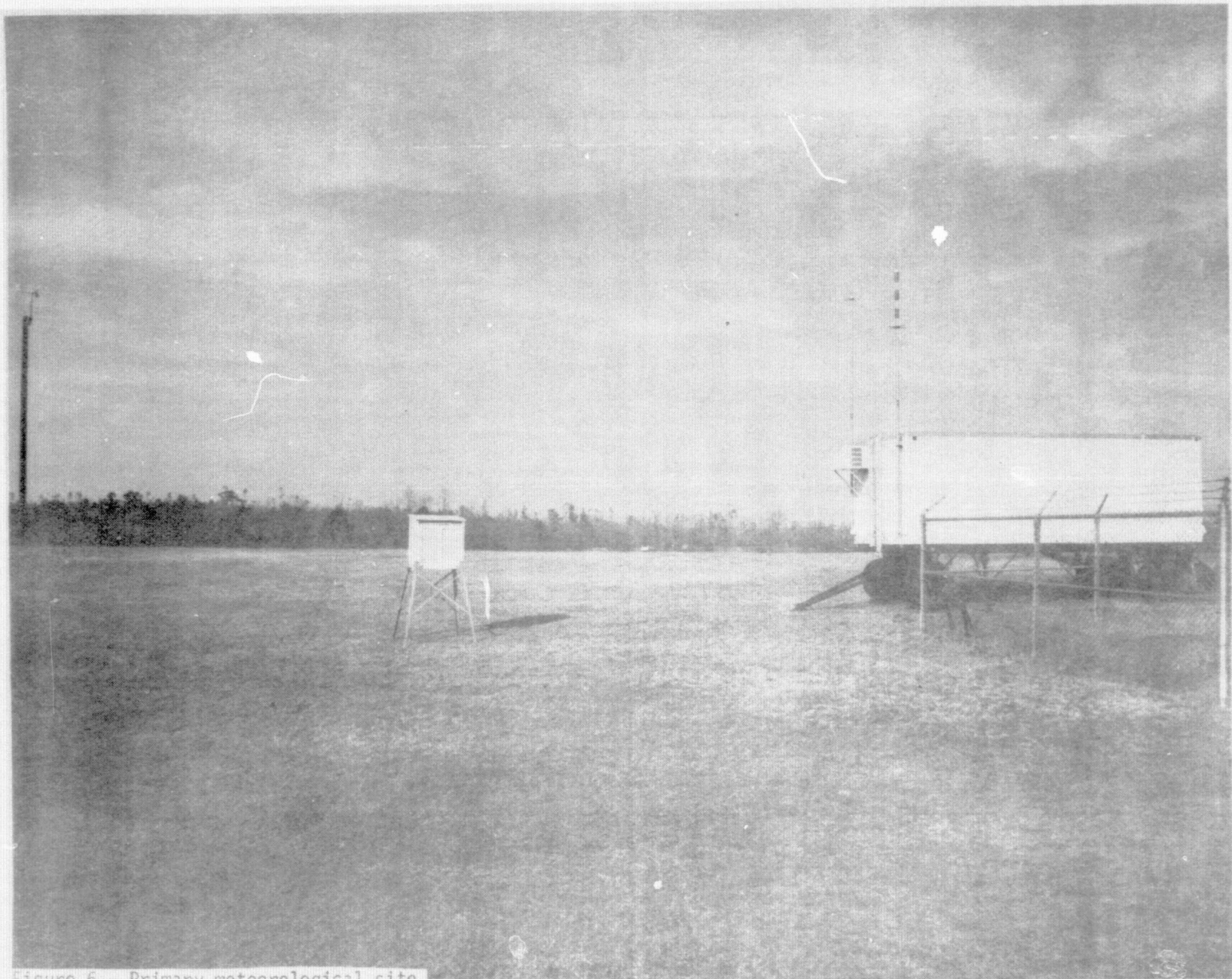
Figure 6.- Primary meteorological site.
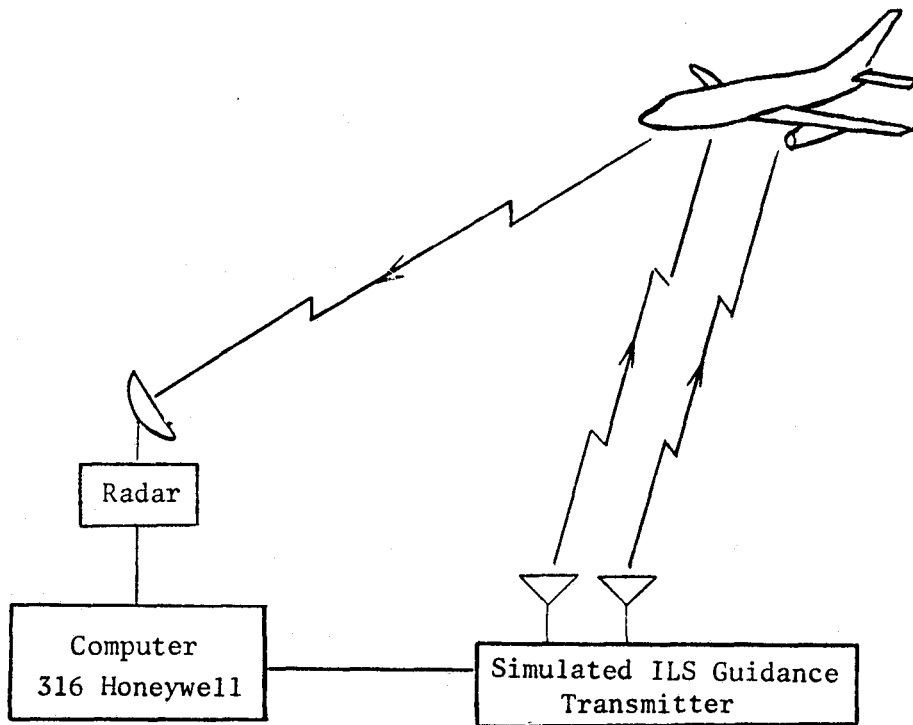
Figure 7.- Simulated ILS guidance system.

Runway

2.5°

2.5°

¢

(a) Localizer

Touchdown Point

Threshold

1829m (6000 ft)

304m (1000 ft)

Glidepath apex

0.7°

0.7°

¢

3°
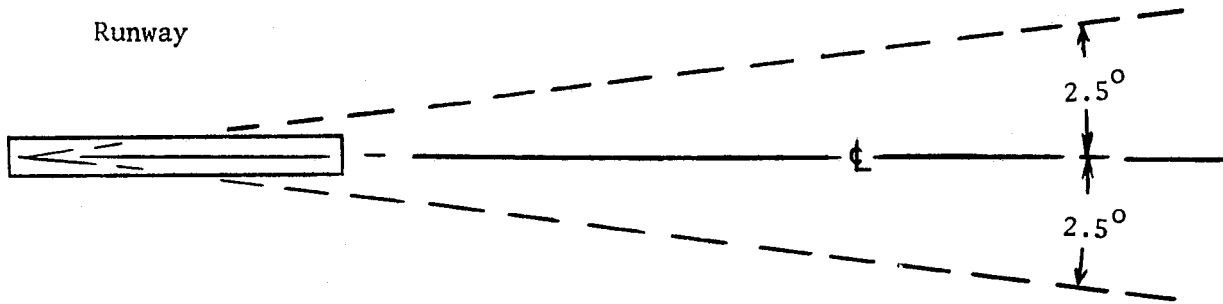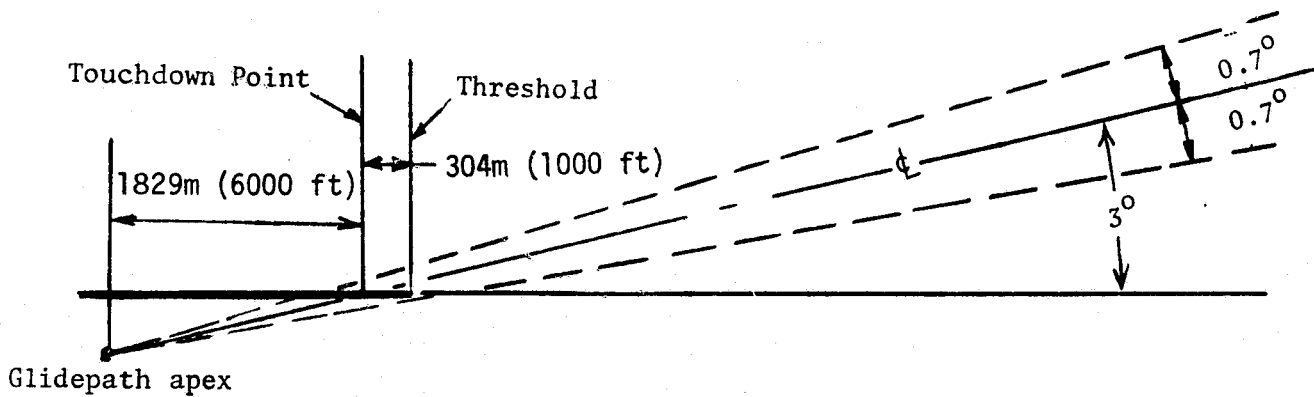
(b) Glideslope

Figure 8.- Simulated guidance geometry.
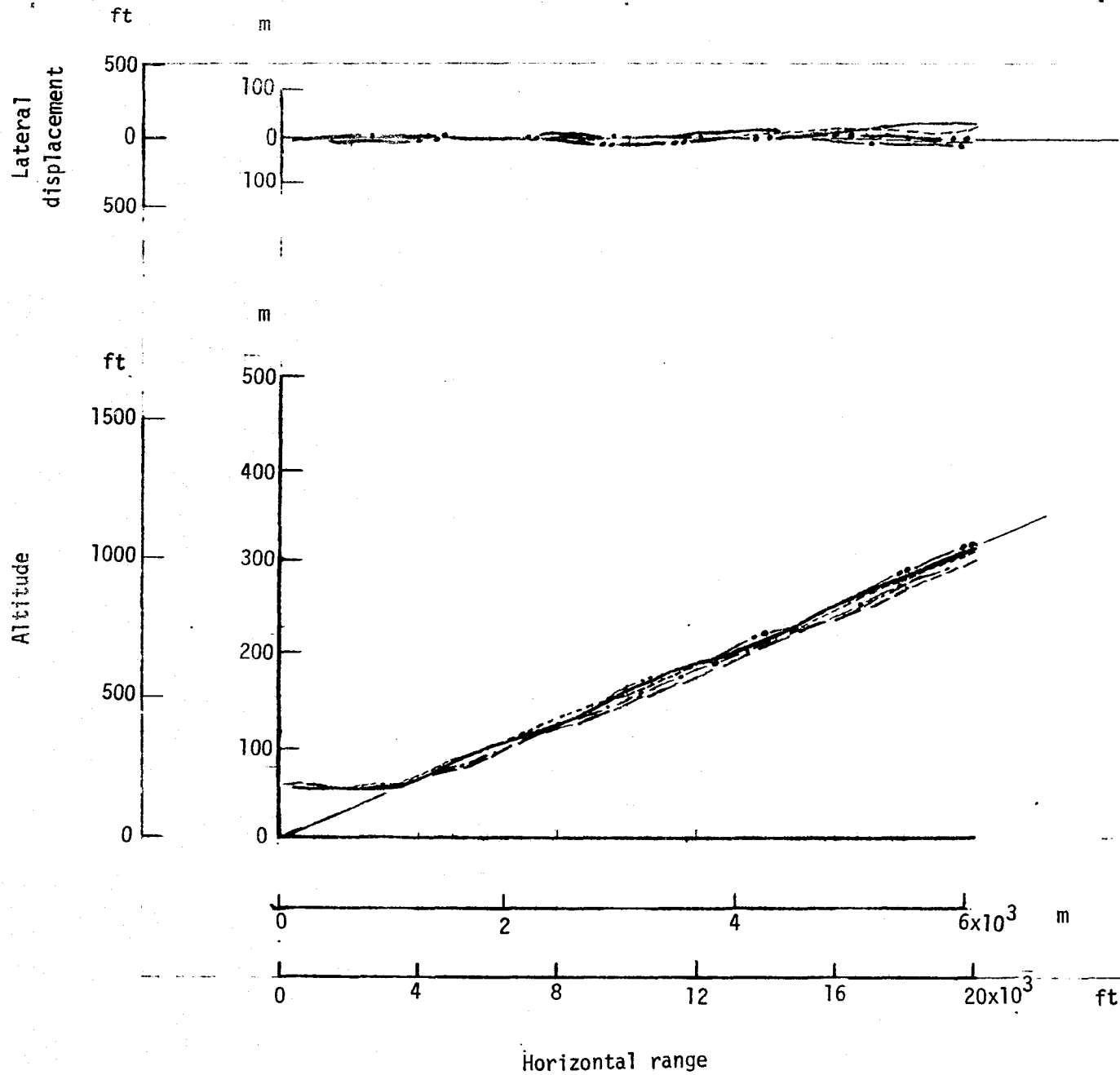
Figure 9.- Altitude-plan-position data from ground-based radar for the 3° approaches.

ft

Lateral displacement

500

0

500

m

100

0

100

ft

m

800

2500

700

2000

600

Altitude

500

1500

400

1000

300

200

500

100

0

0

1500   0   1500   m

5000   0   5000   ft

Distance from station
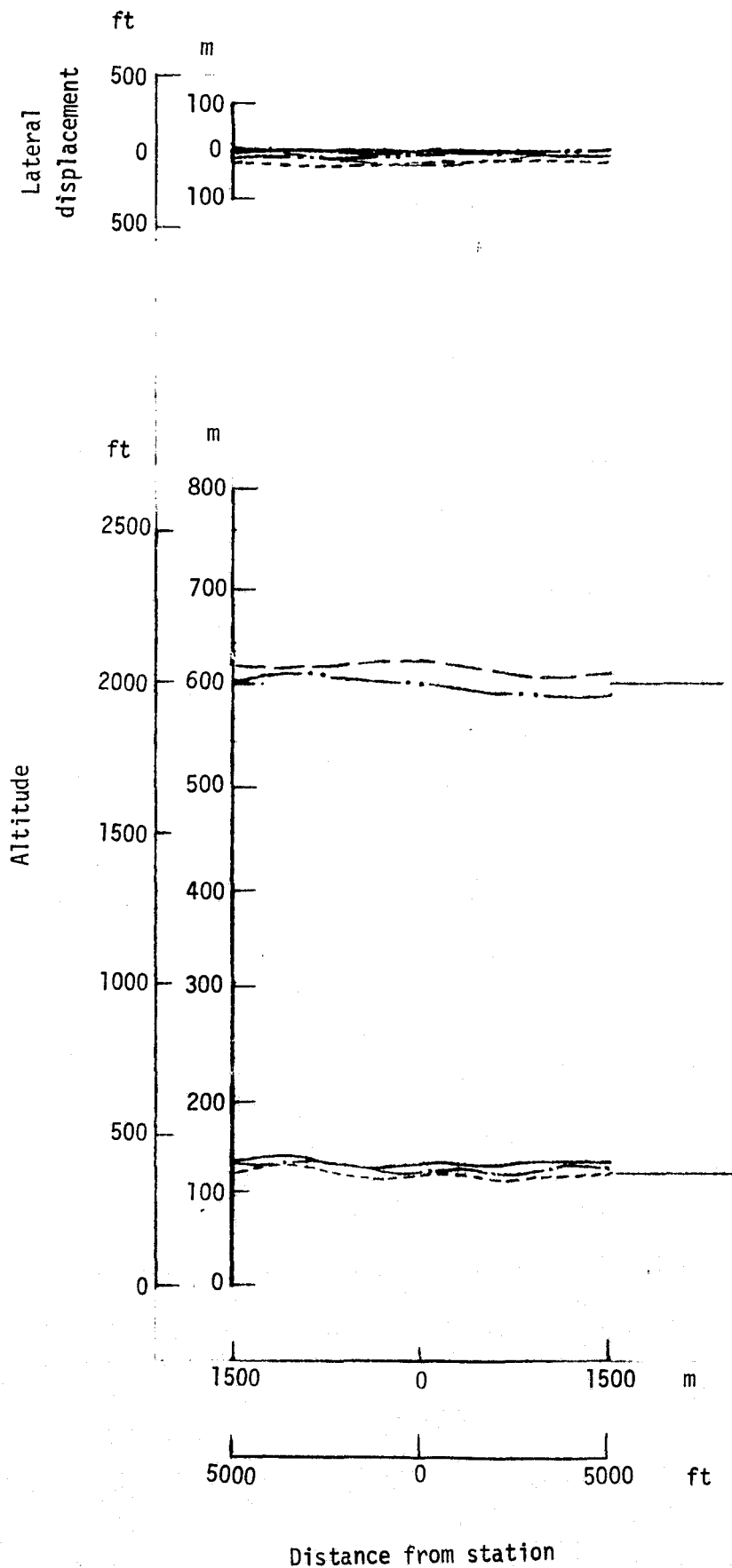
Figure 10.- Altitude-plan-position data from ground-based
radar for the level flyovers.
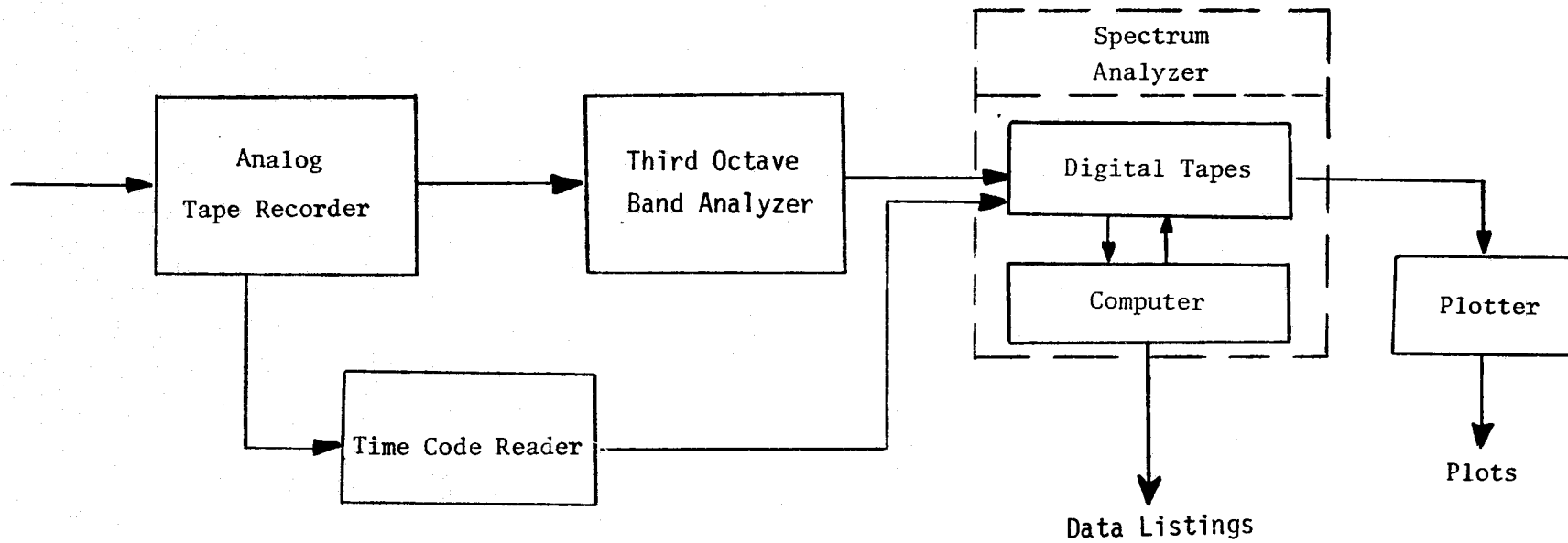
Figure 11.- Schematic diagram of acoustic data reduction system.
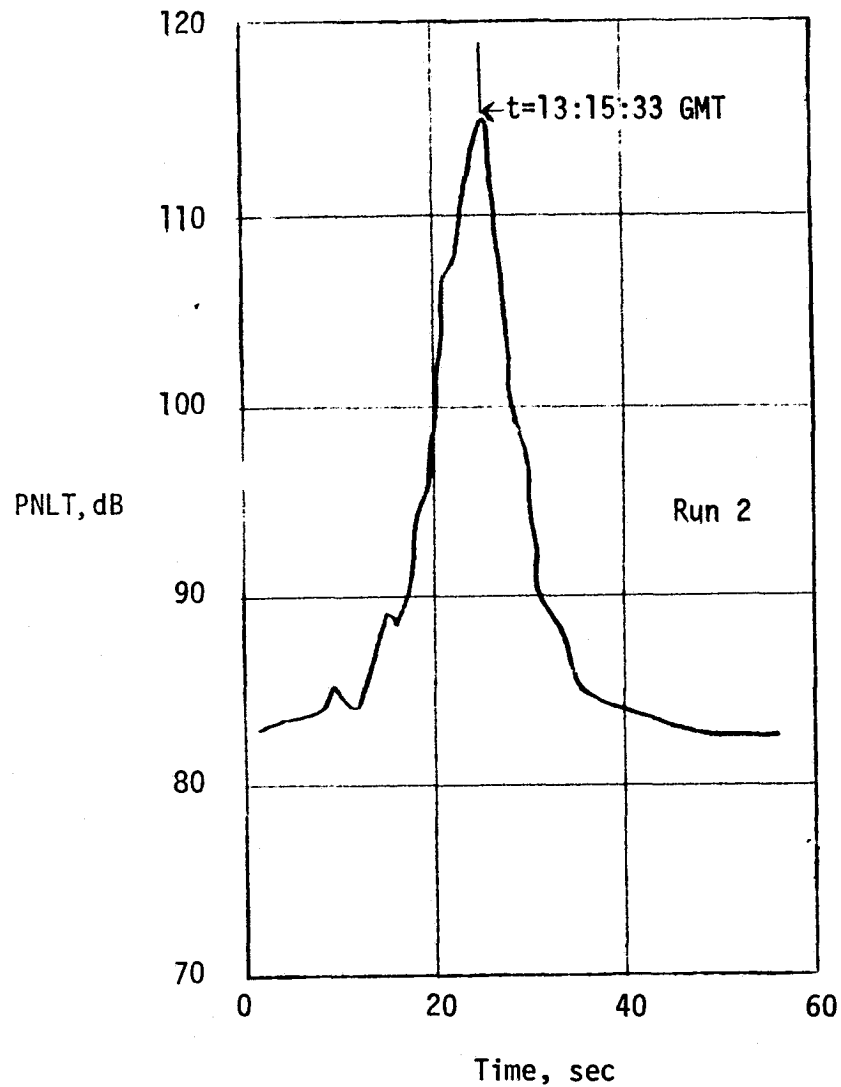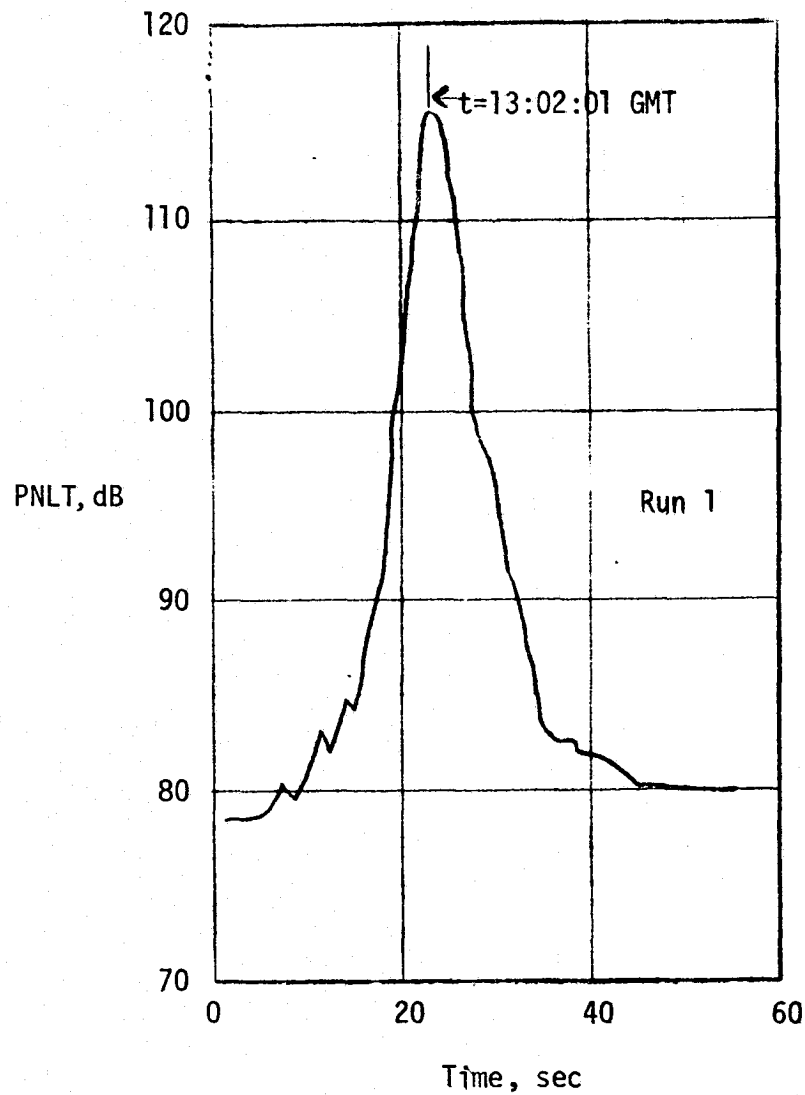
(a) Runs 1 and 2.

Figure 12.- Noise histories for 3° approaches.
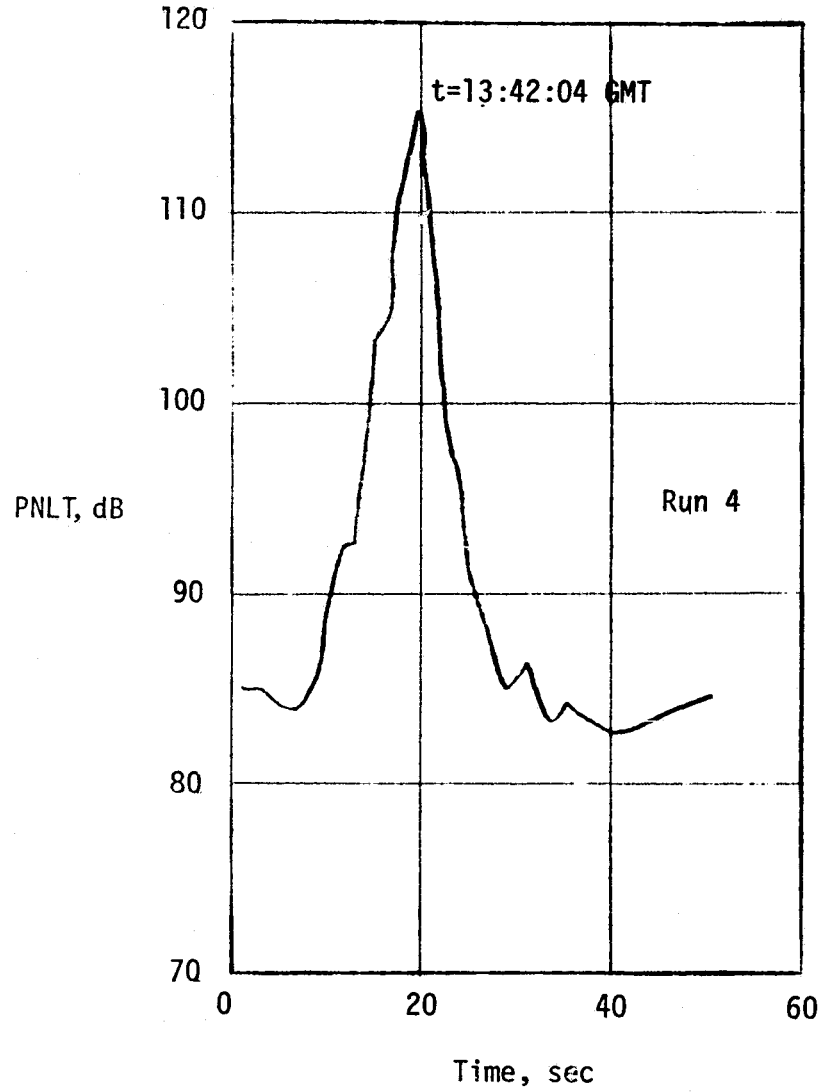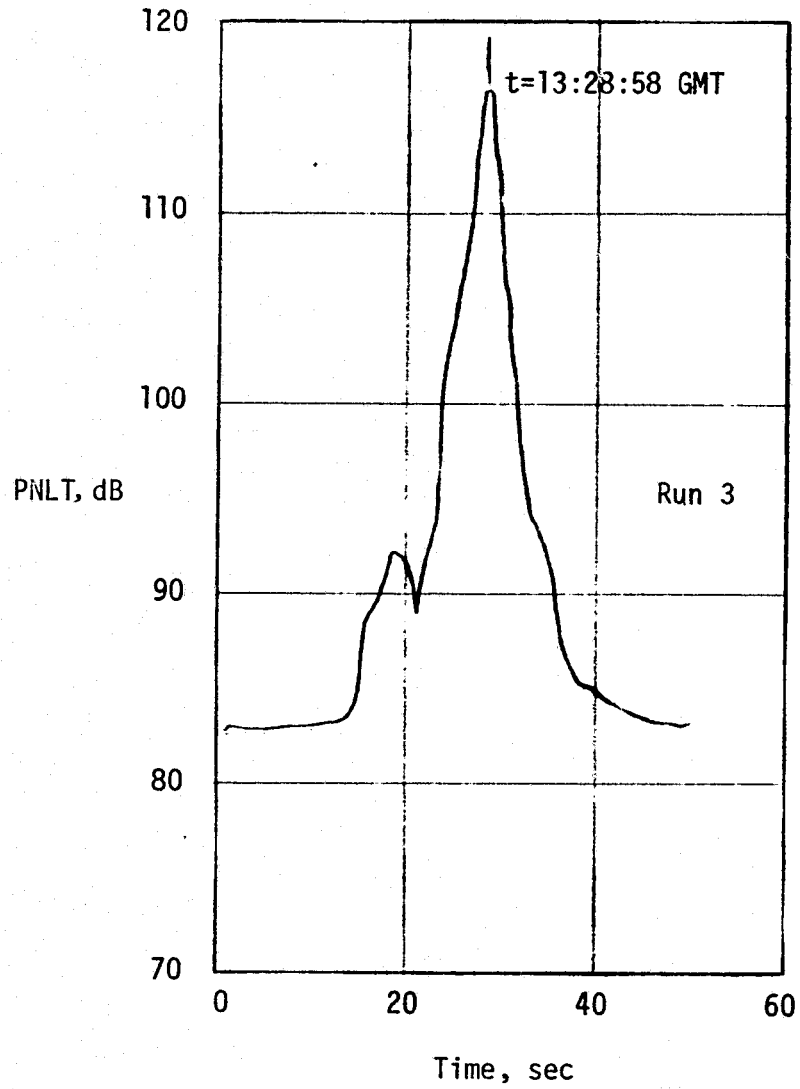
(b) Runs 3 and 4.

Figure 12. Continued.
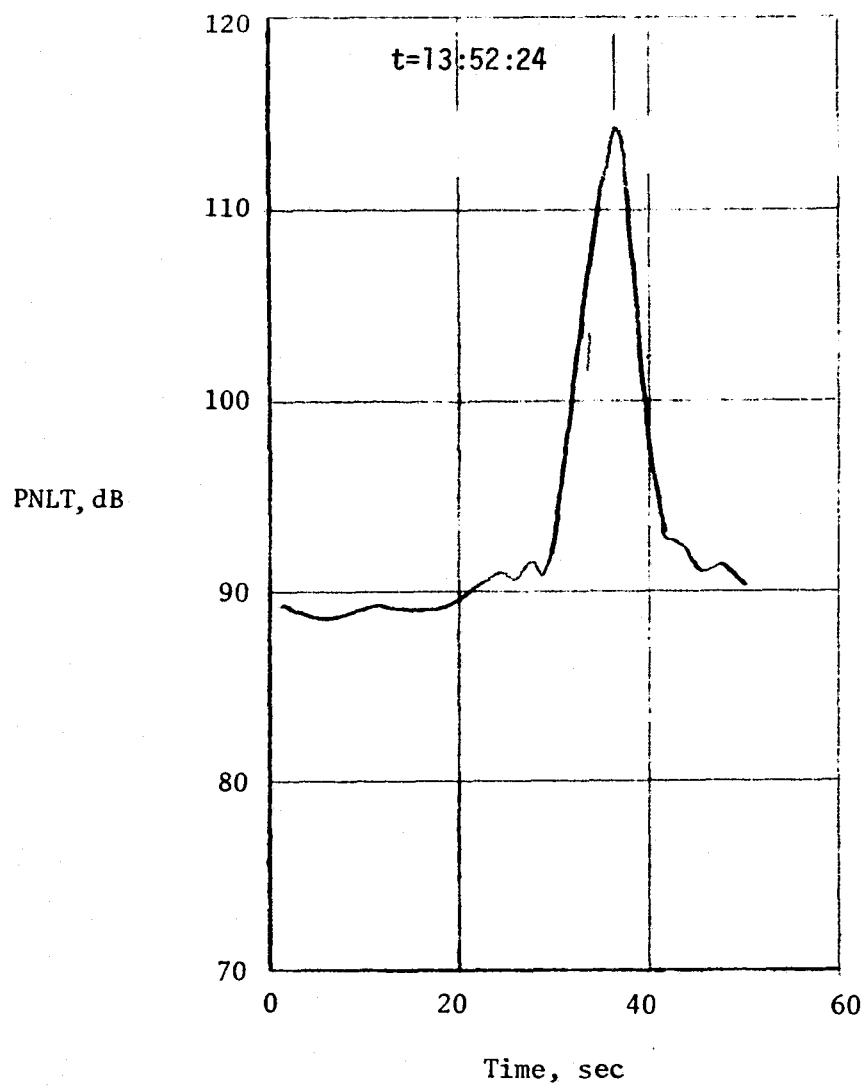
(c) Run 5

Figure 12.- Concluded.
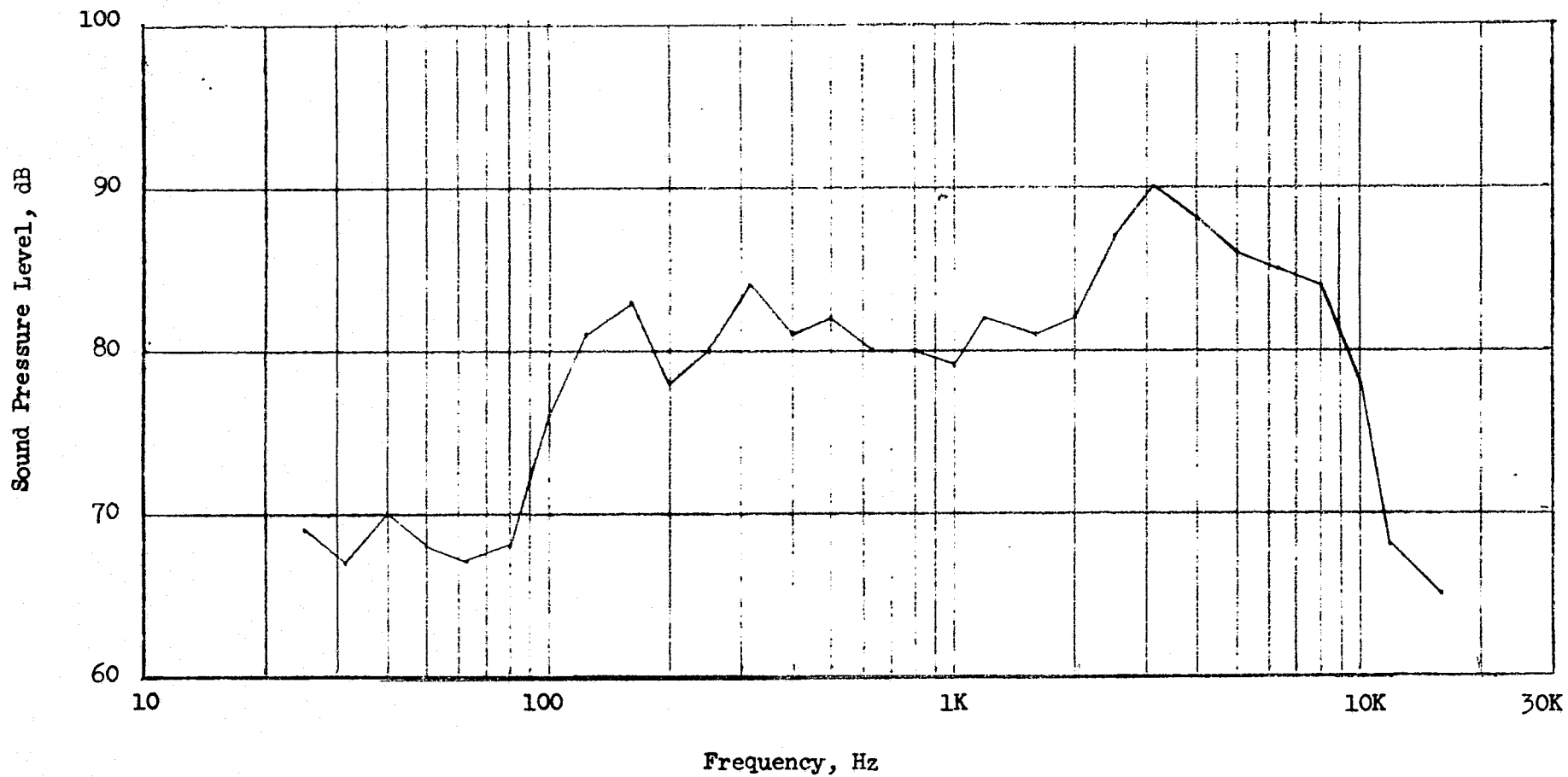
Figure 13.- Run 1 spectral data at PNLTM.
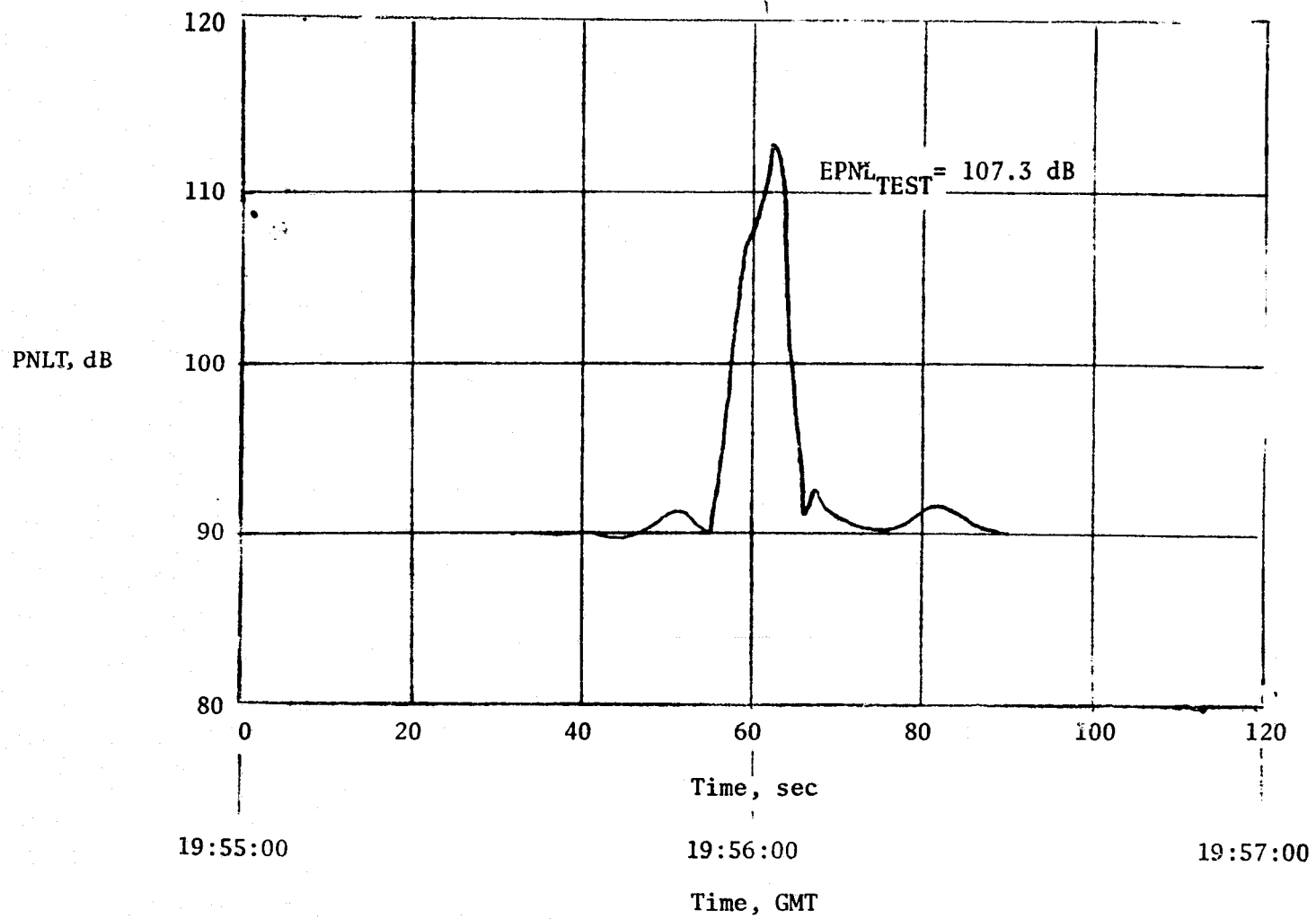
Figure 14.- Typical level flyover at 122m (400ft) with Fn/δ = 19,037 n/eng (4280 lb/eng). Run 1.1.
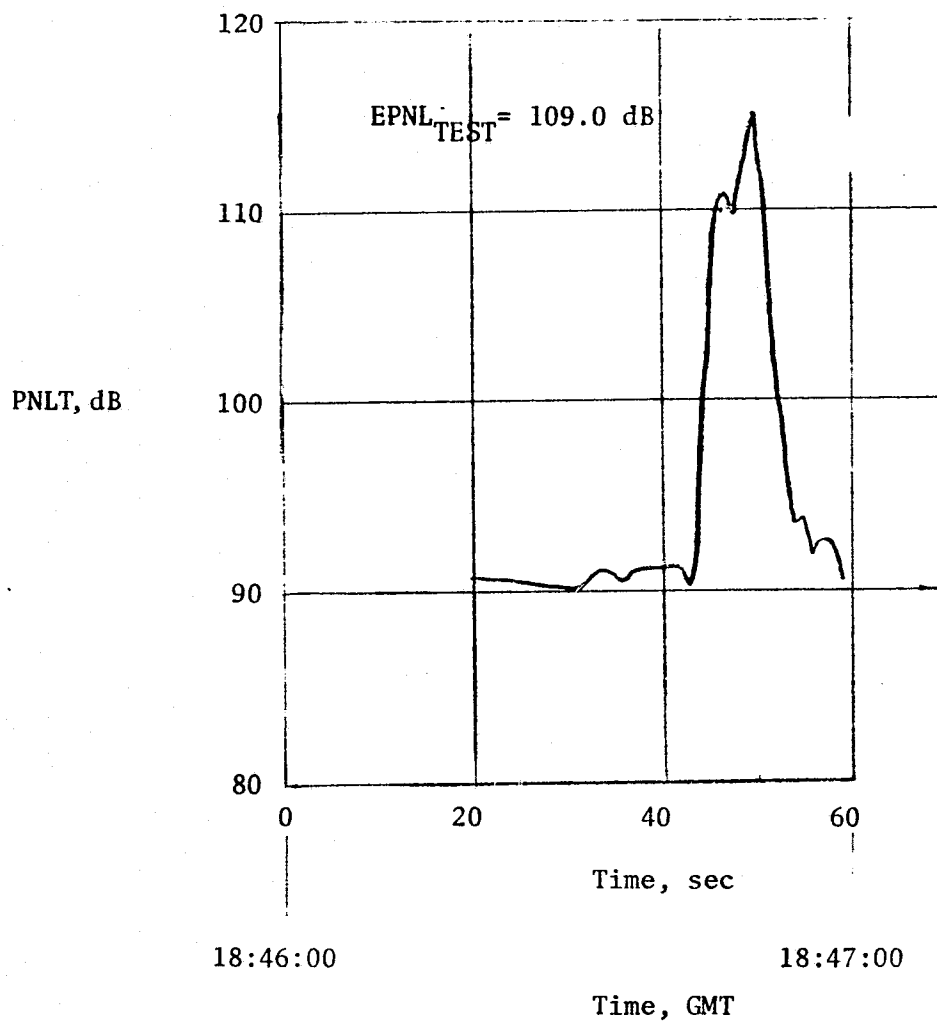
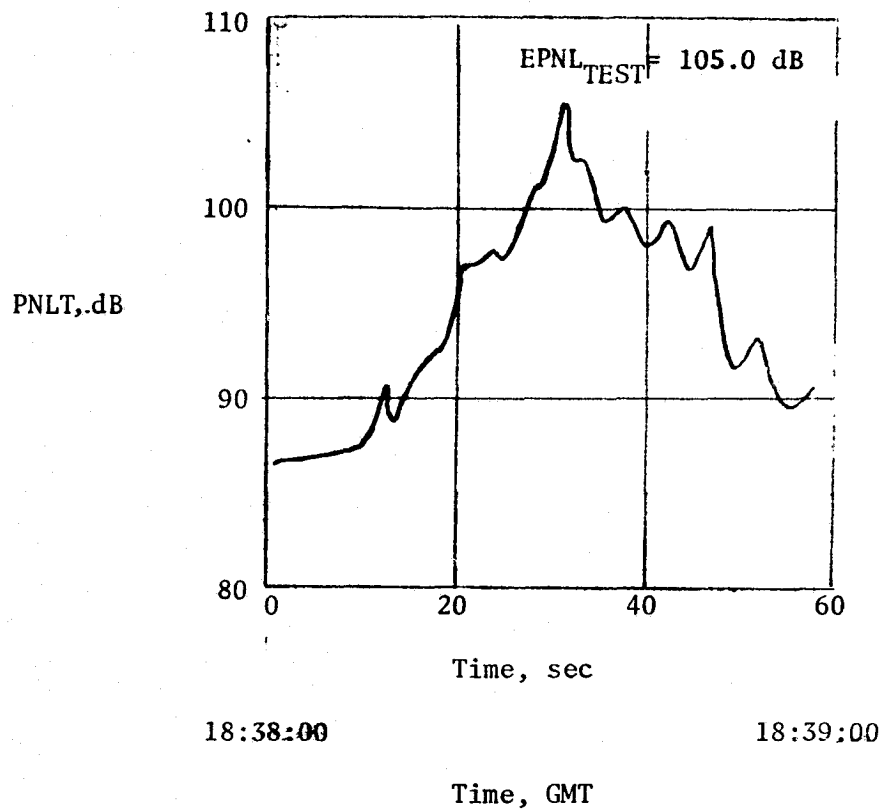Figure 15.- Typical level flyover at 122m (400ft) with Fn/δ = 24,064 n/eng (5410 lb/eng). Run 2.1.
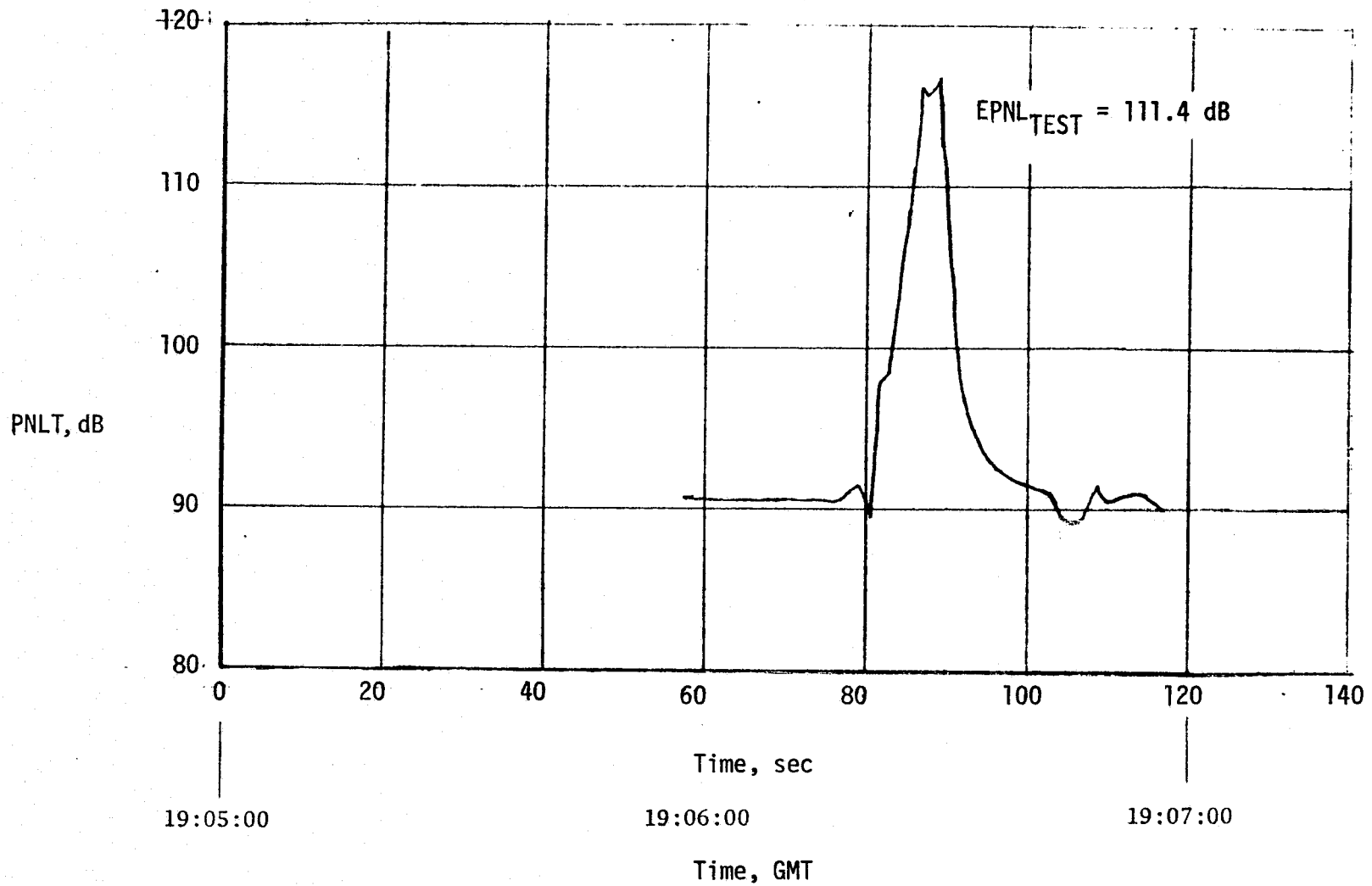
Figure 16.- Typical level flyover at 122m (400ft) with Fn/δ = 28,556 n/eng (6420 lb/eng). Run 3.1.
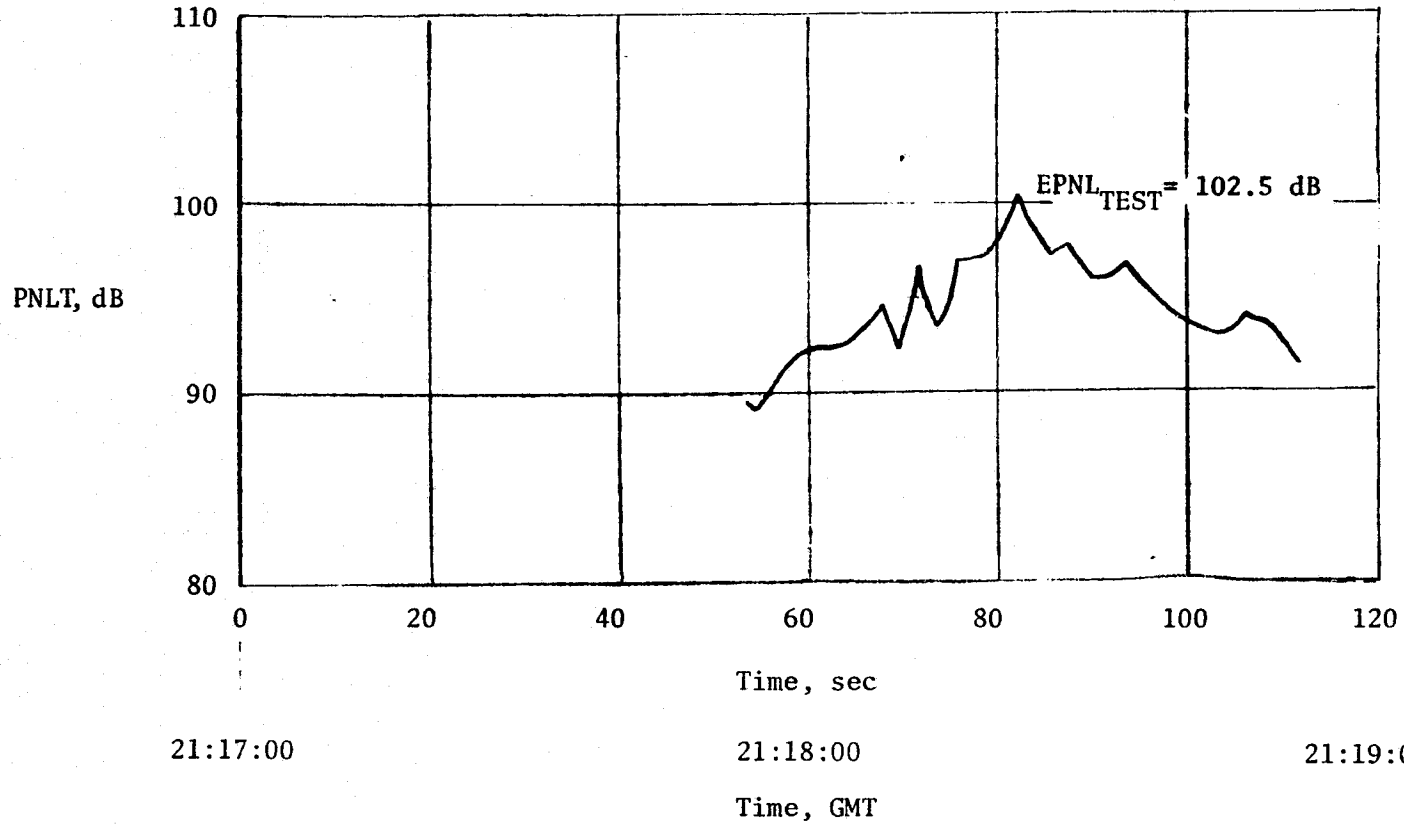
Figure 17.- Typical level flyover at 610m (2000ft) with Fn/δ = 46,704 n/eng (10,500 lb/eng). Run 4.1.

Figure 18.- Typical level flyover at 610m (2000ft) with Fn/δ = 56,934 n/eng (12,800 lb/eng). Run 5.1.
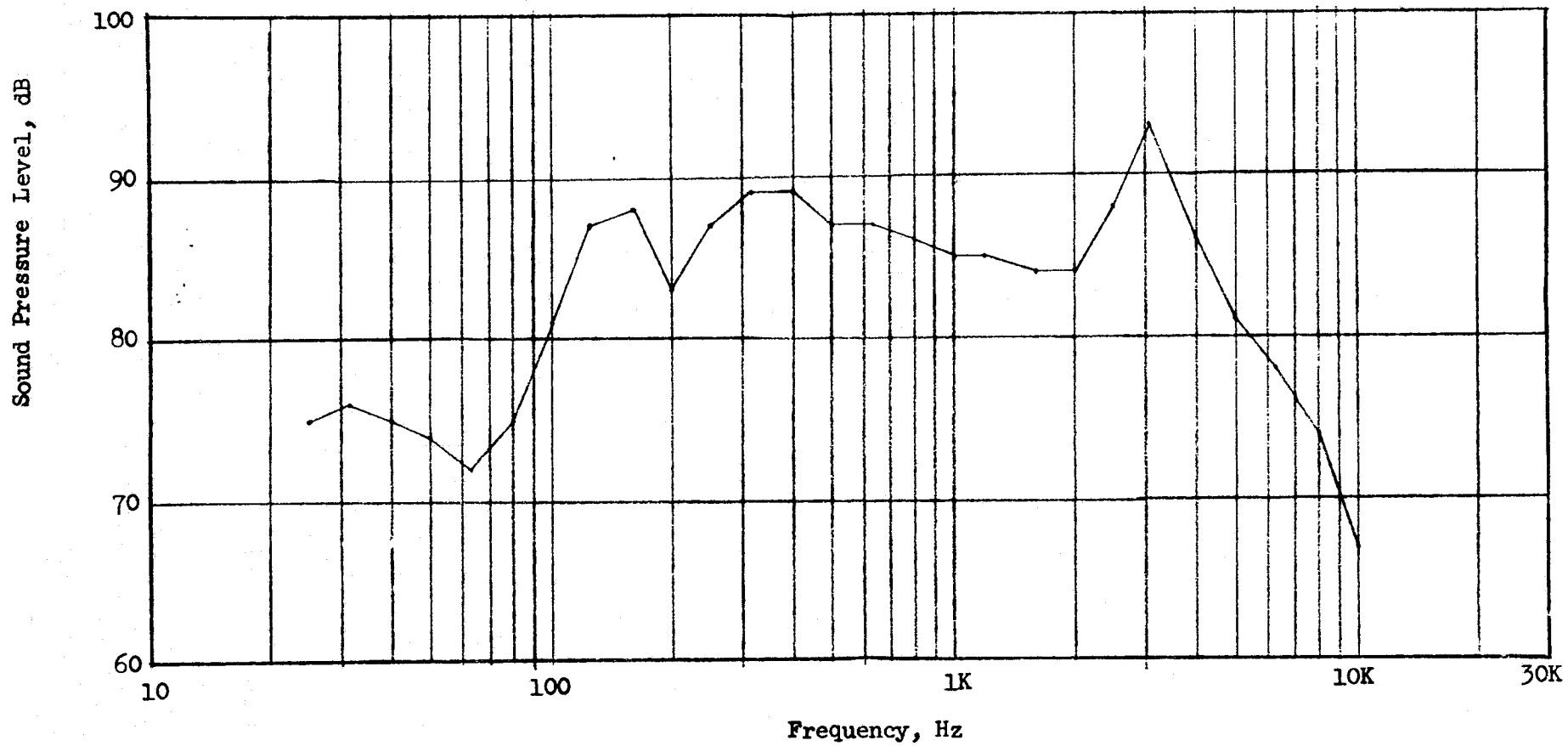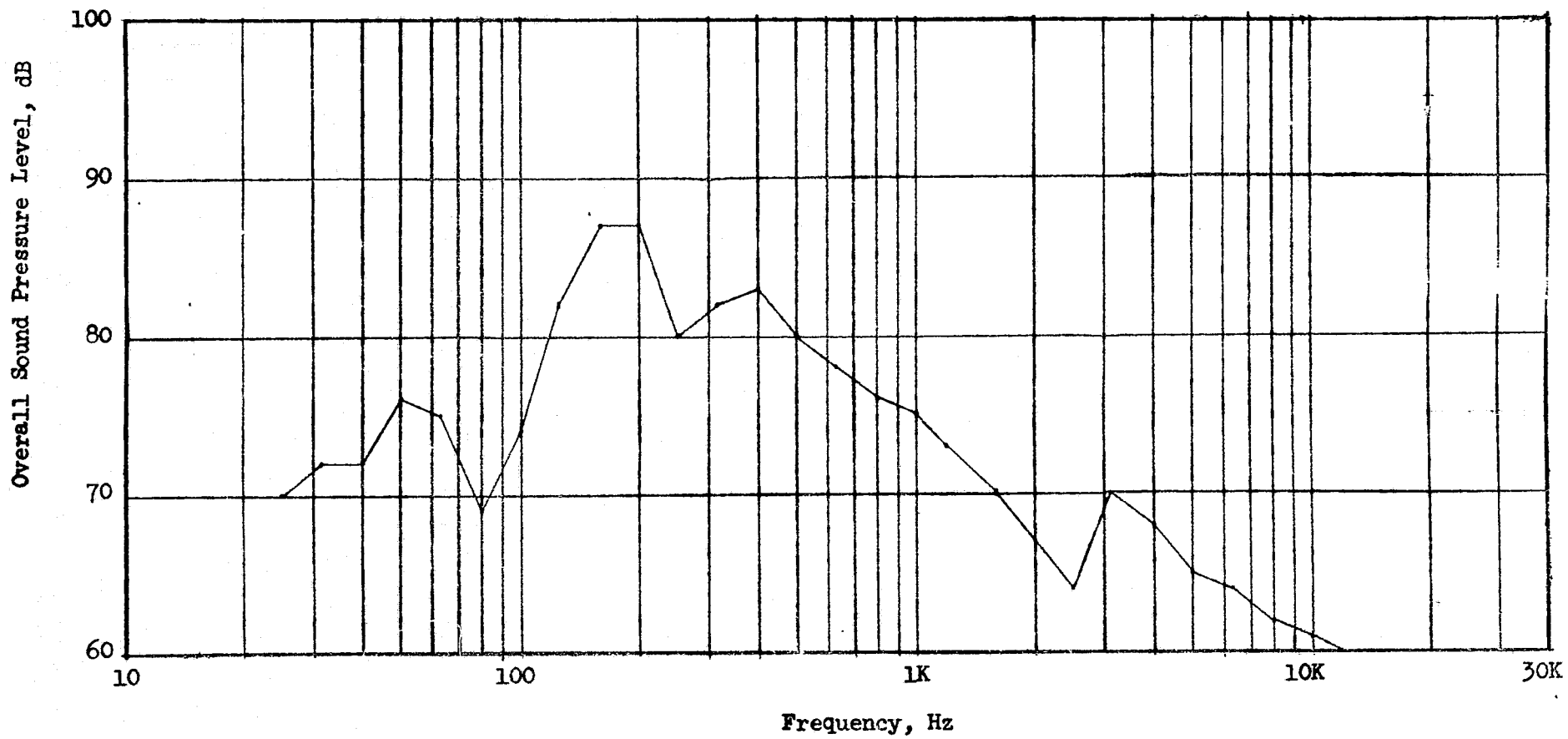
Figure 19.- Run 1.1 spectral data at PNLTM.
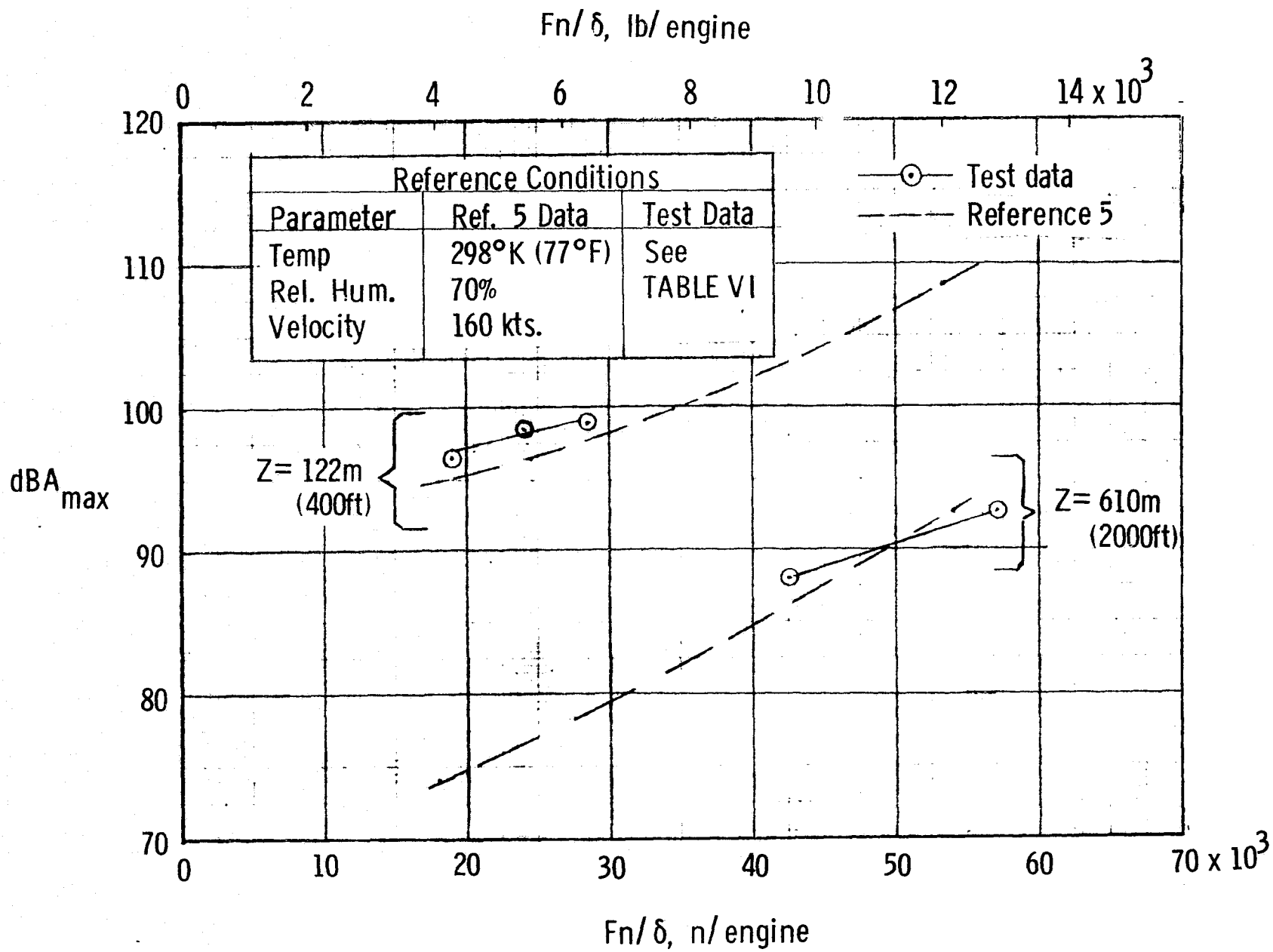
Figure 20.- Run 4.1 spectral data at PNLTM.

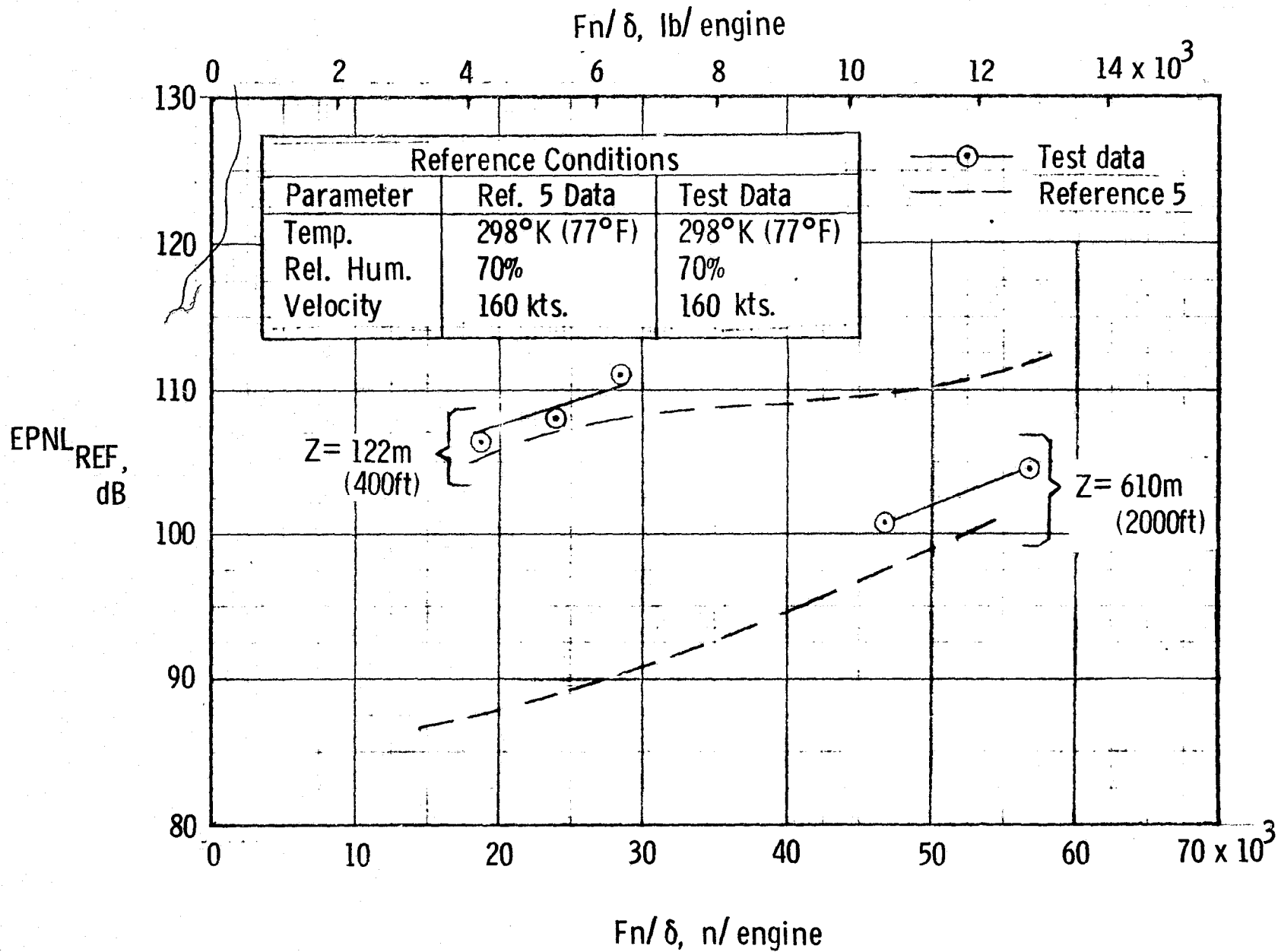Figure 21. – Noise level in dBA$_{max}$ as a function of thrust and altitude.

Figure 22. – Noise level in EPNL as a function of thrust and altitude.