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EFFECT OF TEMPERATURE AND HUMIDITY ON AIRCRAFT NOISE PROPAGATION

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September 1975

Final Report

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16. Abstract

This report presents the results of a test program conducted to measure the effect of varying meteorological conditions on aircraft flyover noise levels. Detailed temperature and humidity data were obtained using an instrument system carried by a light aircraft. High and low altitude inversions as well as standard lapse rate atmospheres were investigated. Level flyovers were conducted, using a DC-9-10 aircraft operated at a thrust (F_n/δ) of 6,000 lbs., as a constant noise source. Measured noise levels varied up to 4 EPNdB depending upon the absorptive properties of the atmosphere. Several analysis procedures were investigated in an effort to correct noise data for weather conditions. Weather correction procedures based on single point meteorological data were inadequate to normalize, to reference conditions, the noise data for those conditions with non-uniform temperature and humidity profiles. A layered analysis procedure, however, normalized all flyover noise levels to those levels taken under near reference conditions. The layered analysis procedure incrementally adjusts the measured peak spectra based on the acoustic absorption in each increment. These results indicated that noise certification testing under non-uniform temperature and humidity conditions could, if allowed, be conducted provided that frequent and detailed meteorological data is available and the layered weather correction procedure is used.

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FAA/Office of Environmental Quality - identification of program requirement

FAA/Systems Research and Development Service, Aircraft Safety and Noise Abatement Division - overall program management, test direction and data analysis

FAA/Academy - noise source aircraft, flight crew and support crews

FAA/National Aviation Facilities Experimental Center - meteorological sounding aircraft and flight crew

FAA/Western Region - flight test engineer, acoustic consulting and test site operations support

NASA/Langley Research Center - noise measurement equipment, atmospheric acoustic sounding and technical support

NCAR/National Committee for Atmospheric Research, Boulder, Colorado - Kytoon atmospheric sounder and crew

U. S. Army Proving Grounds, Yuma, Arizona - lower atmospheric wind measurements at Yuma, Arizona

Noise and Vibration Control Corporation - test site computer analysis of as measured data and test program computer data reduction

Wyle Laboratories (Subcontractor to NASA) - noise recording

U. S. Marine Corps Air Station, Yuma, Arizona - test site operation support at Yuma, Arizona.

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SYMBOLS AND DEFINITIONS

AGL---------------------------Above ground level

ANOMALOUS---------------------Deviating from the common rule; inconsistent with the accepted or the expected

ARP-866-----------------------Standard Values of Atmospheric Absorption as a Function of Temperature and Humidity

BASELINE----------------------Reference to standard acoustic day meteorological conditions and FAR 36 analysis procedures

C_T---------------------------Temperature structural coefficient of turbulence

dB----------------------------Decibel, a unit of level which is defined as 20 times the logarithm to the base 10 of the ratio of the sound pressure to a reference pressure of $2x10^{-4}$ microbars.

DC-9-10-----------------------Douglas Aircraft Model 9 Series 10

EPNL--------------------------Effective Perceived Noise Level, Units of Effective Perceived Decibels, EPNdB

FAR---------------------------Federal Aviation Regulation

(FAR) - Part 36---------------Noise Standards: Aircraft Type Certification

Fn/δ-------------------------Single jet engine thrust divided by the term "δ" the ratio of ambient pressure to sea level reference pressure

FLYOVER-----------------------Overflight of the microphone stations at a constant altitude

H-----------------------------Relative Humidity in percent saturation

hz----------------------------Hertz, cycles per second

IAS---------------------------Indicated Airspeed, knots

INVERSION---------------------Temperature Increase With Altitude

(k)---------------------------Time Increment Index. The numerical indicator that denotes the number of equal time increments that have elapsed from a reference zero.

MET---------------------------Meteorological

SYMBOLS AND DEFINITIONS

NOAA------------------------ National Oceanographic and Atmospheric Administration

PNLTM----------------------- Maximum Tone Corrected Perceived Noise Level. The maximum value of PNLT (k) that occurs during the aircraft flyover.

SAE------------------------- Society of Automotive Engineers

SPL--------------------------Sound Pressure Level referenced to $2x10^{-4}$ microbar, with units in decibels, dB.

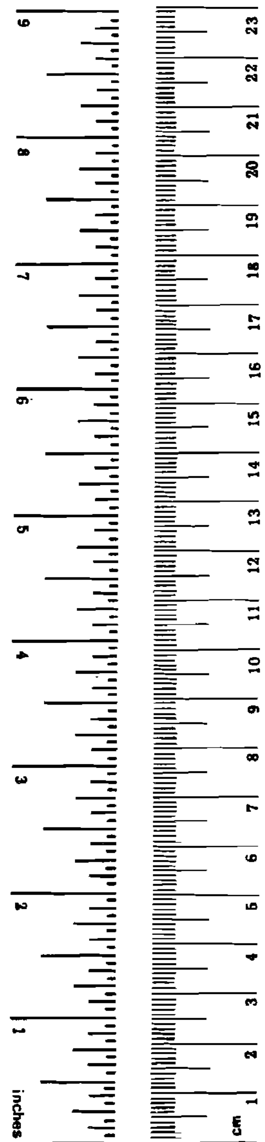
T----------------------------Temperature, °F

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

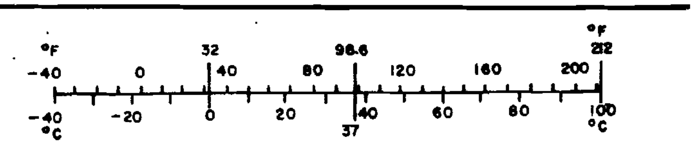
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



SUMMARY

This report presents the results of a test program conducted to measure the effect of varying meteorological conditions on aircraft flyover noise levels. A DC-9 Series 10 aircraft was used as the noise source. Level flyovers, at a constant thrust setting (Fn/δ) of 6,000 lbs., were used to obtain a constant noise source. Meteorological data (temperature, humidity, and turbulence) was obtained by an instrumented light aircraft. Flyover noise levels measured under meteorological "anomalies" such as temperature inversions were compared to "baseline" meteorological conditions. Baseline conditions were defined as a standard temperature lapse rate, constant absolute humidity, calm winds, and with temperature and relative humidity inside of the FAR Part 36 window.

Weather corrections, calculated by four methods, were applied to the flyover noise data measured under varying meteorological conditions. The weather corrected noise levels were then compared to determine which, if any, weather correction procedures consistantly normalized all noise data to those levels measured under baseline conditions.

The four weather correction procedures included three "single point" corrections and a "layered" correction. The single point correction methods were based on the temperature and relative humidity at (1) 10 meters above the ground (FAR Part 36 rule), (2) at the DC-9 flight altitude, and (3) the arithmetic average of the 10 meter and flight altitude conditions. The layered procedure incrementally corrected the measured noise based on the actual temperature and relative humidity in each 100 foot altitude increment along the propagation path. Each weather correction procedure modified the as-measured spectra at time of Maximum Tone Corrected Perceived Noise Level (PNLTM) by the differences in atmospheric absorption, calculated as a function of temperature and relative humidity, between the test and reference conditions of 77°F, and 70 percent relative humidity. The magnitude of the weather correction is then, as per FAR Part 36, equal to the difference between measured and corrected PNLTM.

A typical example of the results of this program are illustrated in Figure 1. Shown are the "as-measured" and "weather corrected" PNLTM spectra for baseline and anomaly conditions. The anomaly was a strong low altitude temperature inversion with hot and very dry conditions above the knee of the inversion up to flight altitude. The high atmospheric absorption associated with this very hot and dry air attenuated the fan tone at 3150 Hz by more than 6 dB relative to the baseline data (compare as-measured spectra A and B). The low frequency noise (below 1000 Hz) is similar for both baseline and anomaly while the higher frequencies were significantly attenuated by the atmosphere during the anomaly. This is expected because atmospheric absorption is substantially larger at high frequencies and consequently affects the high frequencies more than the low frequencies. On Figure 1, spectra A and B are the as-measured baseline and anomaly PNLTM spectra. A1 and B1 are the PNLTM spectra corrected to 10 meter conditions. A2 and . are the PNLTM spectra corrected by the layered procedure.

The weather corrections, for the baseline run, Lines A1 and A2 were similar and small because the atmospheric absorption characteristics were near those of a standard acoustic day. The 10 meter correction for the anomalous run, spectra B1, is small and the resulting corrected level is still substantially below the baseline level. This occurs because the absorption characteristics at 10 meters are not representative of thos existing over most of the propagation path. The layered correction method for the anomaly, Line B2, integrates the absorption characteristics of the entire propagation path and corrects the spectra to the baseline level. This analysis was performed for all runs with the result that the layered correction accurately normalized noise data taken over a wide range of temperature and humidity anomalies.

Table 1 summarizes the average EPNL and scatter for the 6,000 lb., 1100 foot altitude runs. The meteorological conditions encountered ranged from 50°F, 87 percent relative humidity to 88°F and 13 percent relative humidity with temperature lapse rates ranging from near standard to an inversion strength (temperature at knee of inversion minus temperature near ground) of almost 20°F. This temperature difference often occurred in 150 feet of altitude. Single point 10 meter weather corrections under-correct nearly all meteorological anomalies relative to the baseline by up to 2.8 EPNdB. The layered analysis, however, corrects the anomalies to the baseline level with a typical tolerance of plus or minus 1/2 EPNdB. Temperature and humidity profiles and additional noise data are provided in Section 5.0. The testing was performed under generally calm winds and low turbulence levels. Therefore, no results concerning the effect of turbulence or wind shear were obtained.

CONCLUSIONS

1. Flyover noise levels are significantly influenced by the absorption characteristics of the noise propagation path. Measured noise levels varied up 4 EPNdB depending upon the temperature and relative humidity during the test.*

2. The 10 meter single point weather correction (per FAR Part 36) only corrects flyover noise data accurately when the temperature and humidity are constant with altitude. The use of the 10 meter weather correction, when a non-uniform atmosphere is present, gives erroneous results because the acoustic absorption properties in the propagation path would then differ from the conditions at 10 meters.

3. Single point corrections based on average conditions between surface and flight altitude give erratic results because (1) the absorption characteristics of the atmosphere do not vary linearly with temperature and relative humidity and (2) average conditions are very difficult to determine when an inversion is present. Single poing corrections based on flight altitude conditions tended to over-correct with a large amount of scatter.

*NOTE -- See Section 5.0 and Table 5 for tabulated measured and corrected noise levels.

4. Measured flyover noise levels, including both anomalous and standard atmospheres, can be accurately corrected to reference acoustic day atmospheric conditions by applying an incremental layered weather correction to the PNLTM spectra which corrects the measured noise levels based on incremental absorption characteristics in the propagation path. An altitude increment of 100 feet, used for this analysis should be the maximum increment. Low altitude flights (400 feet) with strong temperature and humidity gradients will require a smaller altitude calculation increment.

5. Detailed real time meteorological data as a function of altitude is necessary to satisfactorily use the layered weather correction procedures. Time intervals between meteorological measurements should not exceed 30 minutes during testing because of the dynamic nature of the atmosphere. Meteorological data should be interpolated to actual times of each noise measurement.

6. Detailed and frequent meteorological data can easily be obtained by a meteorological aircraft equipped and operated as described in Reference 1.0. This system can provide continuous on-line meteorological data which can be used for on-site decision making and subsequent layered weather corrections.

7. Based upon these test results it appears that the noise certification test window could be enlarged to that shown on Figure 2. Meteorological parameters should remain inside the window up to the flight altitude.

8. This program successfully demonstrated the feasibility of conducting flyover noise tests during anomalous temperature and humidity conditions provided that:

   a. Frequent and detailed weather measurements are taken and interpolated to the actual time of noise measurement.

   b. A layered weather correction procedure is used.

   c. The temperature and relative humidity remain within the limits proposed in Figure 2 from surface to flight altitude.

   d. Low turbulence levels and wind velocities within FAR Part 36 exist from surface to flight altitude.

9. The success of the layered weather correction method tends to verify that the SAE ARP-866 absorption coefficients are essentially correct (within acceptable scatter) in the range of 1 to 5 KHz.

10. Because low levels of turbulence and wind existed during this program, no general conclusions can be drawn concerning the effects of turbulence or wind shear. A special test program, designed to measured aircraft noise in turbul t and wind shear conditions, should be conducted.

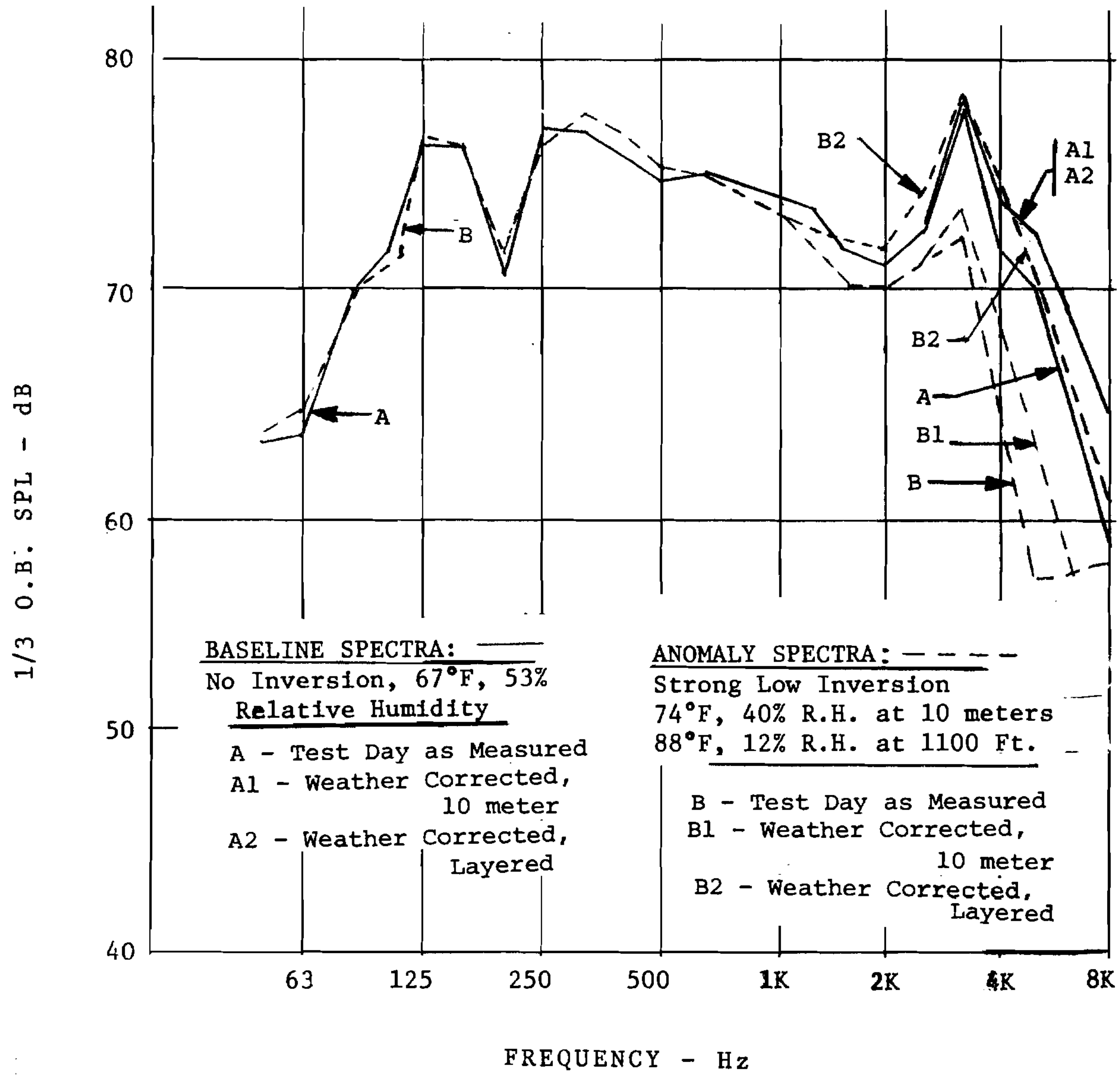


FIGURE 1--Normalization of Flyover Noise Data Taken Under Anomalous Meteorological Conditions. Measured and Corrected Spectra at Time of PNLTM. FAA DC-9, Fn/δ = 6000 lb., Altitude = 1100 Feet

TABLE 1

SUMMARY OF AVERAGE NOISE LEVEL UNDER VARYING METEOROLOGICAL CONDITIONS

ALTITUDE = 1100 Ft., Fn/δ = 6,000 lb.

METEOROLOGICAL CONDITIONS	RUNS	10 METER SINGLE POINT WEATHER CORRECTION			LAYERED WEATHER CORRECTION		
		MAX RANGE	(EPNdB) AVG EPNL	ΔBASELINE	MAX RANGE	(EPNdB) AVG EPNL	ΔBASELINE
FRESNO BASELINE	371-374	0.4 EPNdB	99.1	----	.4 EPNdB	99.2	-----
YUMA BASELINE	415-418	1.1	99.0	----	1.0	99.3	-----
NO INVERSION, HOT AND DRY	118-123	0.7	98.4	-0.6	0.7	98.7	-0.5
STRONG LOW INVERSION, HOT & DRY	174-178	0.9	96.2	-2.8	0.9	99.9	+0.6
LOW INVERSION, MILD	211-215	0.8	97.2	-1.8	0.7	98.7	-0.5
LOW WEAK INVERSION, HOT & DRY	237-241	1.7	97.4	-1.6	1.7	100.1	+0.8
HIGH INVERSION, COOL & MOIST	360-364	0.7	98.4	-0.6	0.8	98.6	-0.6
YUMA-WEAK LOW INVERSION CALM WINDS	385-388	0.3	98.0	-1.0	0.5	99.2	-0.1
YUMA-WEAK LOW INVERSION WIND GRADIENT	436-439	1.1	99.0	0	1.2	99.6	+0.3

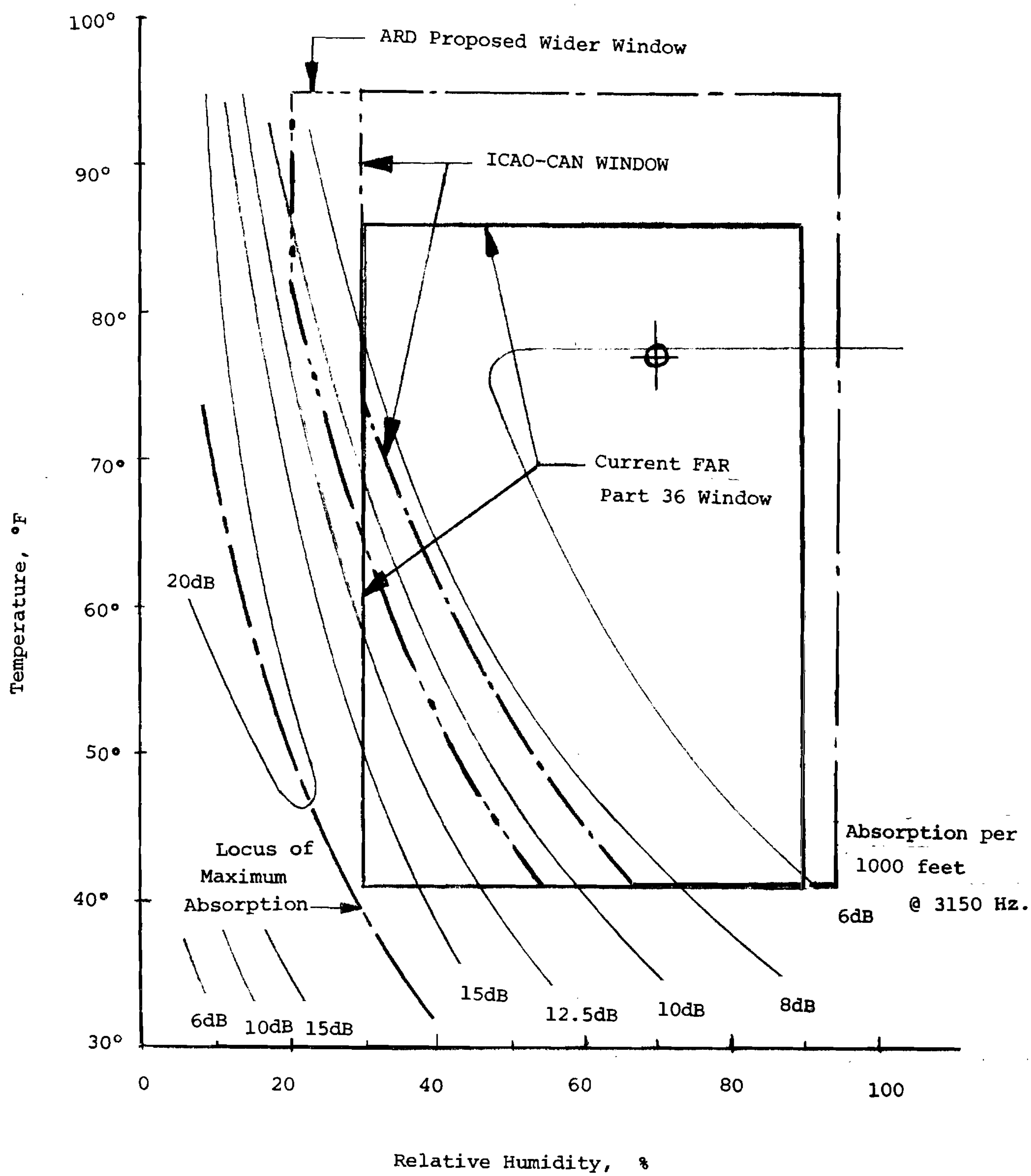


Figure 2 .PROPOSED WIDER TEST WINDOW

1.0 INTRODUCTION

Appendix A of Federal Aviation Regulations, Part 36, "Noise Standards: Aircraft Type Certification", establishes the meteorological limits, and conditions for the measurements that apply to Aircraft Noise Certification:

1. All performance and acoustic data must be corrected to standard sea level pressure, ambient temperature of 77°F, relative humidity of 70 percent.

2. During testing, temperature and wind data must be measured at 10 meters above the ground near the microphone stations used to measure approach, sideline and takeoff noise. Temperatures may not be above 86°F or below 41°F. Wind velocity not to exceed 10 knots and crosswind component must not exceed 5 knots. These data must be taken at hourly intervals or less.

3. During testing, relative humidity must be measured at hourly intervals or less and may not be higher than 90 percent or less than 30 percent.

4. No temperature inversion or anomalous wind condition that would significantly affect the noise level of the aircraft when the noise is recorded at the measuring points is acceptable.

5. An airport tower or another facility may be used for meteorological data, if, such a facility is approved as one which provides data representative over the geographical area in which noise measurements are made.

Numerous questions have been raised with regard to interpretation of these requirements and procedures. Therefore, a need to define variations in measured noise levels caused by meteorological conditions was indicated. The adequacy of existing meteorological data requirements as applicable to aircraft noise certification measurements must be further clarified and defined.

The FAA Office of Environmental Quality recognized this need and requested the Systems Research and Development Service to design and implement a suitable test program to resolve these questions.

The specific objective of the test program was to investigate the effect of temperature inversions, humidity, and anomalous wind conditions on measured aircraft noise levels.

A test plan was prepared which emphasized the following key points:

1. Tests were to be conducted over a wide range of meteorological conditions.

2. Detailed meteorological measurements would be taken to provide data applicable to the noise propagation path at the time of noise measurement.

3. The noise source and distance would be held constant.

4. Every effort would be made to minimize variables other than meteorological conditions.

The program was conducted from October 14 to November 3, 1974, at Fresno, California and Yuma, Arizona. Testing at Fresno was conducted from 7:00 a.m. to 11:00 p.m. and at Yuma from 10:00 p.m. to 6:00 a.m. A wide range of temperature and humidity conditions were encountered, including very significant temperature inversions and variable humidity profiles. However, due to generally calm wind conditions throughout the testing period, insufficient data was obtained to study effects of anomalous wind conditions on noise measurements.

2.0 TEST PROGRAM

The program was conducted under the management of the FAA Systems Research and Development Service. Technical assistance and equipment was provided by the National Aeronautics and Space Administration (NASA) Langley Research Center of Hampton Virginia.

2.1 NOISE MEASUREMENT

All noise recordings were made by Wyle Laboratories technicians using NASA recording equipment and microphones. This equipment is described in detail in Section 4.0.

Microphones were located under the flight path at two locations 2000 feet apart with three microphones at each location. Two microphones were mounted on stands at 1.2 meters (4 feet) high, one over concrete and one over randomly spaded earth. The third microphone was flush mounted in a 4x4 foot ground board. The 4 foot microphone over concrete was used for the analysis in this report.

Recording equipment was located in a van halfway between the microphone stations and 200 foot to one side. Power was supplied via ground lines with auxiliary power units as back-ups.

At each microphone station, calibrated cameras were mounted on tripods and used to photograph the noise source aircraft over each station. These cameras were also instrumented to provide synchronzied signals on the noise recording tape to provide correlation of aircraft position with recorded noise data.

2.2 NOISE SOURCE

The noise source aircraft used for all tests was a Douglas DC-9 series 10 with JT8D-1 engines. Thrust was set by means of exhaust pressure ratio (EPR). Altitude was determined by a calibrated radar altimeter in the aircraft and the calibrated ground cameras discussed in Section 2.1. The pilot and co-pilot were FAA Academy DC-9 instructor pilots. A Flight Test engineer was responsible for establishing corrected aircraft power settings, and he also was responsible for recording all in-flight data.

Level flyovers at 1100 foot altitude at 6,000 lb. Fn/δ were used as the condition for evaluation of varying meteorological conditions. Level flyovers were also used to simplify aircraft position tracking. The net thrust of 6,000 lb. was used to obtain a representative noise spectra with both low and high frequency components. The 1100 foot altitude was chosen to provide for a propagation path long enough to be able to measure differences in propagation but not so large as to eliminate the fan tone due to atmospheric absorption. Additional anomaly data was taken at flight altitudes of 500 and 2000 feet. Baseline (standard lapse rate atmosphere) data was taken at altitude of 500, 1100 and 2000 feet at net thrusts (Fn/δ) of 3,000; 6,000 and 11,000 lbs.

2.3 METEOROLOGICAL DATA

Extreme importance was given to meteorological conditions in this program. Consequently, several systems were employed to assure complete and accurate measurements of temperature, dewpoint, atmospheric turbulence, and altitude.

A airborne meteorological instrument system developed by the FAA (Reference 1) was employed. This system was installed in a light aircraft which provided soundings from 4 feet above the surface to 3000 feet altitude throughout all testing on a 30 minute schedule starting before and continuing through the test periods. This system made continuous measurements of temperature, dewpoint and atmospheric turbulence versus altitude on a strip chart recorder. This data was analyzed on site for program guidance and later reduced to computerized printout. For the detailed weather corrections the meteorological data was interpolated to actual noise flight times. This system was flown in a figure eight pattern around the microphone stations to provide representative measurements of the propagation path zone.

Additional meteorological instrumentation was provided by NASA Langley Research Center and the National Committee for Atmospheric Research (NCAR) at Boulder, Colorado. NASA Langley provided a mono-static acoustic sounder and a 10 meter tower instrumented for temperature, relative humidity, and wind direction and velocity. The mono-static sounder was used to provide qualitative trends and characteristics of inversion height. NCAR provided a Kytoon which measured wet and dry bulb temperature, wind velocity, and atmospheric temperature induced turbulence. This data was telemetered to a ground recorder. The Kytoon experienced several operational difficulties. Several runs were aborted because of electromagnetic interference from airport radars. The system also had a one-hour turn-around time per altitude profile and was limited to an altitude of 1000 feet because of calm winds. The meteorological aircraft data was used for this analysis because the met aircraft consistantly gave complete, frequent and reliable data.

The U.S. Army Proving Grouns at Yuma, Arizona, provided wind data from the surface to 3000 feet at Yuma, Arizona hourly or less on request by double theodolite measurements of balloon releases. For the night releases required, a light was attached to the balloon for tacking. This data was analyzed on-site and used in later analysis.

2.4 TEST SITES

Two test sites were selected for the test program, Fresno, California and Yuma, Arizona. Fresno was selected as the primary and possibly single test site, due to seasonable climatology. During October, when tests were conducted, Fresno was anticipated to provide the wide range of meteorological conditions needed.

Yuma, Arizona was selected as a contingency test site for possible wind shear conditions as it is known to have nocturnal wind shear conditions during Fall seasons.

3.0 DATA REDUCTION

Out of the 241 recorded level flyovers, 125 significant runs were selected for analysis. The method of analysis was to first compare test day or as-measured data. This data consisted of 1/3 octave band, PNL, and PNLT time histories and Effective Perceived Noise Level (EPNL). Aircraft altitude and thrust setting were closely controlled and kept within acceptable tolerance limits. Corrections were not required for these variables. Velocity corrections (10 log ^{V}/V Reference) were applied where necessary to correct to reference aircraft velocity.

Weather corrections were then applied to the noise spectra at time of Maximum Tone Corrected Perceived Noise Level, (PNLTM). The weather correction was calculated by the current FAR Part 36 method (10 meter meteorological data) and by two additional "single point methods and a "Layered" or stratified method. The two additional single point methods were similar to the FAR Part 36 method but were based on temperature and humidity data at (1) the flight altitude and (2) averaged between the flight altitude and 10 meters. The layered method incrementally calculated the atmospheric absorption for each 100 foot altitude layer based on the average temperature and relative humidity for each layer. The meteorological data was interpolated to the exact time of each DC-9 flight. SAE-ARP-866 absorption coefficients were used throughout for this analysis (Reference 4).

Two special procedures were employed in the calculation of the weather corrections. First, the propagation path length was averaged for each altitude and thrust setting. This was done to eliminate random scatter caused by the tracking method and the finite 1/2 second noise integration time. Before the averaging was done, the as-measured data was inspected to see if any trends of maximum propagation angle with meteorological conditions could be found for constant thrust and altitude. As no trends could be found, the averaged propagation path lengths were used. Secondly, the weather corrected spectra were "rolled off", usually from 5000 or 6300 hz. Rolloff is the term used for the application of an arbitrary slope in dB per 1/3 octave band, to the high frequency portion of the spectra starting from a specified frequency. This rolloff is needed because (1) the atmospheric absorption coefficients can become quite large at high frequencies as shown on Figure 3, and (2) the as-measured high frequency data was lost because of noise floors as in the example shown in Figure 4. Figure 4 also shows that when the large high frequency weather corrections are applied to the contaminated high frequency bands, the spectra tends to peal in the highest 1/3 octave band. It was established in these tests, by inspection of low altitude data where the high frequency noise to signal ratio is less of a problem, that the fan tone or "spike" of the spectra occurred at 3150 hz. This then gave confidence to the assumption that the tone spike in the higher altitude data should also be at 3150 hz and that the rolloff was necessary to achieve this. Several EPNL's were calculated with and without the rolloff and, except for obviously bad data, the rolloff decreased the EPNL by typically 0.2 EPNdB which is considered negligible.

Figure 5 is a block diagram of the data reduction procedure used in this program.

4.0 DESCRIPTION OF NOISE MEASUREMENT SYSTEM

NASA Langley Noise Measurement System -- This section presents a technical description of the noise measurement system provided by the NASA Langley Research Center. Detailed specifications and block diagrams of the system used are located in Appendix "A" of this report.

System Description -- The data acquisition system block diagram is shown in Appendix A. Principal system components are pressure microphones with accessory windscreens and preamplifiers, variable gain amplifiers, and an FM tape recorder. An oscillograph was used for in-field data verification and to establish optimum recording levels. Specifications for all commercial hardware items are tabulated.

The microphones were configured with the standard grid cap. Above ground measurements were made using Bruel and Kjaer Model UA-0237 windscreens with the microphones oriented for grazing incidence at a height of 1.2m. Ground level measurements were accomplished with the microphones flush mounted in 4 foot square ($1.49m^2$) ground boards. NASA fabricated cheesecloth windscreens replaced the Bruel and Kjaer Model UA-0237 windscreen and are described in the enclosed microphone specification.

The tape recorder was operated at 30 ips (IRIG Intermediate Band FM) for all measurements. IRIG B time code, 1000 Hz modulated signal, was recorded on magnetic tape with microphone data in all cases.

The Bruel and Kjaer Model 2804 power supplies were used in conjunction with NASA Line drivers to accommodate the use of 1500-foot signal cables.

System Calibration -- Prior to the conduct of field measurements, extensive system calibration and testing were conducted to verify proper system operation and document system performance. Specifications for the acoustic calibration devices used are included in the Appendix.

All system components were individually calibrated in accordance with the manufacturer's recommended procedures, or an alternate method approved by NASA. General calibration laboratory policies and procedures were as recommended by the Navy Standard Laboratory Information Manual (SLIM).

All test measurements were made with instruments and devices calibrated in accordance with the National Bureau of Standards (NBS) established procedures for instrument calibration. In the case of microphones, an electrostatic calibration was performed using a Bruel and Kjaer Model 4142 microphone calibration apparatus to determine frequency response. Microphone sensitivity was determined using a Bruel and Kjaer Model 3220 pistonphone.

The systems were assembled and the critical parameters of frequency response, distortion, linearity, and noise floor were measured and reached. System level tests are summarized in Appendix A. Typical system frequency response plots are shown. The rolloff at high frequencies exhibited by all frequency response plots is a function of the low-pass filter in the tape recorder electronics. All system microphone channels were field calibrated prior to each test day as follows:

End-to-end system sensitivity was determined using a Bruel and Kjaer Model 4220 pistonphone. The calibration signal of 124 dB at 250 Hz was recorded on magnetic tape.

An oscillator signal was inserted at the preamplifier input and system frequency response was verified through the tape recorder.

A pink noise signal from a General Radio Model 1382 random noise genrator was inserted at the preamplifier input and recorded on magnetic tape as a frequency response reference for subsequent data reduction.

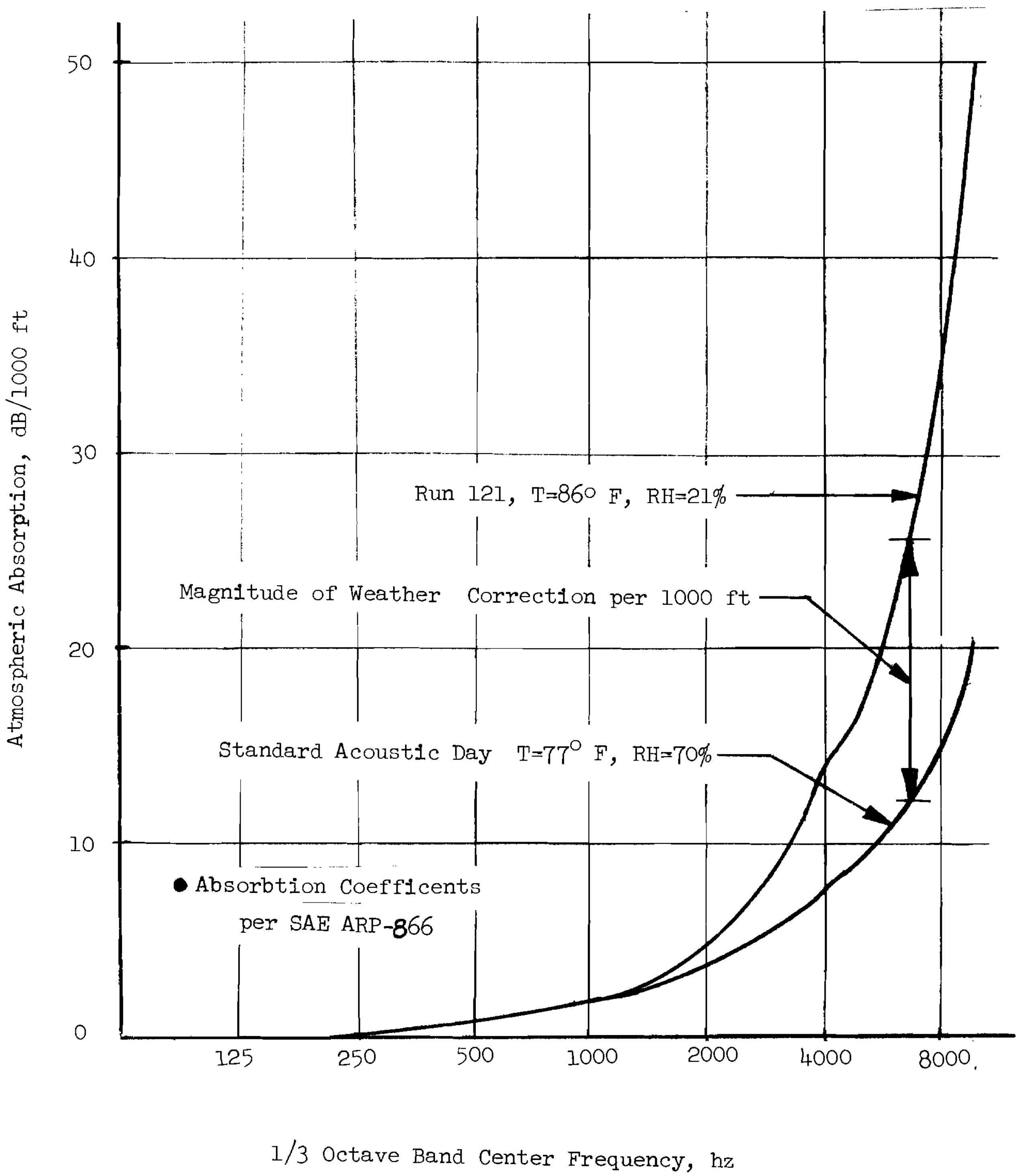


Figure 3, Frequency Dependence of Atmospheric Absorption

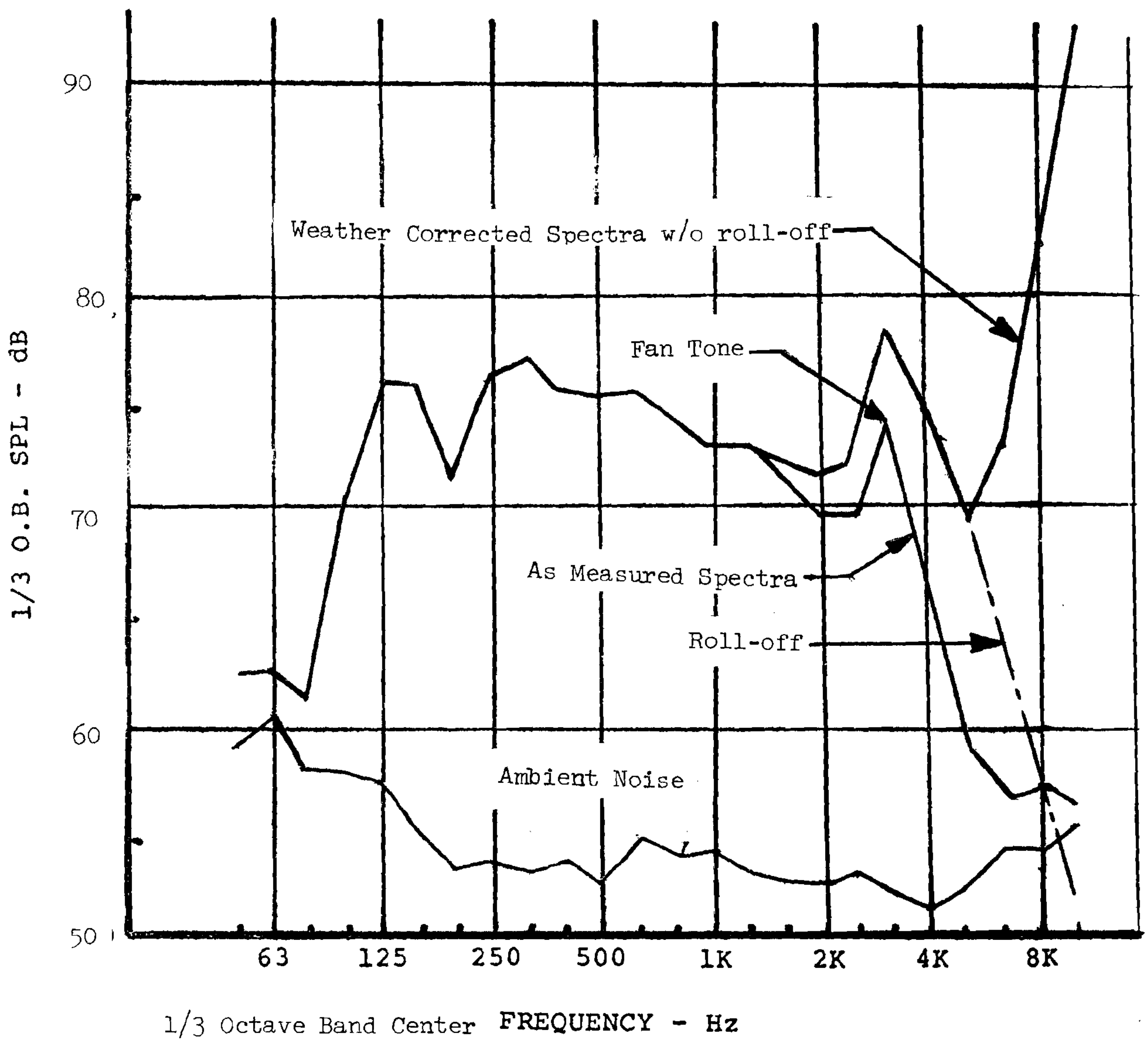
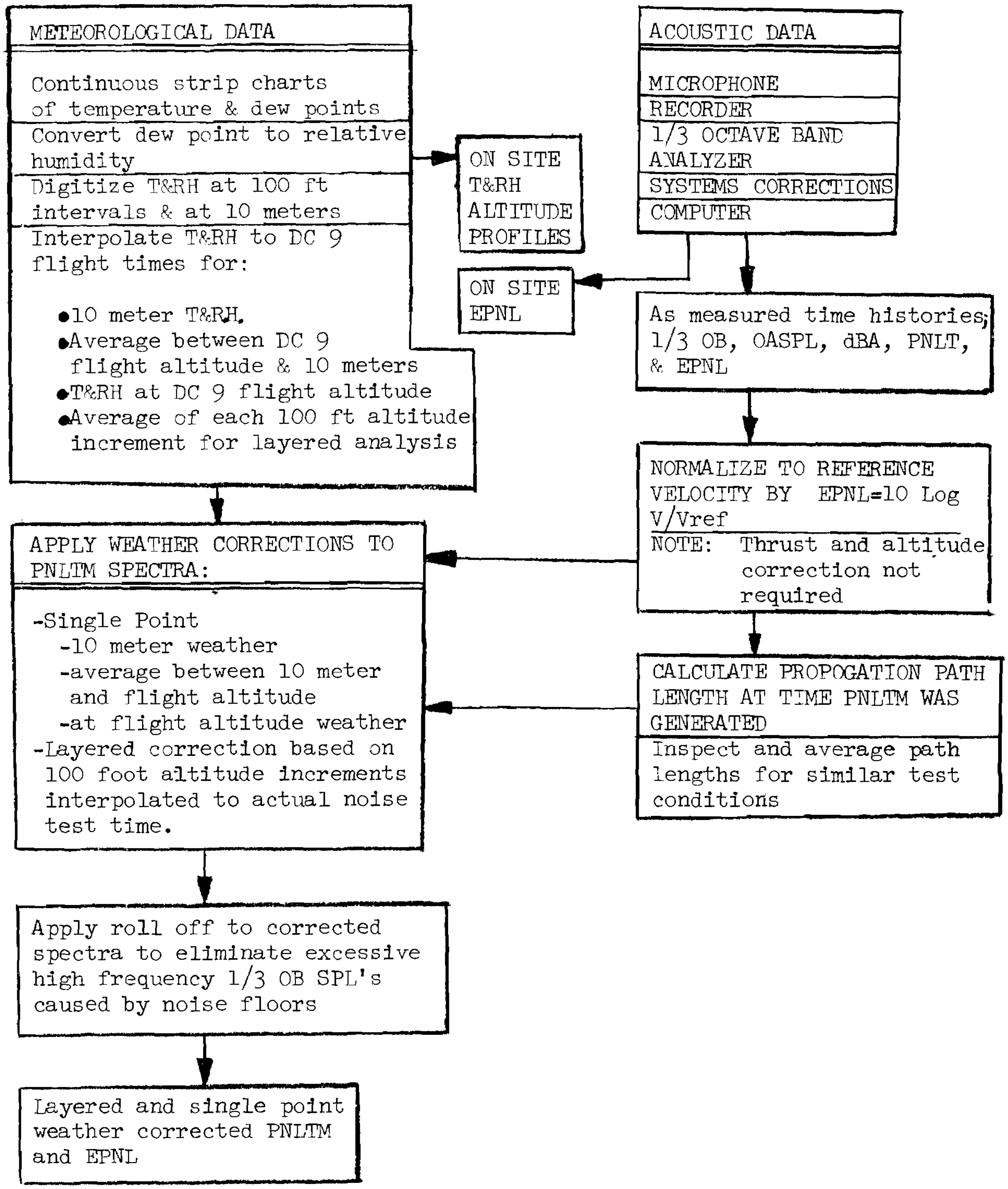


Figure 4, Effect of Roll-off on Corrected Spectra

FIGURE 5, ACOUSTIC AND METEOROLOGICAL DATA REDUCTION



5.0 DISCUSSION OF RESULTS

This section describes the analysis of the test data and presents the results obtained from this analysis. During the testing phase of the program, flyover noise levels were measured under a wide range of meteorological conditions. Included were "baseline" conditions which are defined as having a near standard lapse rate, a near constant absolute humidity and with temperature and relative humidity inside of the FAR Part 36 window. The noise levels measured under baseline conditions were considered to be the reference levels. Other meteorological conditions were classified as "anomalous". Noise levels measured under these meteorological conditions were compared to the baseline levels. Single point and layered weather corrections were applied to all runs to investigate the ability of various weather correction procedures to normalize the data to that value measured under baseline meteorological conditions.

The initial analysis task was to classify the data by meteorological condition and flight condition such as altitude or thrust and to inspect the on-line EPNL data to determine trends. Runs were then selected to encompass the entire range of meteorological conditions. Many runs could be classified as being flown over a low altitude inversion of varying strength. These series of runs, along with the corresponding "baseline" runs are described in detail in Sections 5.1 and 5.2 for flight altitudes of 1100 and 2000 feet. Runs were also flown at the knee of, or below, a high altitude inversion. These runs are described in Section 5.3. The runs in Section 5.1, 5.2 and 5.3 were flown at a thrust (F_n/δ) of 6,000 lbs. A matrix of runs with varying thrust and altitude were flown under baseline conditions. An EPNL, thrust, altitude plot was developed from this data and is shown in Section 5.4. The analysis method and weather calculation procedure, along with a summary table of analyzed runs are presented in Section 5.5.

5.1 EFFECT OF LOW ALTITUDE INVERSION -- 1100 FEET FLIGHT ALTITUDE

Table 2 summarizes the noise results for a representative DC-9 flyover noise run during each of the meteorological conditions shown on Figures 6 through 13. Figures 6 through 13 are temperature and relative humidity profiles for the various tested meteorological conditions. These are characterized by inversion strength (temperature at knee minus ground temperature) as weak, strong or no inversion and by the temperature and humidity conditions (hot and dry, temperate, or cool and moist). The Yuma runs 386 and 439 show the effect of wind aloft (shear not known) versus calm conditions (Figure 14).

Figure 15 is an "altitude attenuation plot" of the runs in Table 2. This plot shows the iso-attenuation lines for a frequency of 3150 hz as a function of temperature and relative humidity. The frequency 3150 hz was chosen because this corresponds to the DC-9 blade passage frequency at 6,000 lb. thrust and tends to be the critical frequency for calculation of Perceived Noise Level. This plot is useful in interpreting data because:

1. As the 10 meter meteorological data point moves away from the reference day on an attenuation basis, the magnitude of the weather correction becomes larger.

2. If the attenuation at the flight altitude differs significantly from the attenuation at 10 meters, a weather correction based on 10 meter data becomes increasingly invalid and a "layered" weather correction becomes necessary to accurately portray the attenuation experienced by the propagation path.

As Figure 15 shows, the tested conditions, with the exception of the runs without a temperature inversion (374, 418, 121), require a layered analysis because the flight altitude exhibits substantially different attenuation characteristics from the 10 meter meteorological data. This attenuation difference, between flight altitude and 10 meter data, is shown on the last column of Table 2. This value should be proportional to the differences between the Part 36 (10 meter single point) and the layered weather correction. This is the case and this correlation lends credence to the conclusion that the layered weather correction method accurately corrects flyover noise data to reference day conditions.

As Table 2 shows, differences up to 3.5 EPNdB were measured for the DC-9 at 6,000 lb. Fn/δ and 1100 foot flight altitude for various meteorological conditions. The single point weather correction based on 10 meter data (Part 36) corrects to reference day only those runs without an inversion. The layered analysis however, corrects all runs to the noise level measured under "baseline" or near-reference conditions. The "average" and "at flight altitude" single-point corrections exhibit unacceptable scatter because single point corrections cannot correct for the non-liner variation of absorption coefficient with temperature and relative humidity. The effect of wind aloft (shear not known) at Yuma is considered negligible because no consistent noise level differences could be found between the runs with or without wind shear.

The as-measured spectra at the time of maximum tone corrected Perceived Noise Level (PNLTM) is shown on Figure 16 for a baseline run and runs measured under hot and dry conditions with and without an inversion. The higher frequencies are significantly attenuated by the absorption characteristics to the hot and dry atmosphere and about 3.5 PNdB lower noise levels result. The weather correction, for both Part 36 (10 meter) and the layered method, were small for the baseline run, Figure 17. The 10 meter weather correction accurately corrects the hot-dry run without the inversion, Figure 18, because the same absorption characteristics exist over the entire propagation path. The layered method, however, does give slightly better correlation with the baseline. Pre-emphasis was not used during data recording and a noise floor caused the data at 5000 Hz and above to be lost for the anomalous runs. A high frequency roll off was applied to the weather corrected runs so as not to distort the data.

The 10 meter weather correction is totally inadequate as a correction procedure when an inversion is present. As shown on Figure 19, the 10 meter correction is small because the atmospheric absorption characteristics at 10 meters are not very different from reference conditions. The layered correction, however, considers the entire propagation path and accurately normalizes the flyover noise level. The layered method for this example tends to slightly over-correct. This may be due to rounding errors in the calculations or to slightly conservative (excessive) attenuation coefficients in the critical area of 1 to 4 KHz as suggested by References 2 and 3. On the other hand, the low inversion with "more temperate" weather appears to be under corrected by a similar amount. These minor discrepancies may be caused by too large increments during the layered analysis or by tolerance build-up during calculations.

Table 2

"EFFECT OF WEATHER AND WEATHER CORRECTION METHOD ON FLYOVER NOISE LEVELS" -- LOW vs. NO INVERSION

ALTITUDE = 1100', FN/δ = 6,000, V = 150KIAS

				WEATHER CORRECTIONS							
				SINGLE POINT							
RUN	LOCATION/WEATHER	10 METER T(°F), RH%	AS-MEAS. EPNL	PART 36	AVG (1)	AT ALTITUDE	LAYERED ANALYSIS	PART 36 EPNL	LAYERED EPNL	ΔEPNL LAYERED MINUS PART 36	(2) ΔATT. ALT
374	FRESNO, BASELINE	67°, 51%	99.2	.1	.3	.4	.2	99.3	99.4	.1	0.2
418	YUMA, BASELINE	61°, 46%	97.6	1.3	1.7	2.3	1.7	98.9	99.3	.4	1.1
121	FRESNO, HOT AND DRY NO INVERSION	86°, 21%	95.8	3.0	3.4	3.7	3.4	98.8	99.2	.4	0.6
175	FRESNO, STRONG INVERSION HOT AND DRY	75°, 38%	95.7	.5	2.0	7.4	4.3	96.2	100.0	3.8	6.6
215	FRESNO, STRONG INVERSION MORE TEMPERATURE	59°, 58%	97.0	.3	.6	1.8	1.5	97.3	98.5	1.2	2.0
239	FRESNO, WEAK INVERSION HOT AND DRY	82°, 31%	96.1	.9	2.1	4.7	3.3	97.4	99.4	2.4	4.8
386	YUMA, WEAK INVERSION CALM WINDS	57°, 65%	98.3	-.1	.5	1.4	1.2	98.3	99.5	1.2	1.7
439	YUMA, WEAK INVERSION STRONGER WINDS	55°, 67%	98.7	-.1	.4	.6	.6	98.6	99.3	.7	0.9

(1) AVERAGE OF 10 METER AND FLIGHT ALTITUDE TEMPERATURE AND RH

(2) $\frac{\Delta \text{ATTENUATION}}{\text{ALTITUDE}}$ = dB/1000 ft. @ 3150 Hz BETWEEN 10 METER AND FLIGHT ALTITUDE CONDITIONS.

Figure 6

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

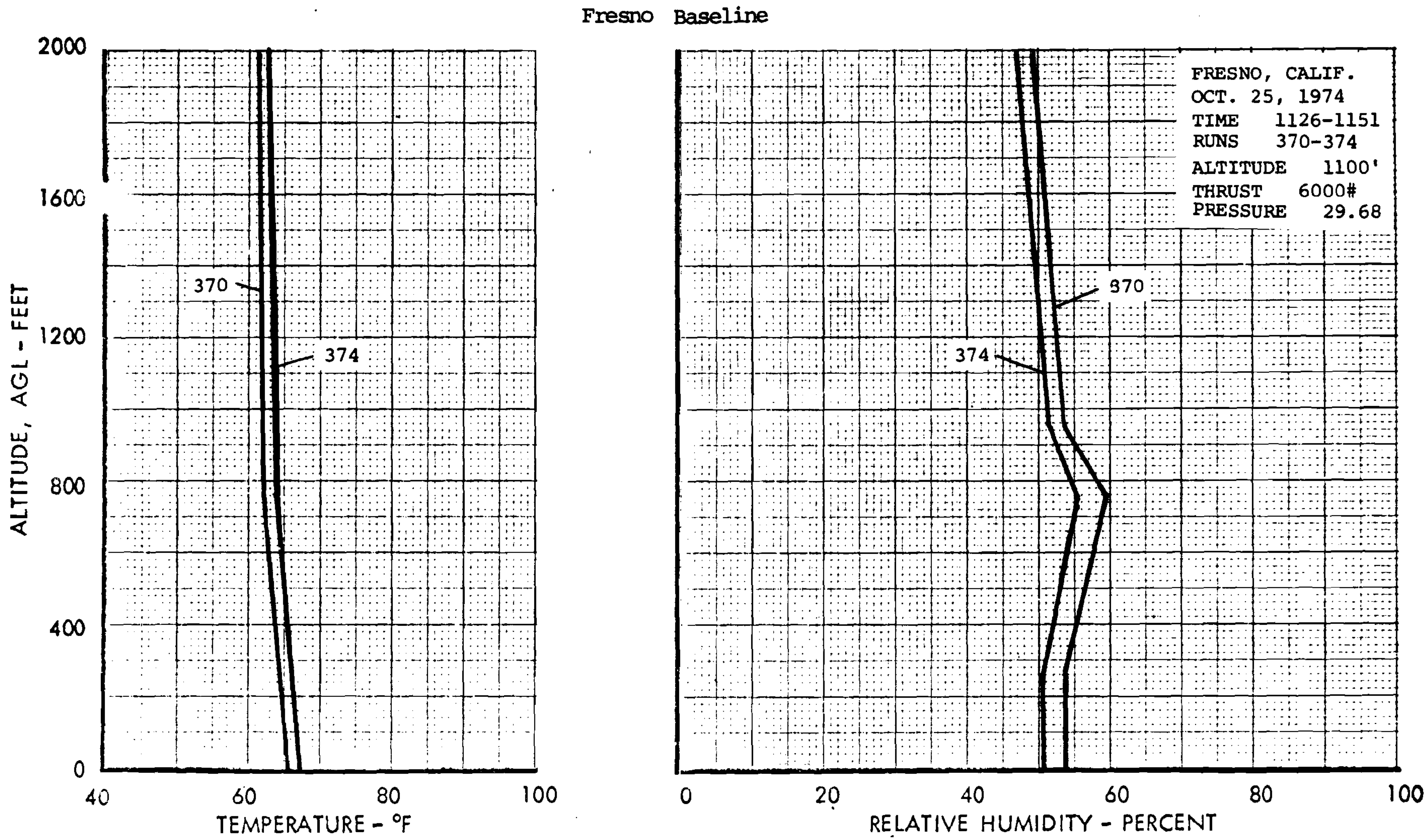


Figure 7

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

Yuma Baseline

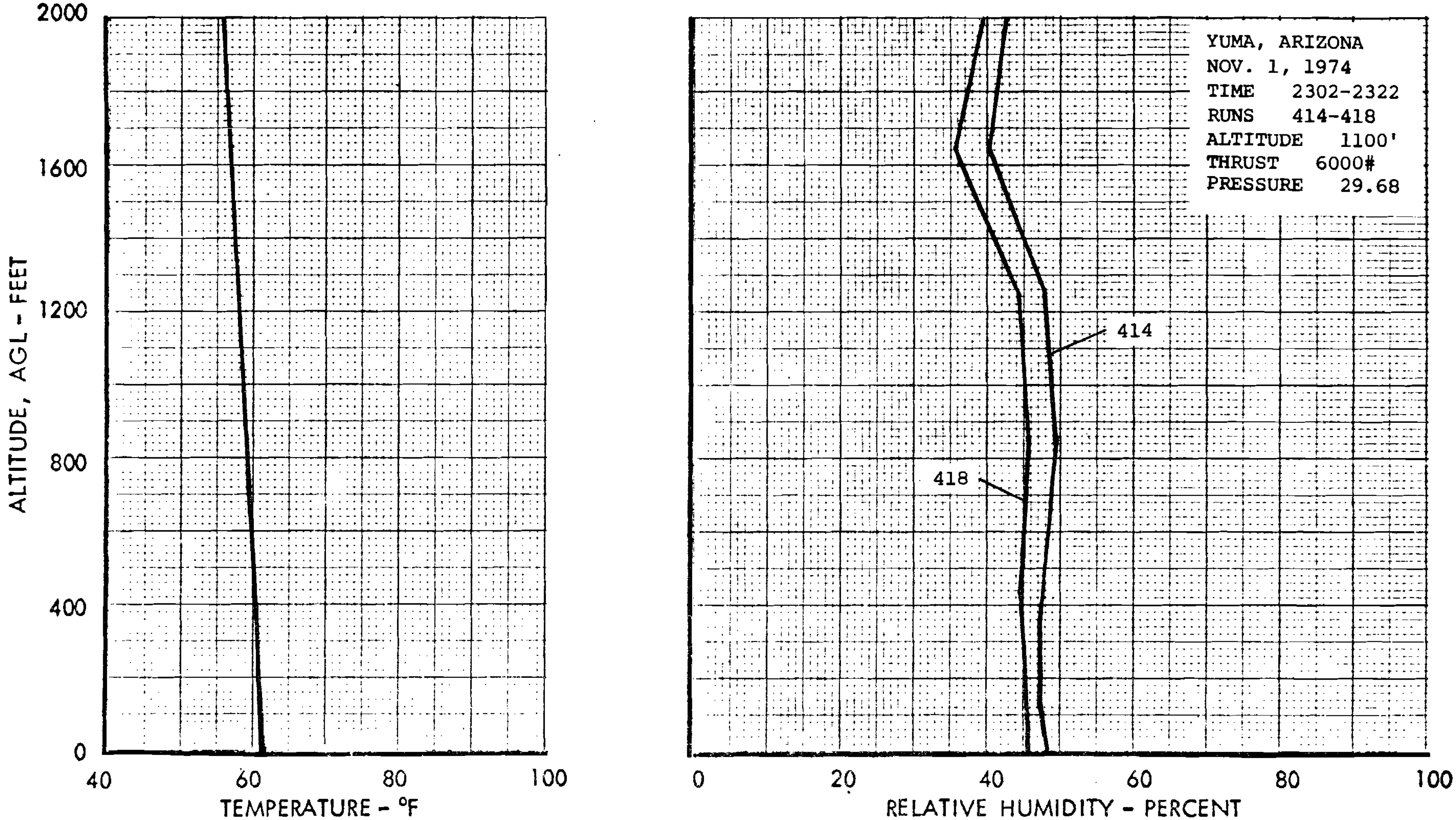


Figure 8

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

Hot and Dry, No Inversion

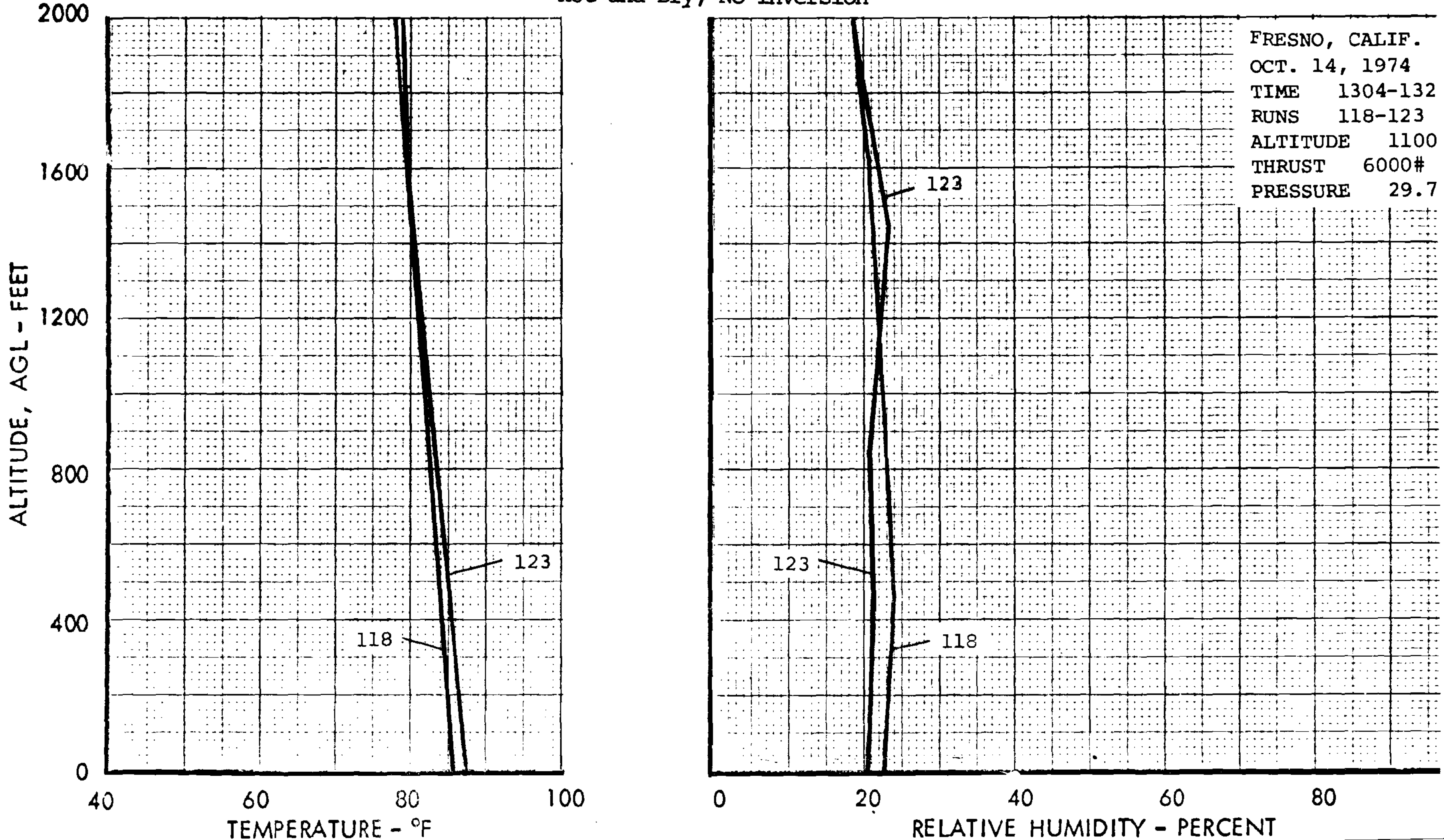


Figure 9

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

Hot and Dry, Strong Inversion

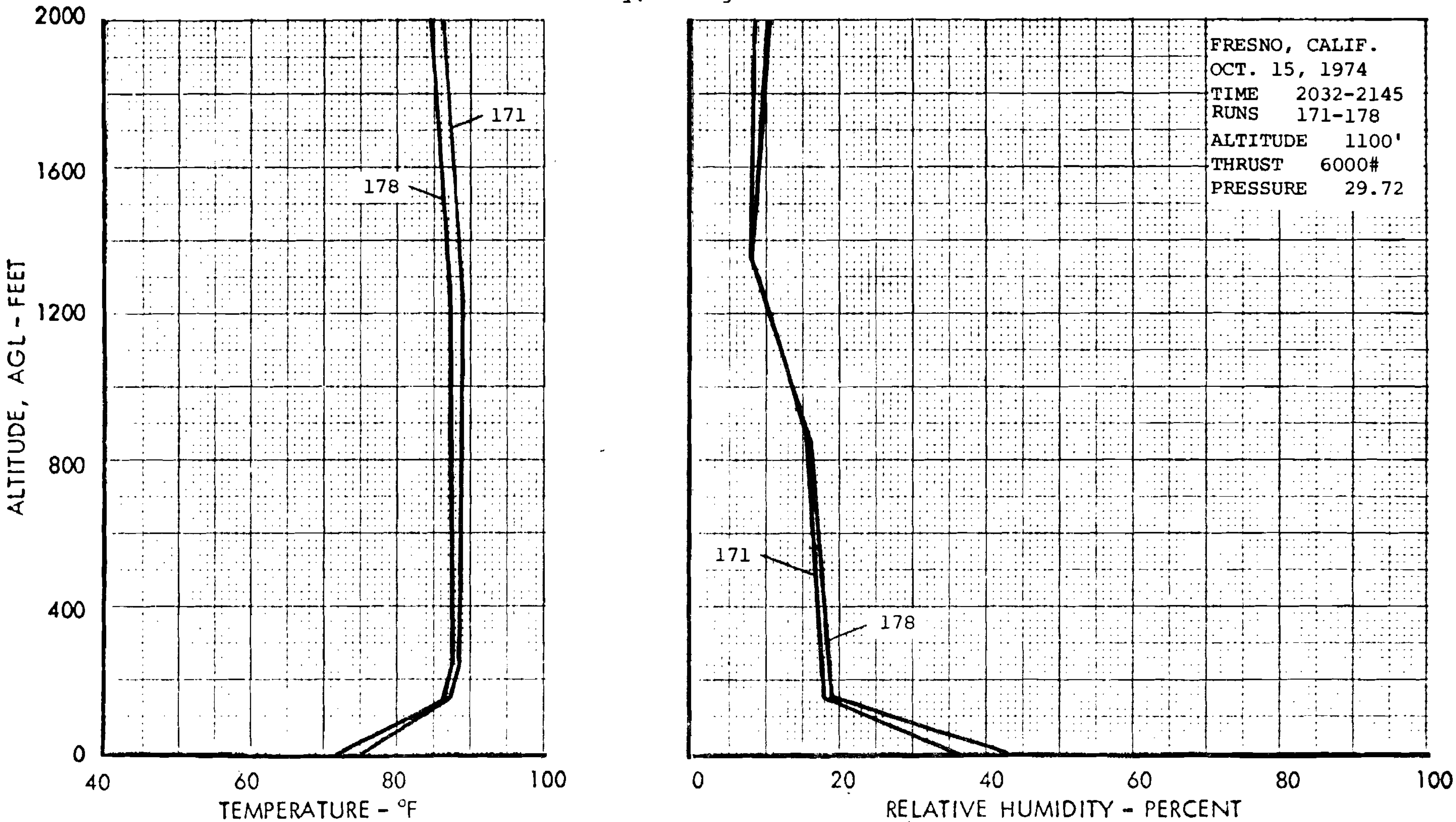


Figure 10

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

Temperate, Strong Inversion

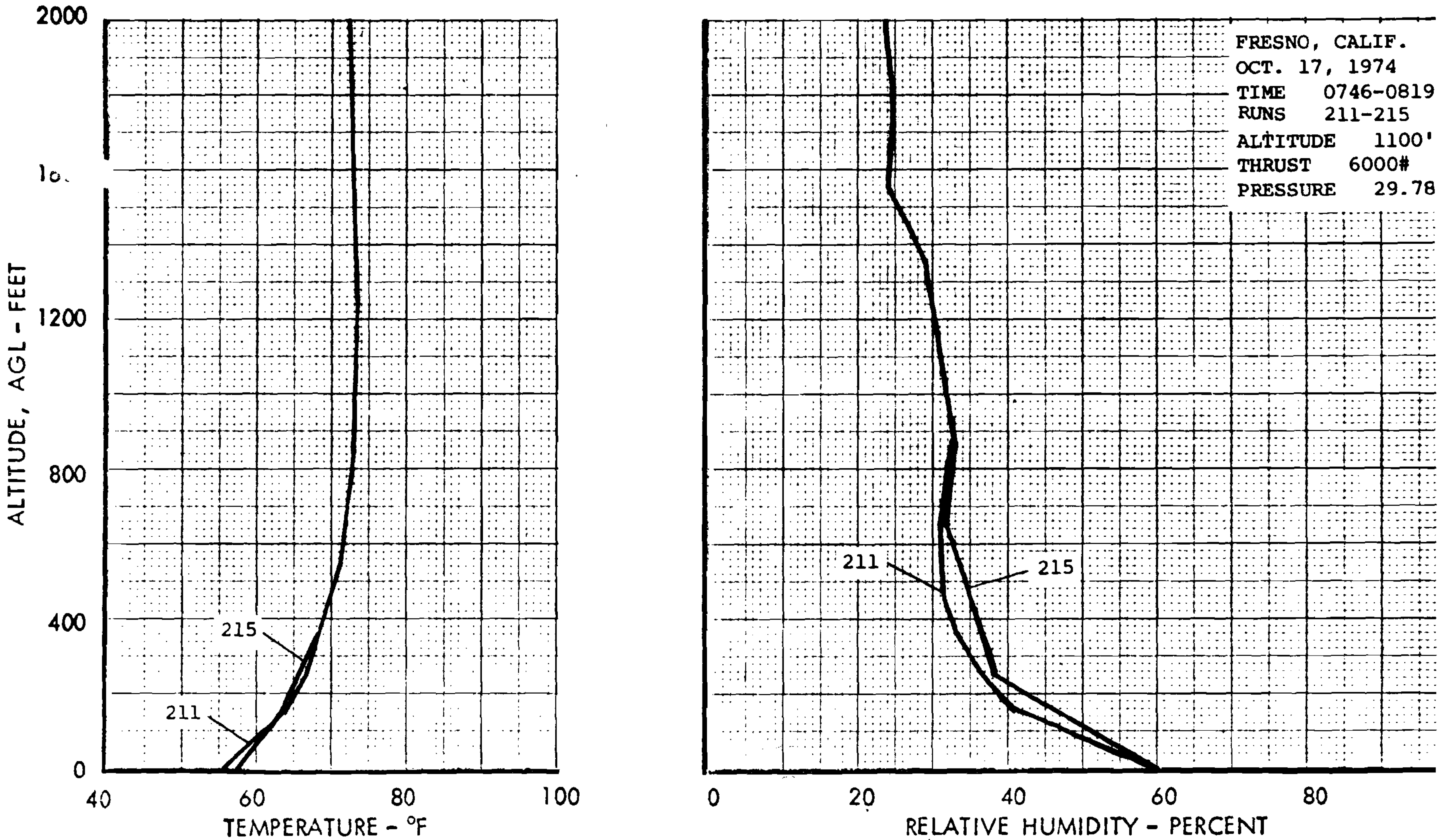


Figure 11

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

Hot and Dry, Weak Inversion

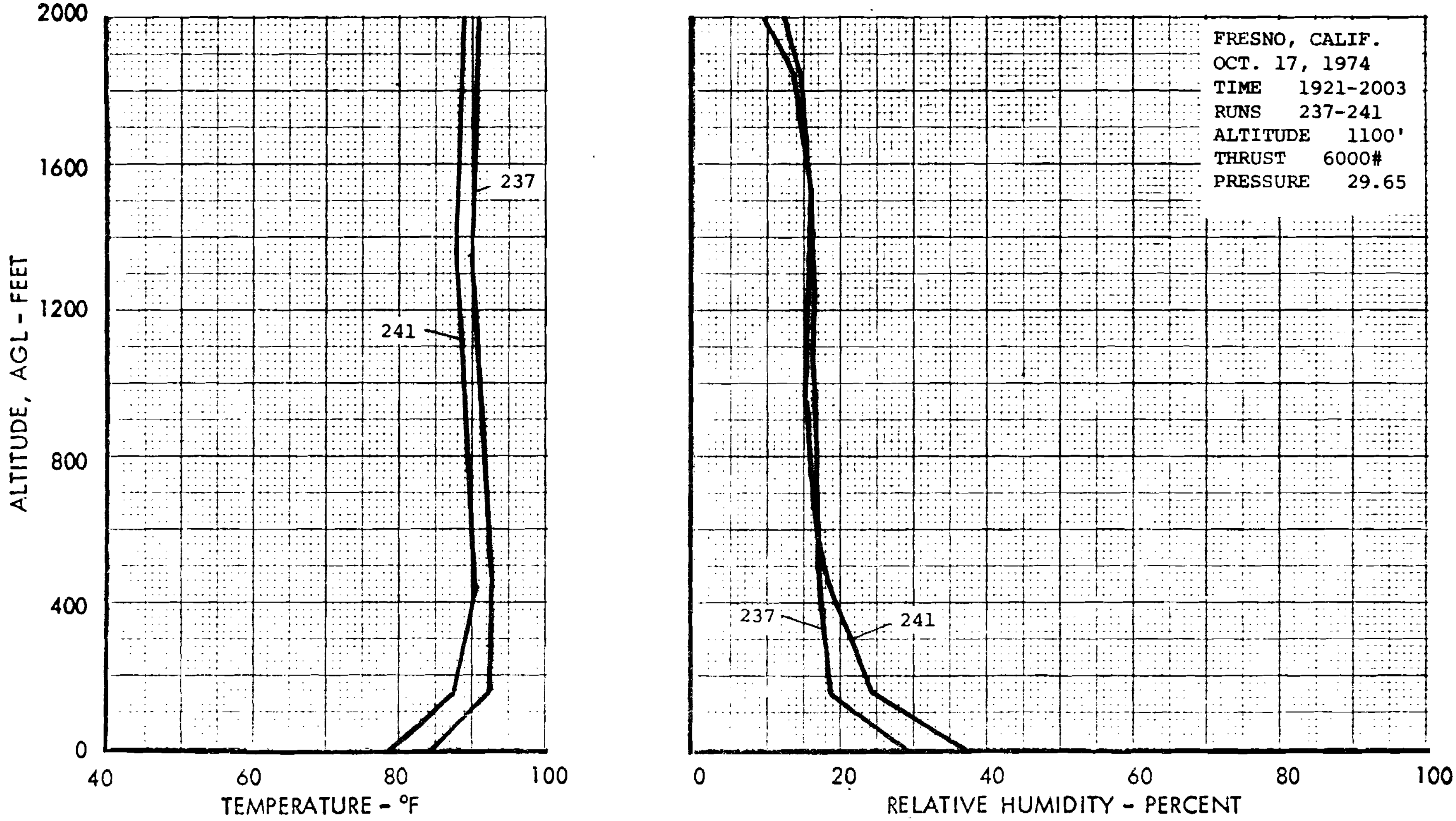


Figure 12

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

Weak Inversion, Calm Winds

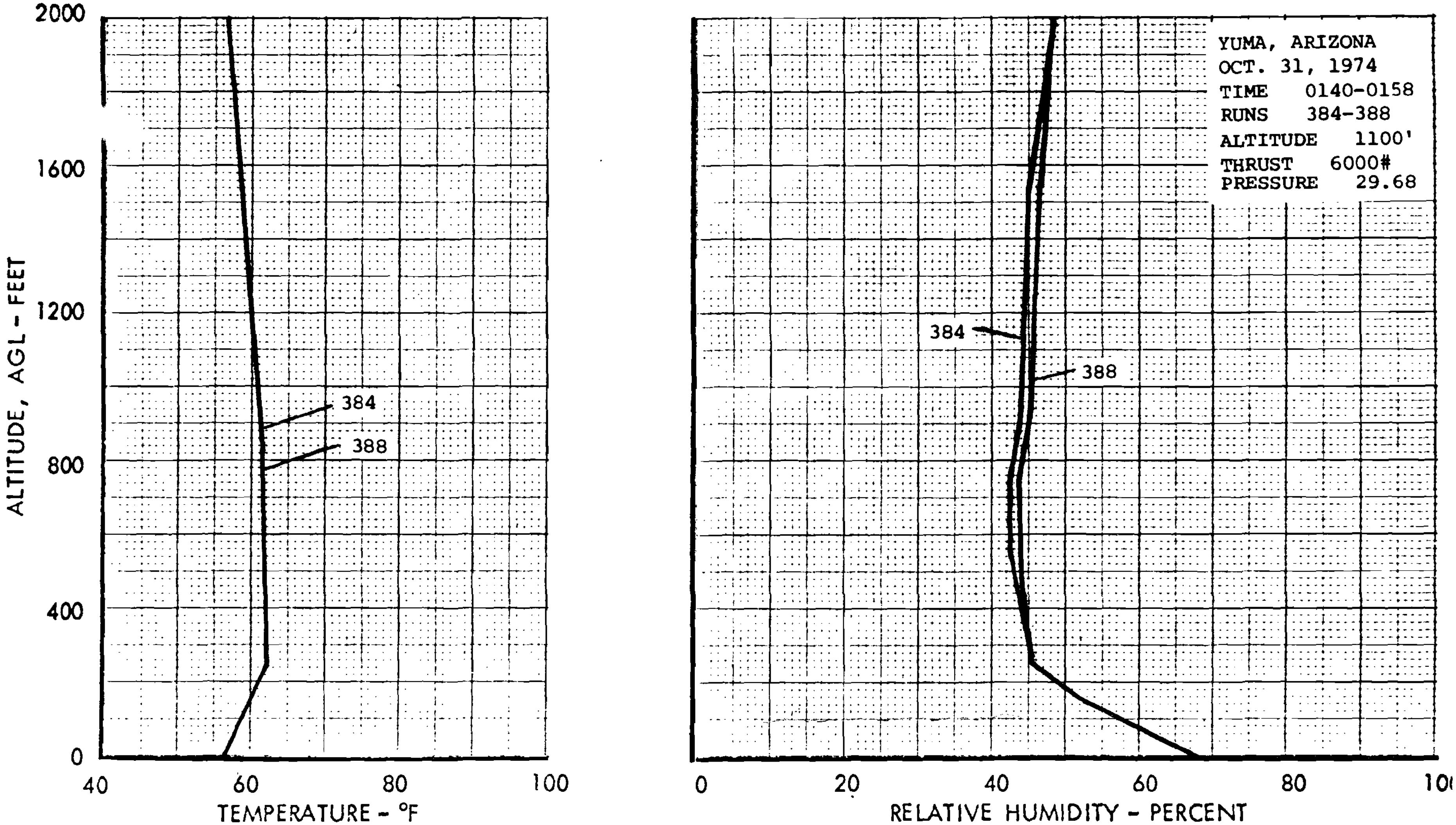
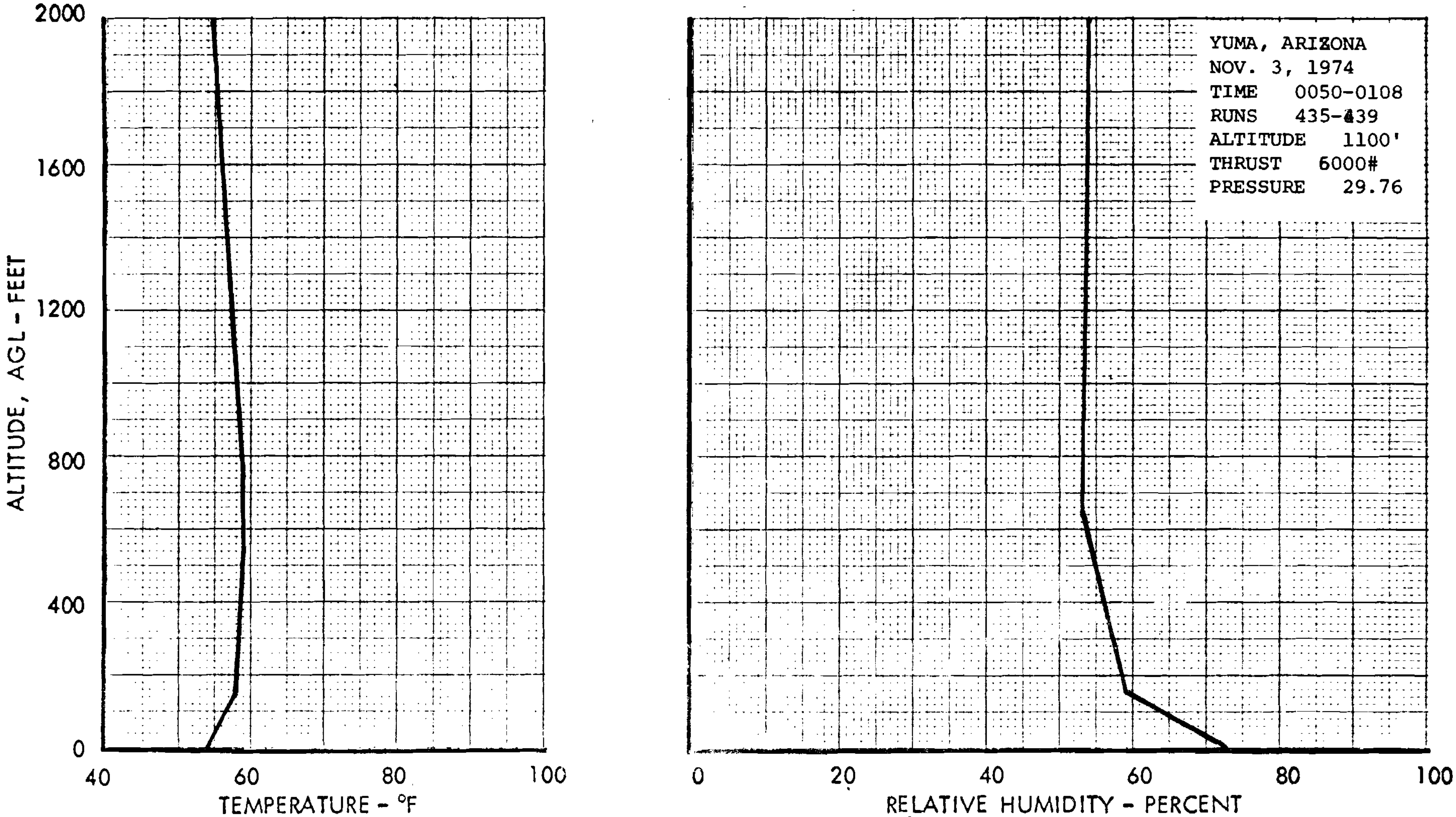


Figure 13

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

Weak Inversion, Stronger Winds



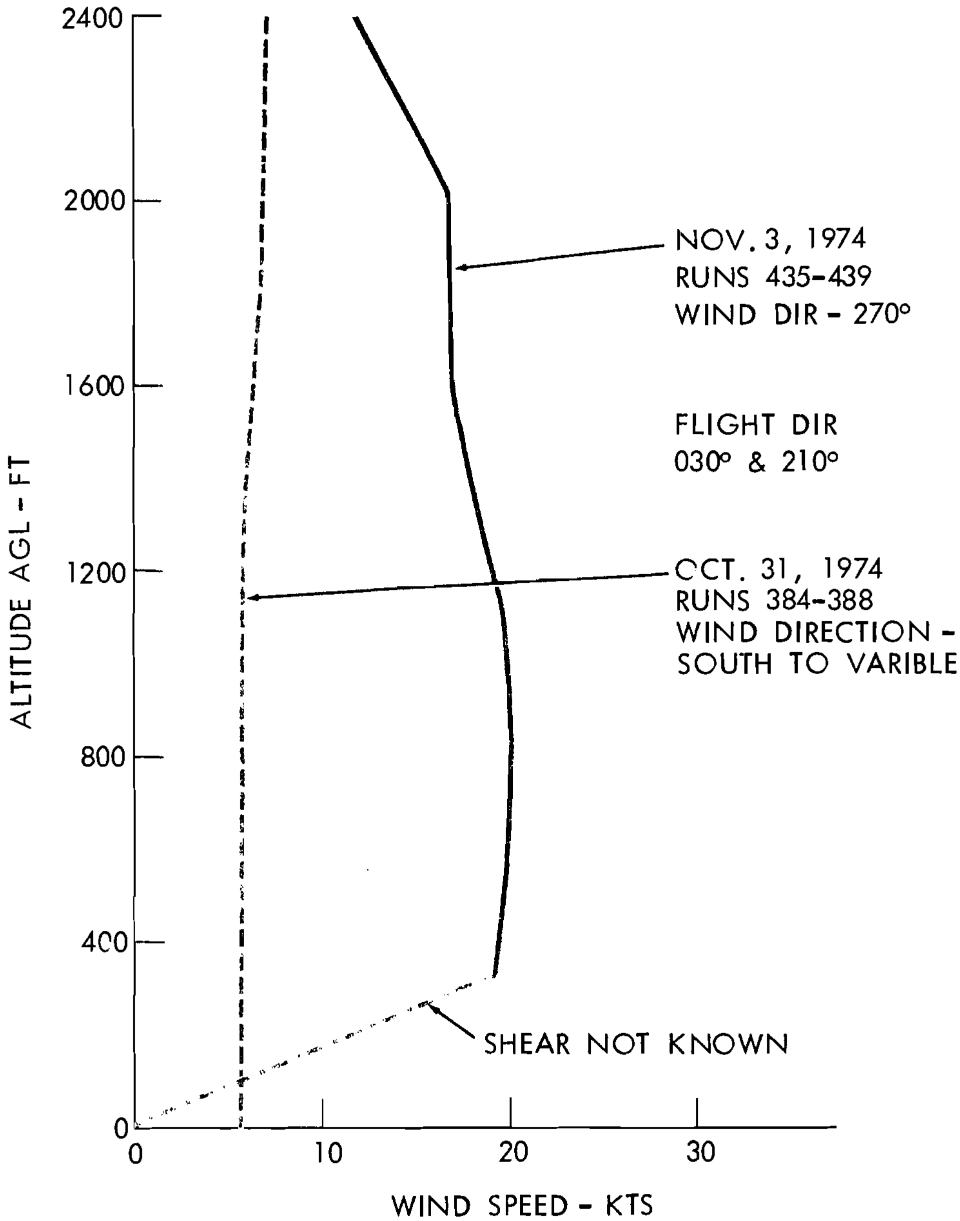


FIG. 14 WIND VELOCITY AND DIRECTION
YUMA ARIZONA

(ATMOSPHERIC ABSORPTION - f = 3150 Hz)

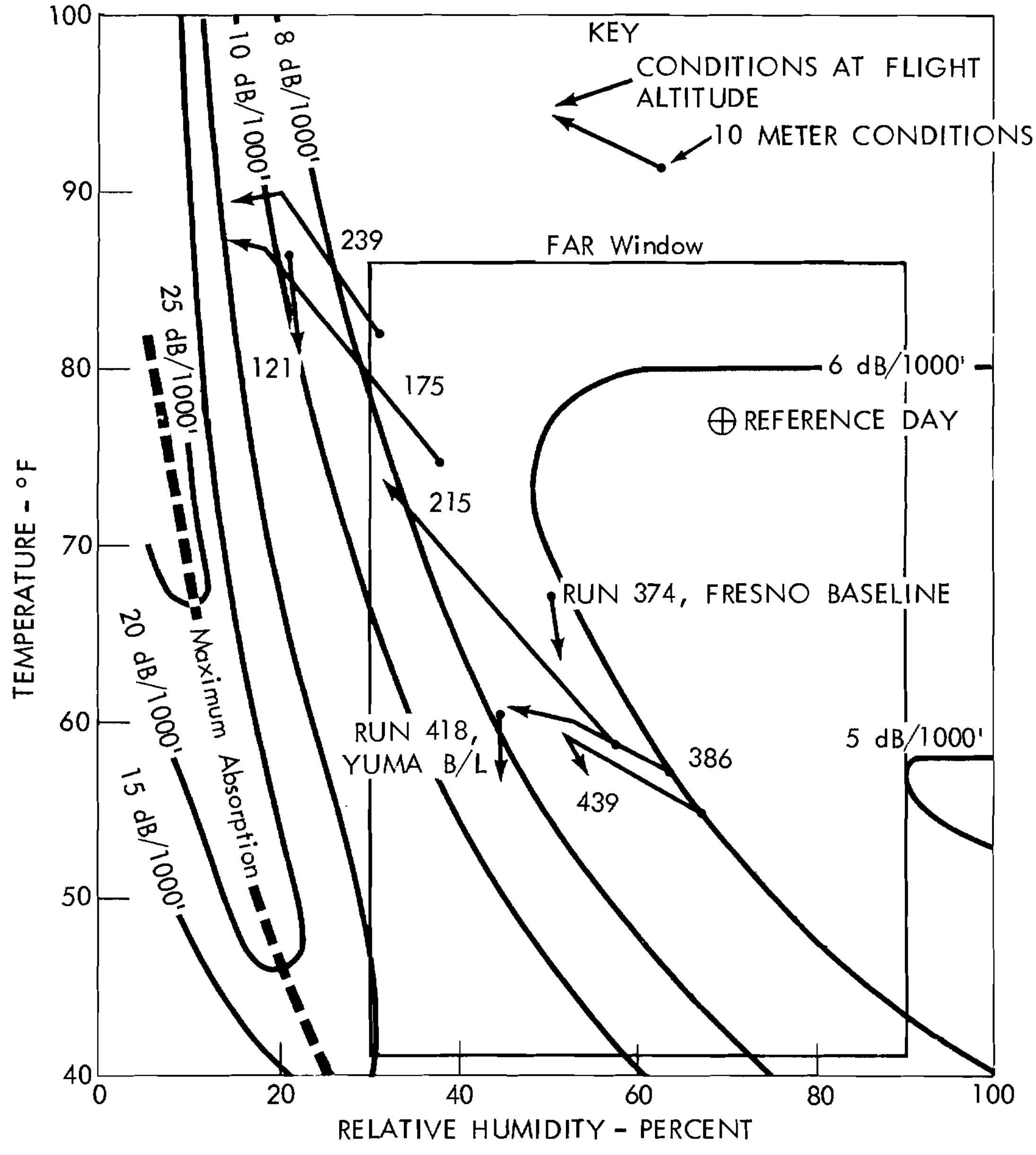


FIG. 15 ALTITUDE ATTENUATION PLOT
LOW ALTITUDE INVERSIONS
FLIGHT ALTITUDE = 1100'

Figure 16 FAA DC-9 PNLTM SPECTRA

As-Measured, Altitude = 1100 ft., Fn/δ = 6,000

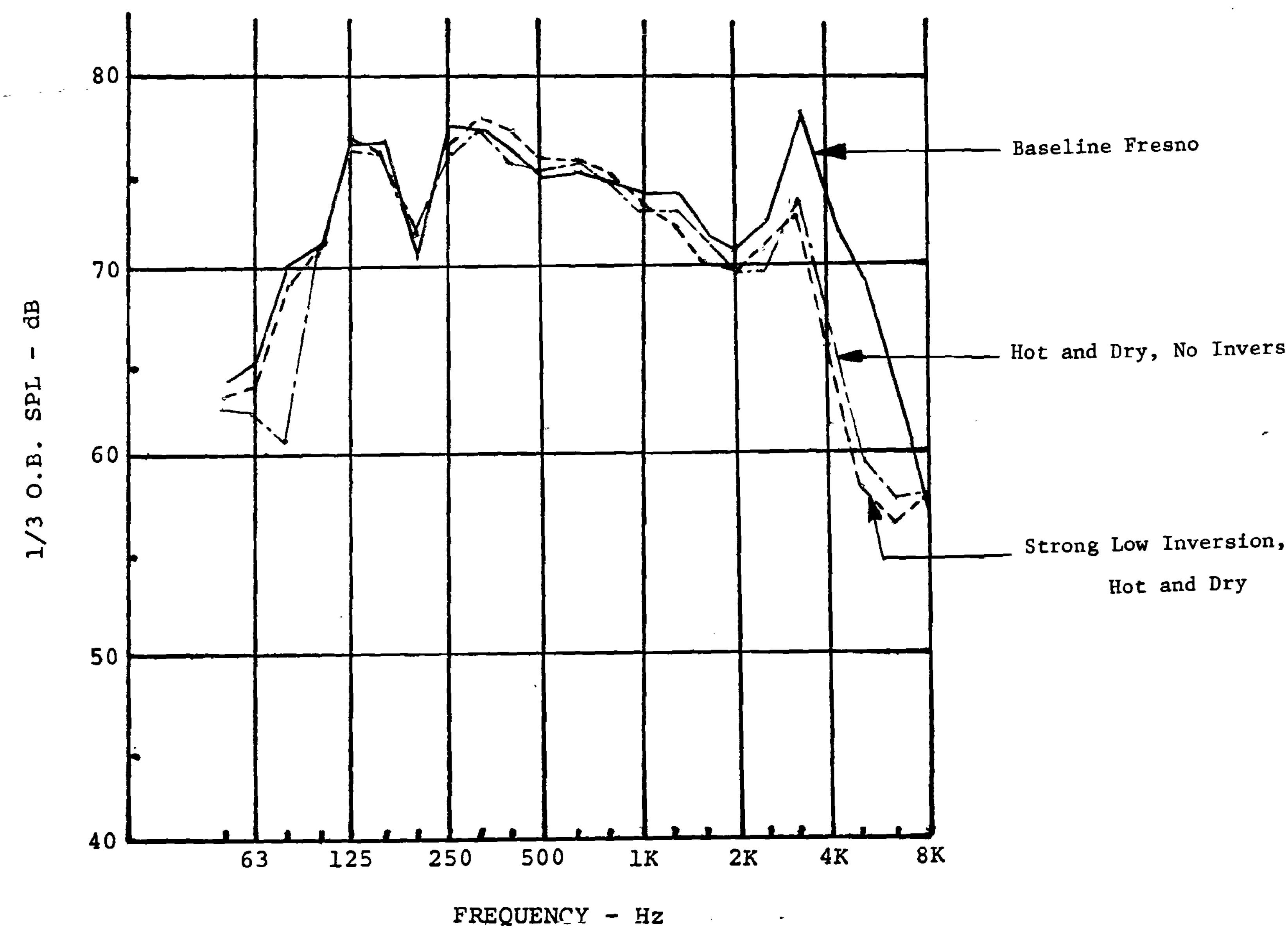


Figure 17 FAA DC-9 PNLTM SPECTRA

Weather Corrections, Fresno Baseline
Altitude = 1100 ft., Fn/δ = 6,000

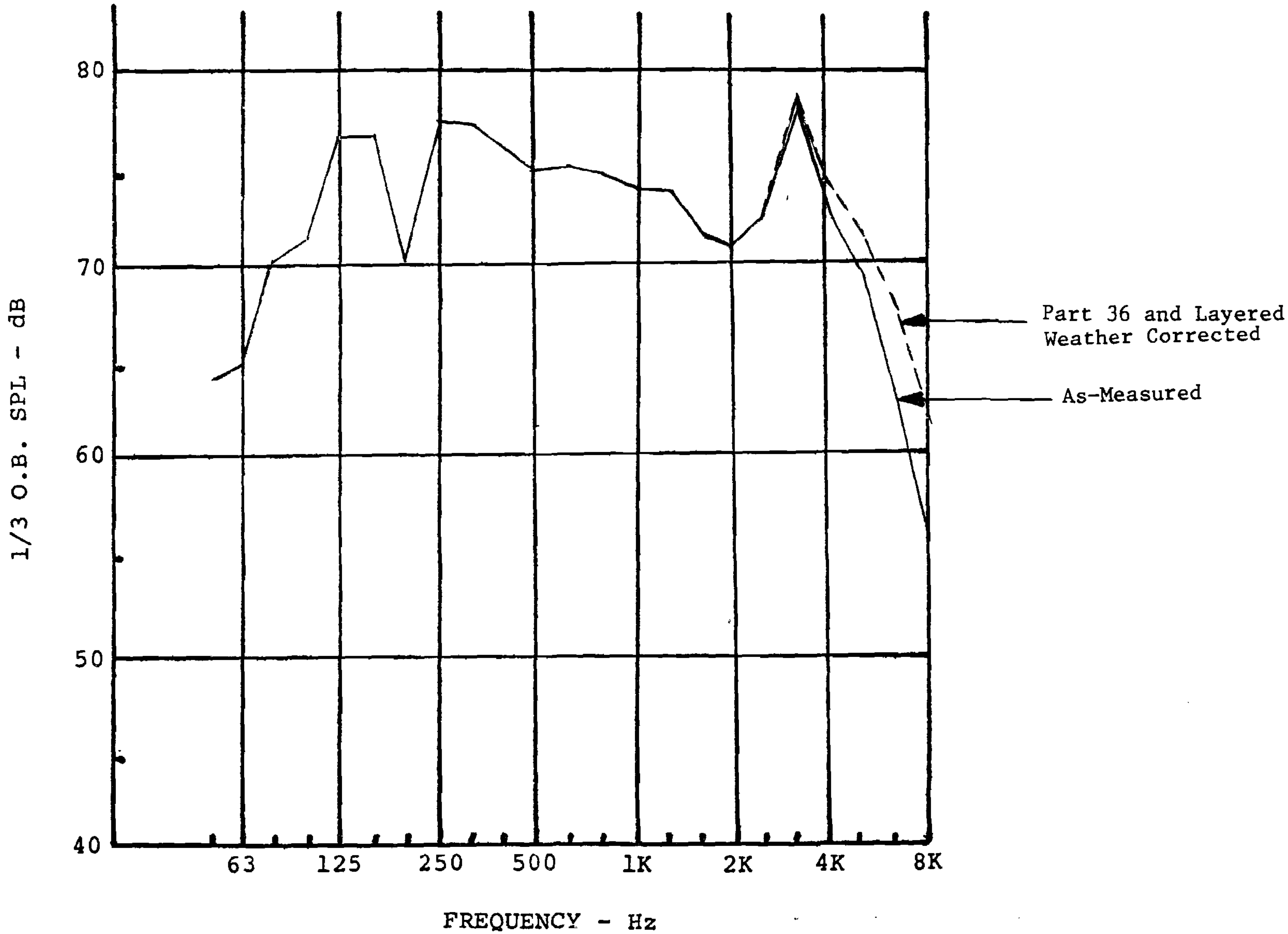


Figure 18 FAA DC-9 PNLTM SPECTRA

Weather Corrections, No Inversion, Hot & Dry
Altitude = 1100 ft., Fn/δ = 6,000

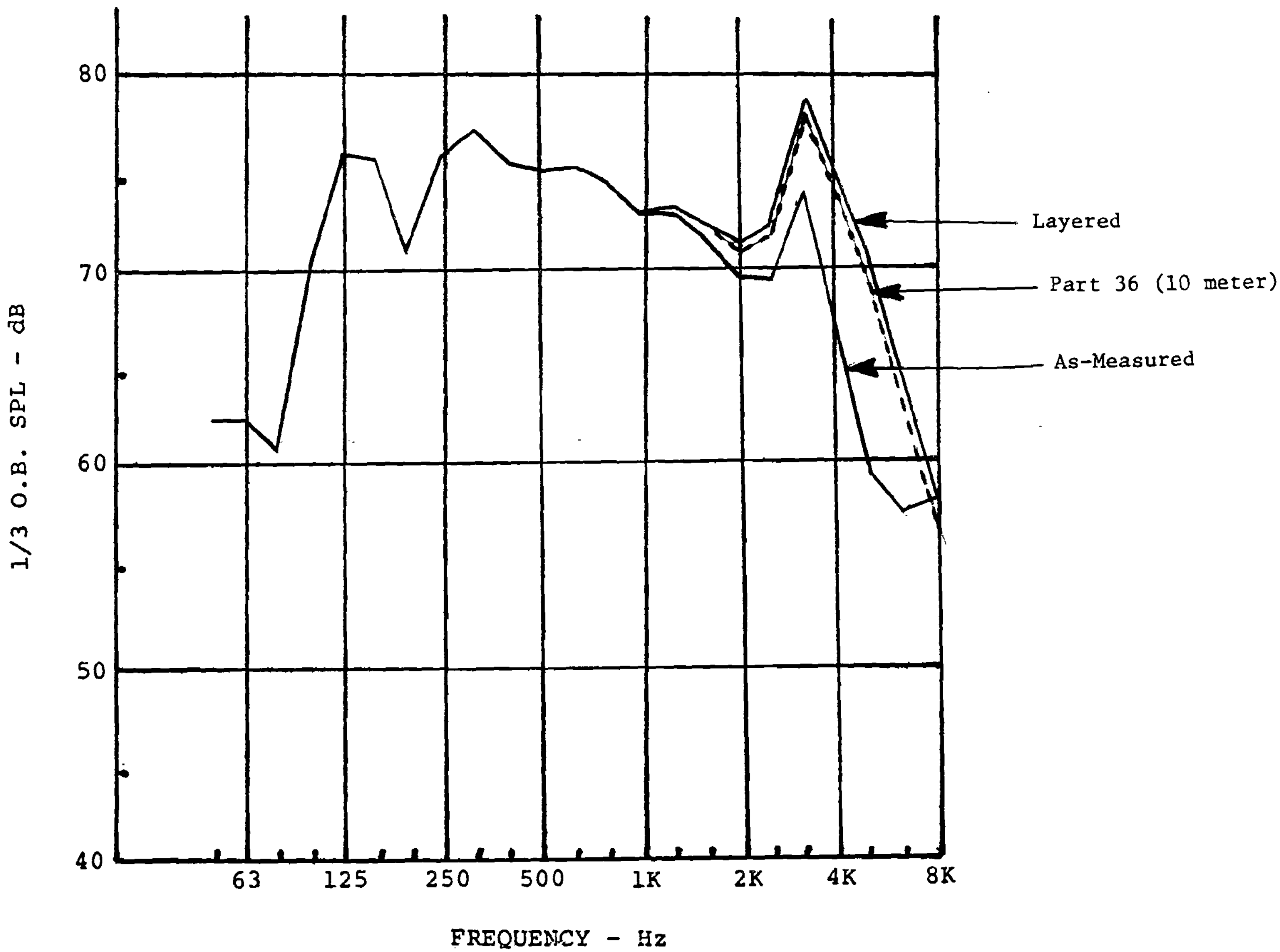
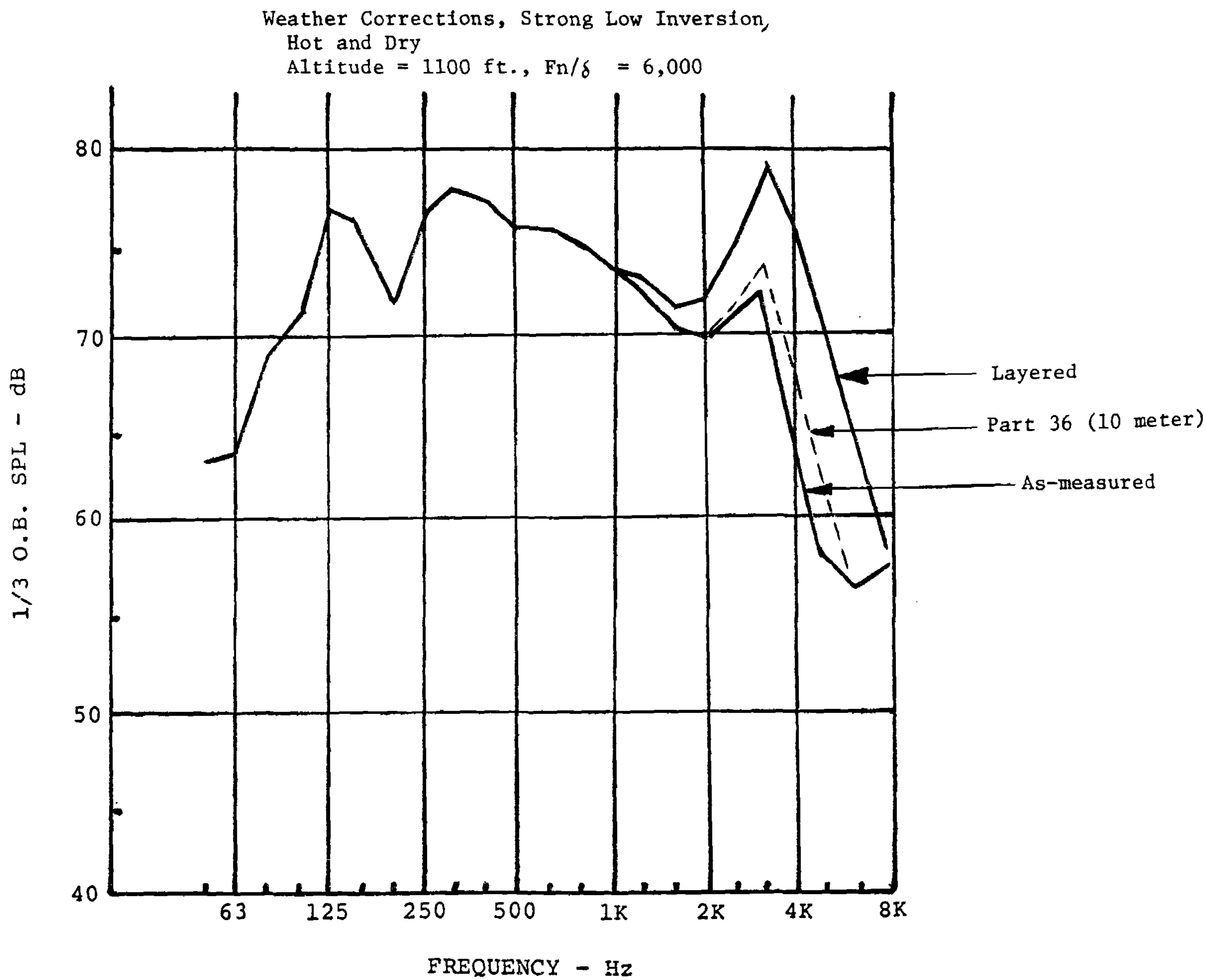


Figure 19 FAA DC-9 PNLTM SPECTRA



5.2 EFFECT OF LOW ALTITUDE INVERSION -- 2000 FOOT FLIGHT ALTITUDE

Increasing the flight altitude to 2000 feet gives results similar to the preceding section. Table 3 summarizes the noise levels and weather corrections for these high altitude runs. Again the layered weather correction procedure is necessary to normalize the noise data to baseline conditions. The temperature and relative humdiity profiles are shown on Figures 20 to 25 and the altitude attenuation plot on Figure 26. The as-measured PNLTM spectra for the "baseline", and hot and dry conditions with and without an inversion are shown on Figure 27. The 2000 foot flight altitude attenuates the high frequencies relative to the low frequencies. This tends to reduce the importance of the high frequencies in determining noise level. The large absorption rate of the hot-dry atmosphere almost attenuates the fan tone.

The magnitude of the weather corrections are small for the baseline, Figure 28. The 10 meter weather correction is substantial for the hot-dry conditions without the inversion, Figure 29, but the layered methodology is needed to accurately correct to baseline conditions. The need for the layered method, even though no inversion was present, can be explained because of the relative humidity for this run decreases slightly above 1000 feet altitude and, at these temperatures and humidities, the atmospheric absorption is very sensitive to percent relative humidity.

The 10 meter and layered weather corrections are shown on Figure 30 for hot-dry conditions with a weak inversion. The 10 meter correction is inadequate to normalize the data because the 10 meter weather is not typical of the propagation path. The layered correction gives a sizeable correction but appears to under-correct by a small amount. Some of this problem may be caused because pre-emphasis was not used during data acquisition and noise floors may distort the data. It should be noted that the 6.3, 8.0, and 10.0 KHz bands are lost for nearly all runs because of noise floor problems. Because weather corrections for the high bands can become extreme due to long distance and absorption rates, a high frequency roll off was applied to ensure that the measured and corrected spectra peaked in the 3150 Hz band. This band corresponds to the blade passage frequency and was dominant at lower test altitudes and during baseline runs. The problems encountered with this run series (approximately 90°F, 15 percent RH at altitude) may be indicative of a limit to allowable test conditions. The 20 percent relative humdity limit on the proposed window mentioned earlier considers that the runs on Figures 21 and 22 (approximately 80°F, 20 percent at altitude) were satisfactorily normalized but problems began to appear for more severe absorption characteristics.

In general, the flyover noise data at 2000 foot altitude confirmed the ability of the layered weather correction procedure to normalize data measured over a wide range of meteorological conditions. The main effect of the increased flight altitude was to increase data scatter. Two problems, typical of long distance measurements appeared. They were a rising and falling of the tail end of the time history which made the 10 dB down points somewhat ambiguous and the high frequency attenuation problem described in the previous paragraph.

Table 3

"EFFECT OF WEATHER AND WEATHER CORRECTION METHOD ON FLYOVER NOISE LEVELS" -- LOW vs. NO INVERSION

ALTITUDE = 2000', FN/δ = 6,000, V = 150 KIAS

RUN	LOCATION/WEATHER	10 METER T(°F), RH%	AS-MEAS EPNL	WEATHER CORRECTIONS				PART 36 EPNL	LAYERED EPNL	EPNL LAYERED MINUS PART 36	(2) ATT/ALT
				SINGLE POINT							
				PART 36	AVG(1)	AT ALTITUDE	LAYERED ANALYSIS				
369	FRESNO, BASELINE	65°, 55%	92.7	.3	--	--	.3	93.0	93.0	0	.8
117	FRESNO, HOT AND DRY NO INVERSION	84°, 25%	89.5	2.1	4.5	8.0	3.9	91.6	93.4	1.8	4.6
219	FRESNO, STRONG INVERSION MORE TEMPERATURE	60°, 56%	90.7	-.2	1.4	6.8	3.3	90.5	94.0	3.5	4.6
245	FRESNO, HOT AND DRY WEAK INVERSION	77°, 39%	89.4	.2	.9	14.5	3.2	89.6	92.6	3.0	9.2
393	YUMA, WEAK INVERSION CALM WINDS	57°, 66%	92.4	-.5	.4	2.2	1.7	91.9	94.1	2.2	1.7
444	YUMA, WEAK INVERSION STRONGER WINDS	54°, 70%	92.1	-.2	.4	1.7	1.0	91.9	93.1	1.2	1.5

(1) AVERAGE OF 10 METER AND FLIGHT ALTITUDE TEMPERATURE AND RH

(2) $\frac{\text{ATTENUATION}}{\text{ALTITUDE}} = \frac{\text{dB}}{1000 \text{ ft.}}$ @ 3150 Hz BETWEEN 10 METER AND FLIGHT ALTITUDE CONDITIONS

Figure 20

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

Fresno Baseline

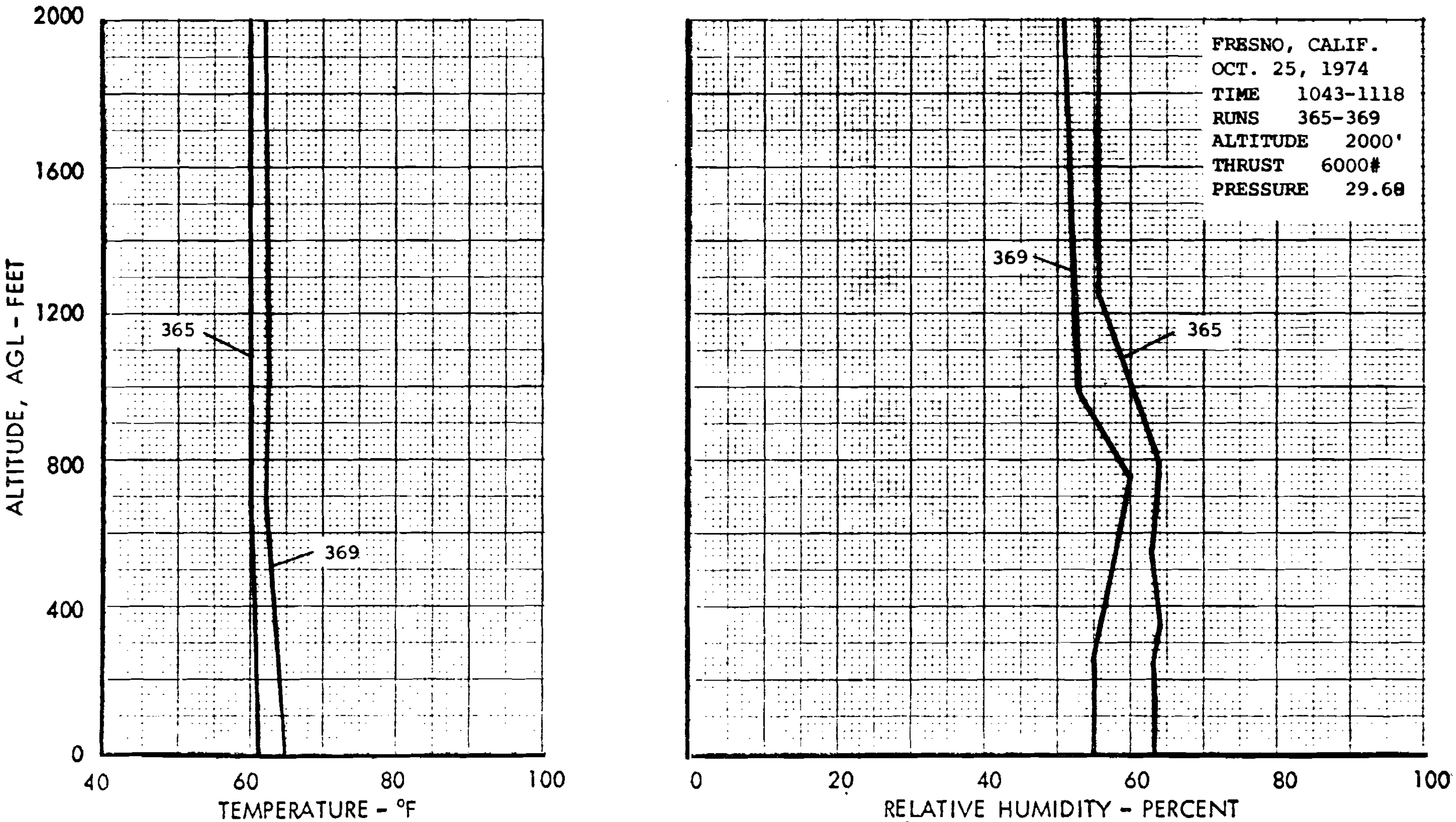


Figure 21

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

Hot and Dry, No Inversion

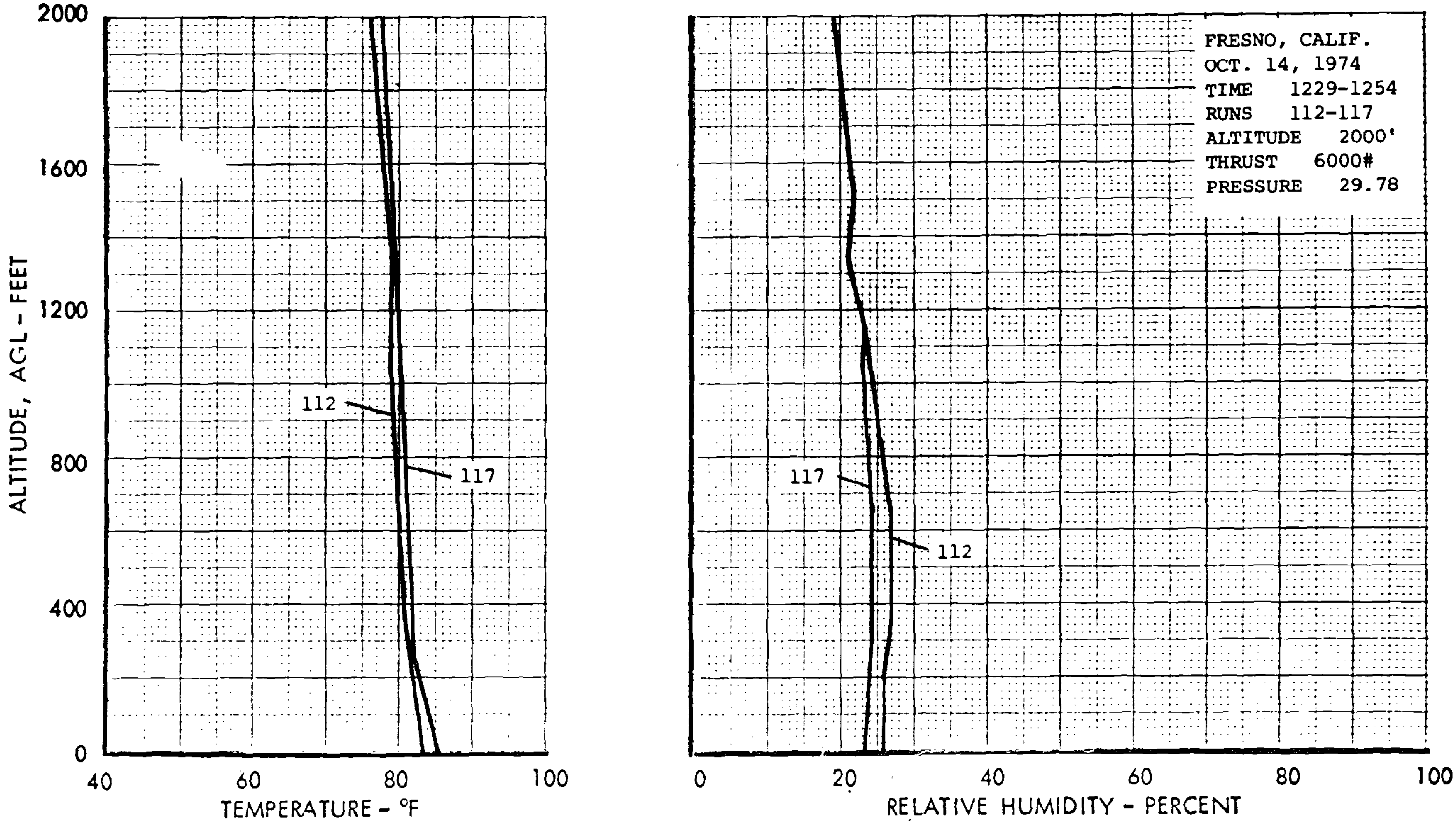


Figure 22

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

Temperate, Strong Inversion

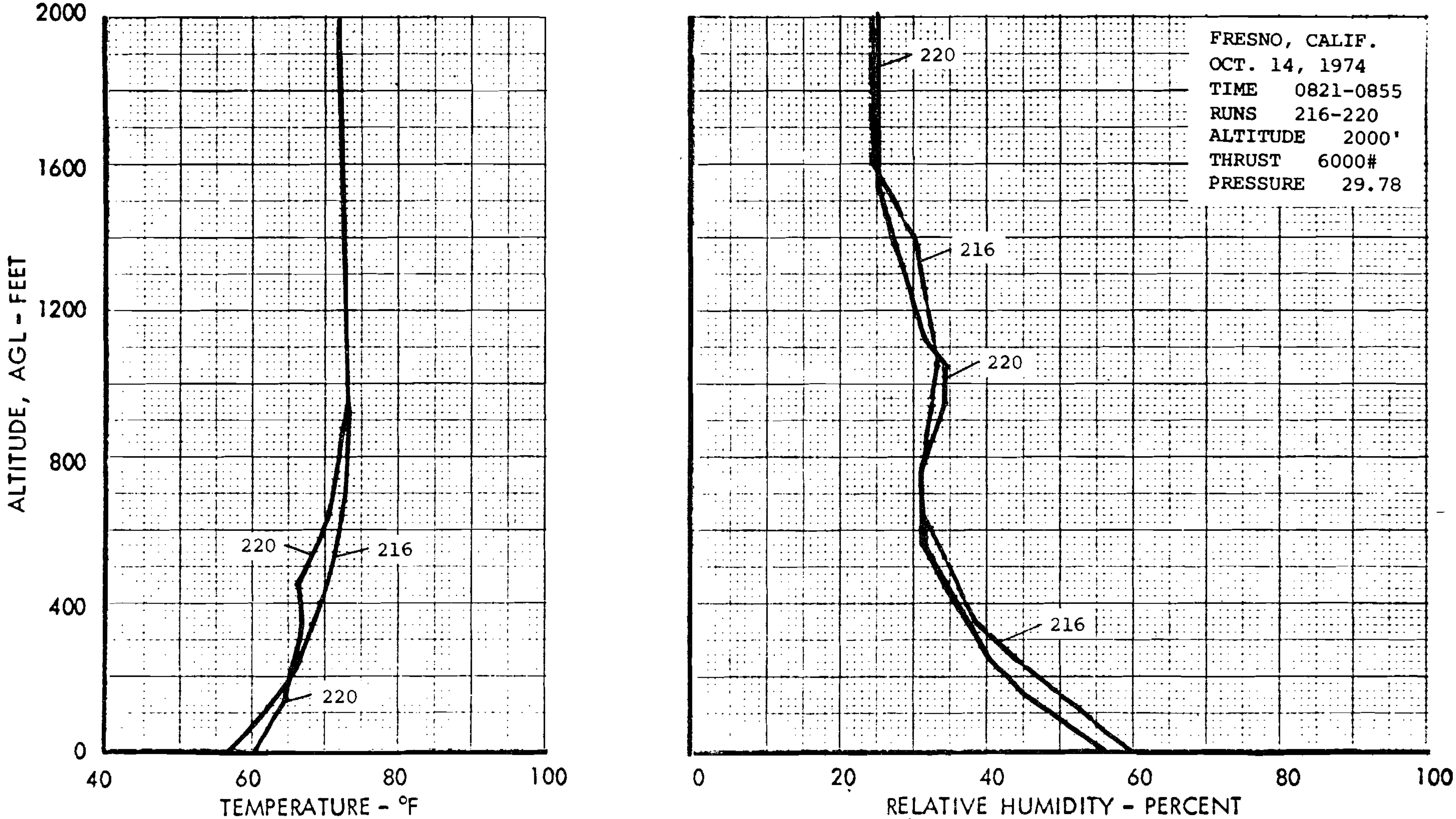


Figure 23

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

Hot and Dry, Weak Inversion

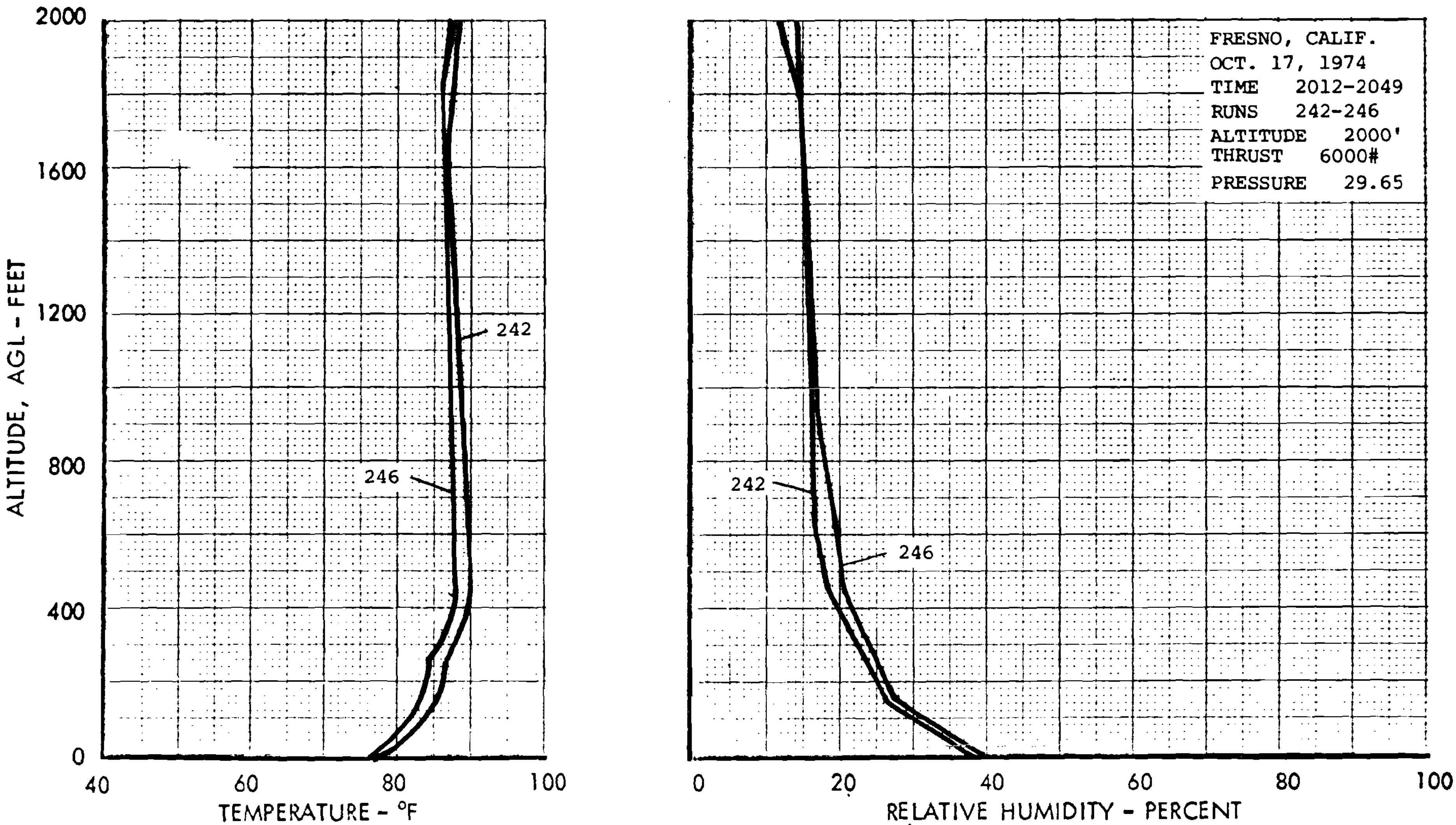


Figure 24

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

Weak Inversion, Calm Winds

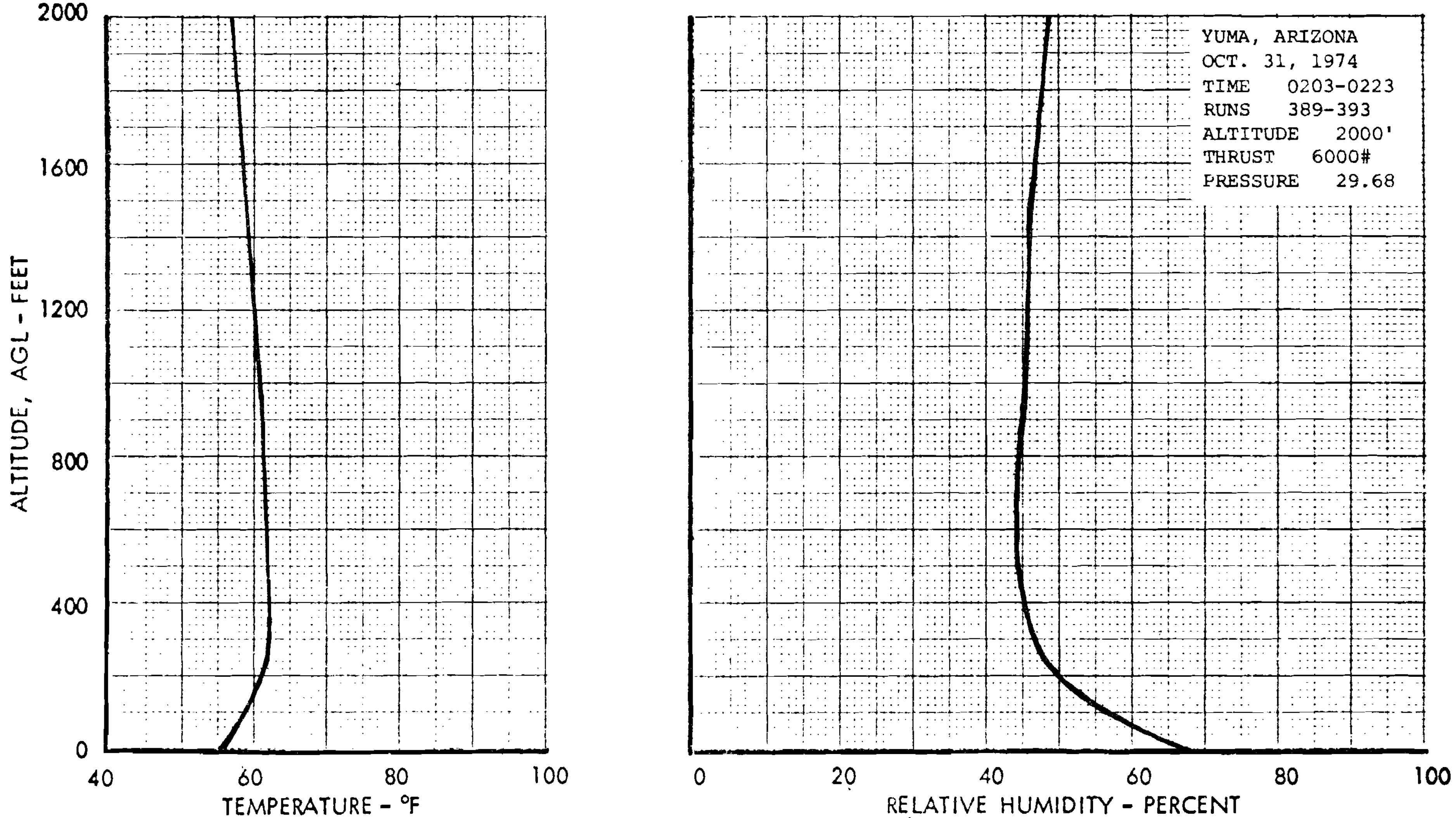
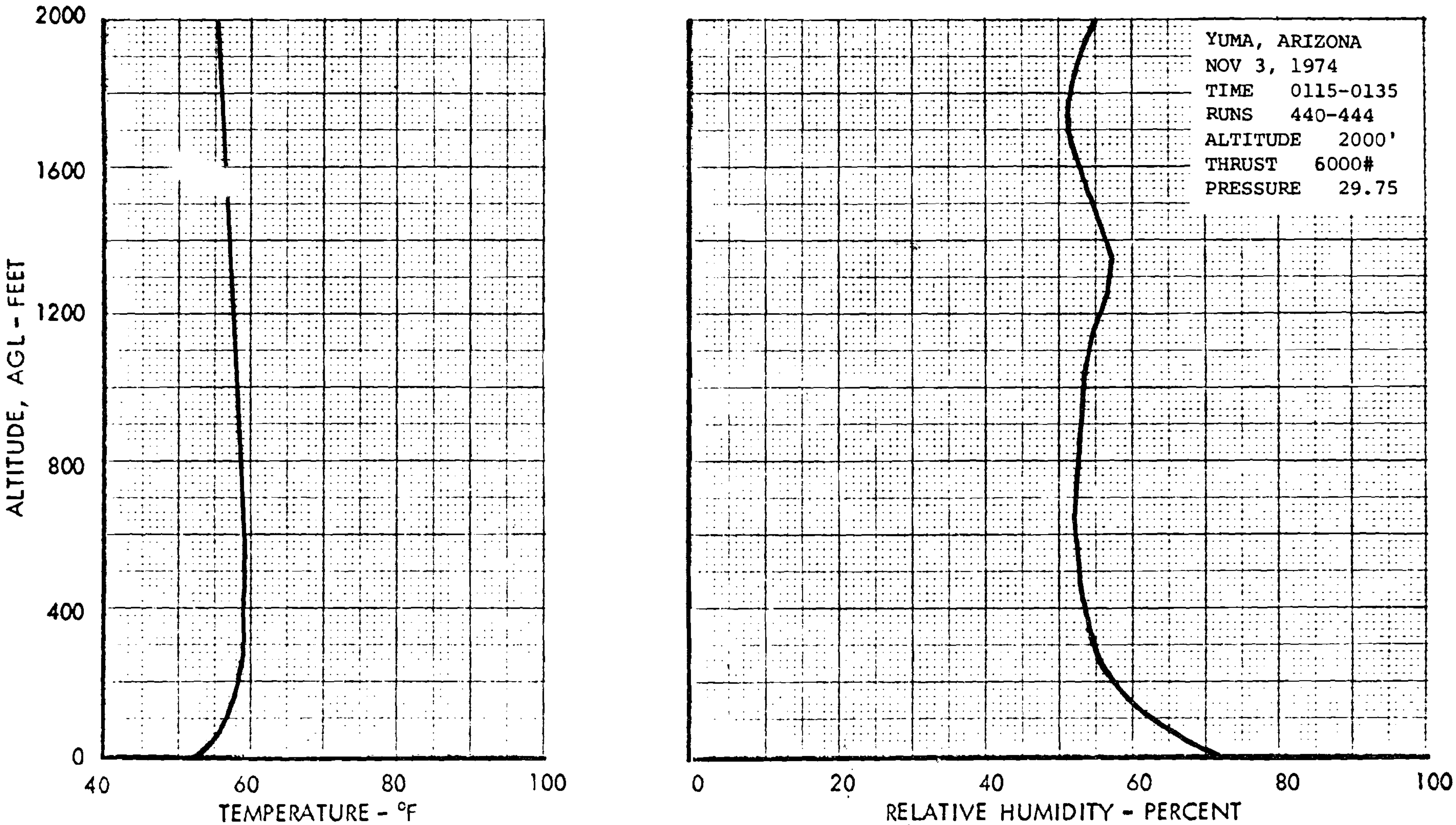


Figure 25

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

Weak Inversion, Stronger Winds



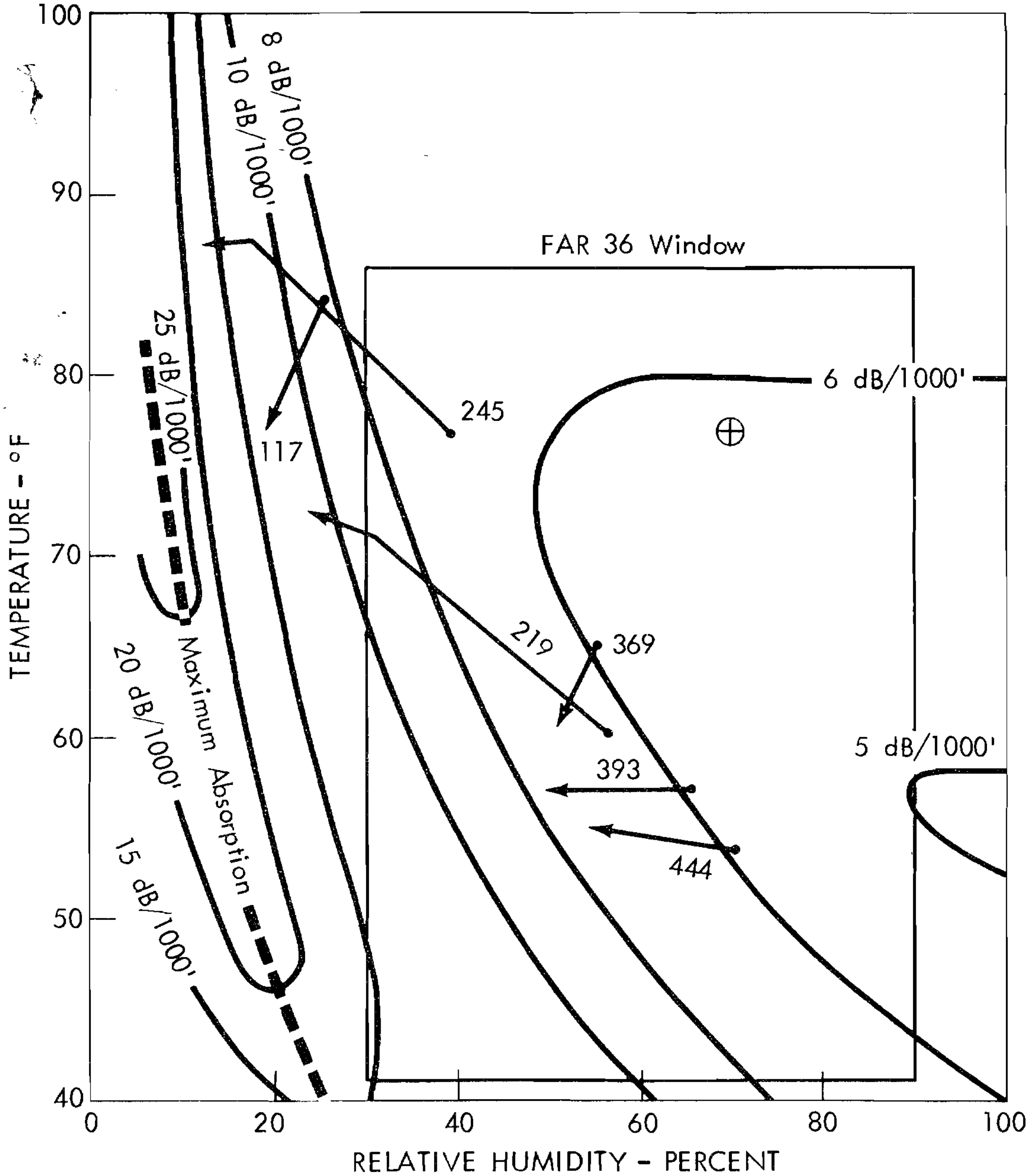


FIG. 26 ALTITUDE ATTENUATION PLOT
LOW ALTITUDE INVERSIONS, FLIGHT ALTITUDE = 2000'
ATMOSPHERIC ABSORPTION - f = 3150 Hz

Figure 27: FAA DC-9 PNLTM SPECTRA

As-Measured, Altitude = 2,000 ft., Fn/δ = 6,000

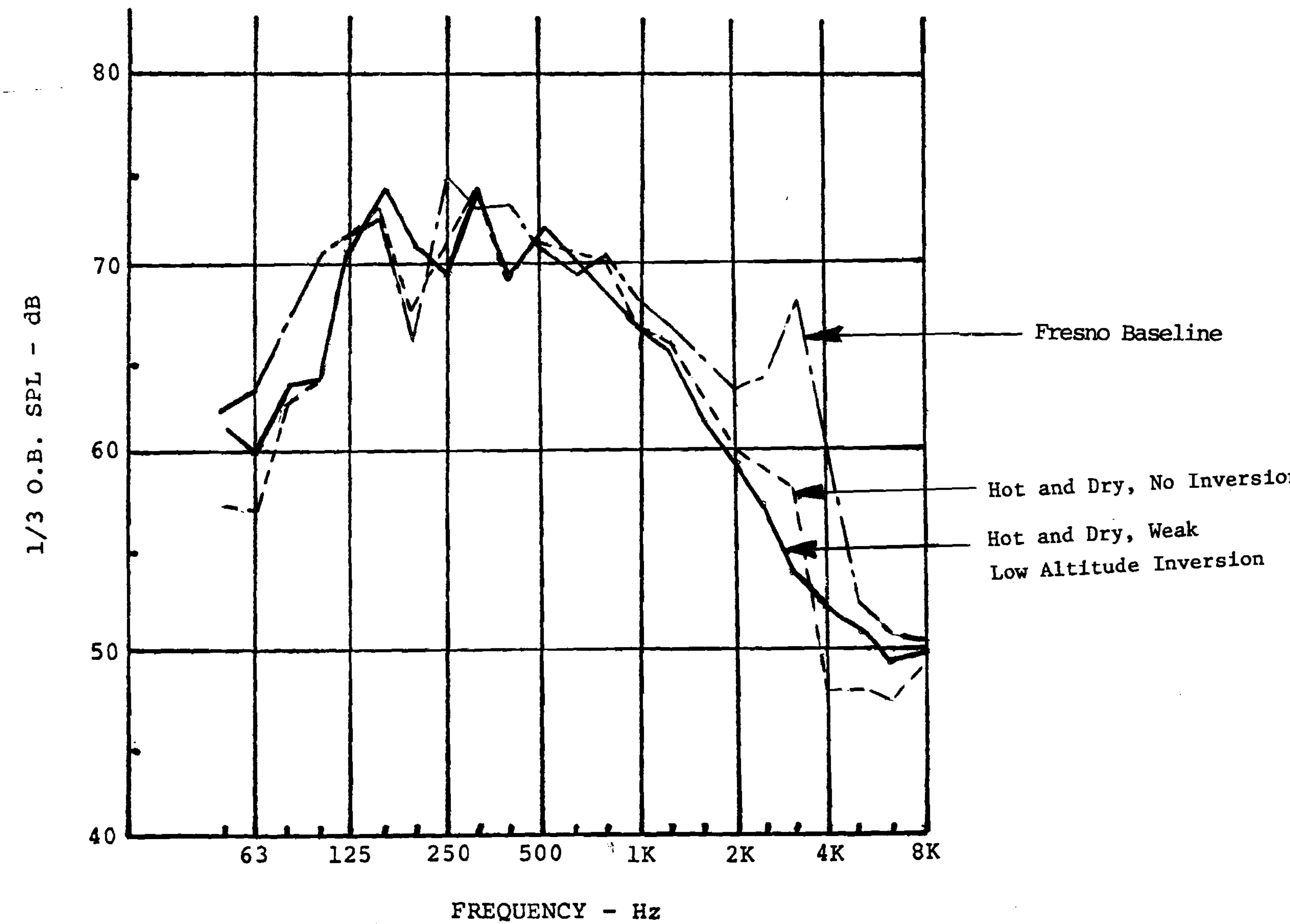


Figure 28 FAA DC-9 PNLTM SPECTRA

Baseline Weather Corrections
Altitude = 2,000 ft., Fn/δ = 6,000

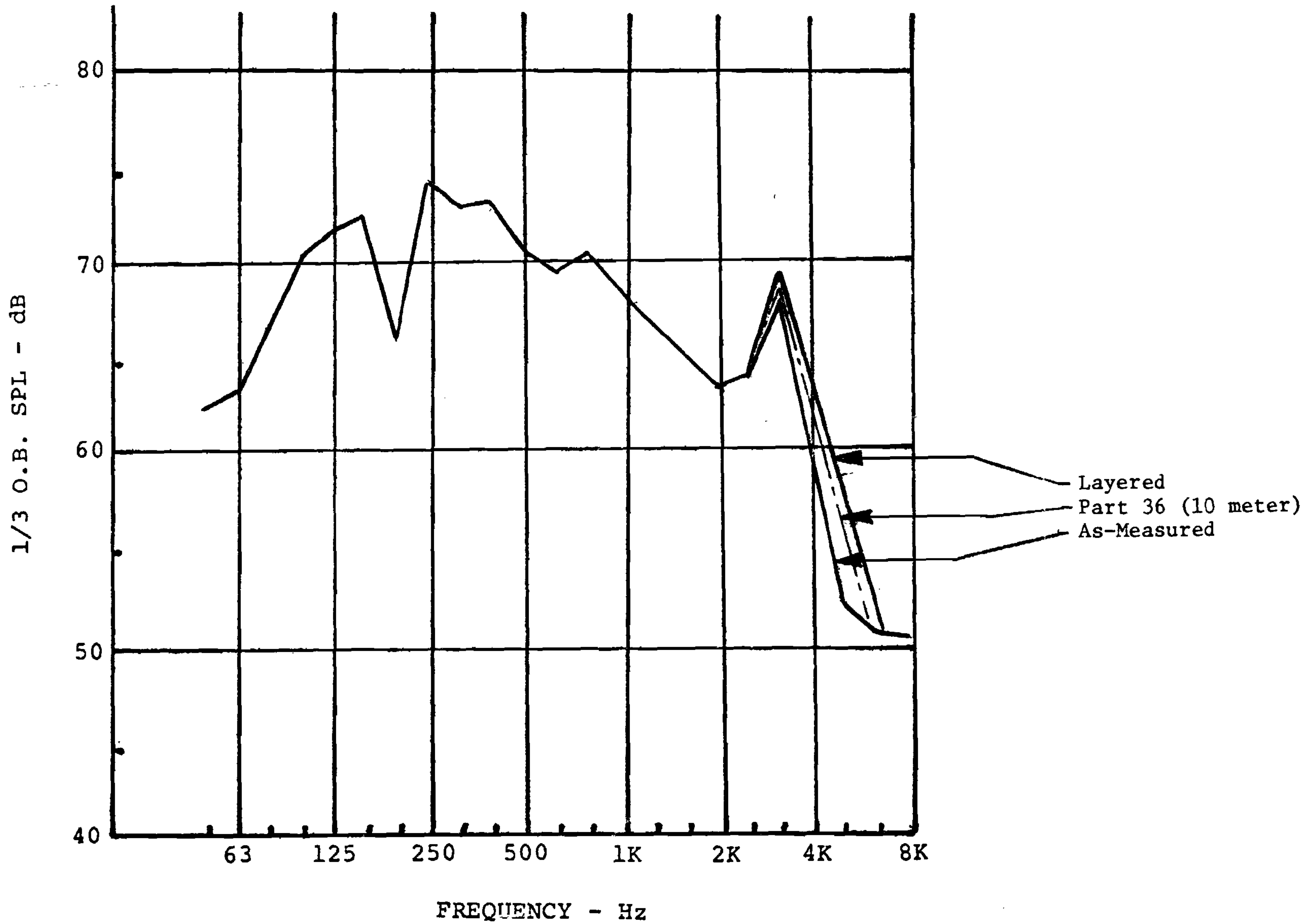


Figure 29 FAA DC-9 PNLTM SPECTRA

Weather Corrections, No Inversion, Hot and Dry

Altitude = 2,000 ft., Fn/δ = 6,000

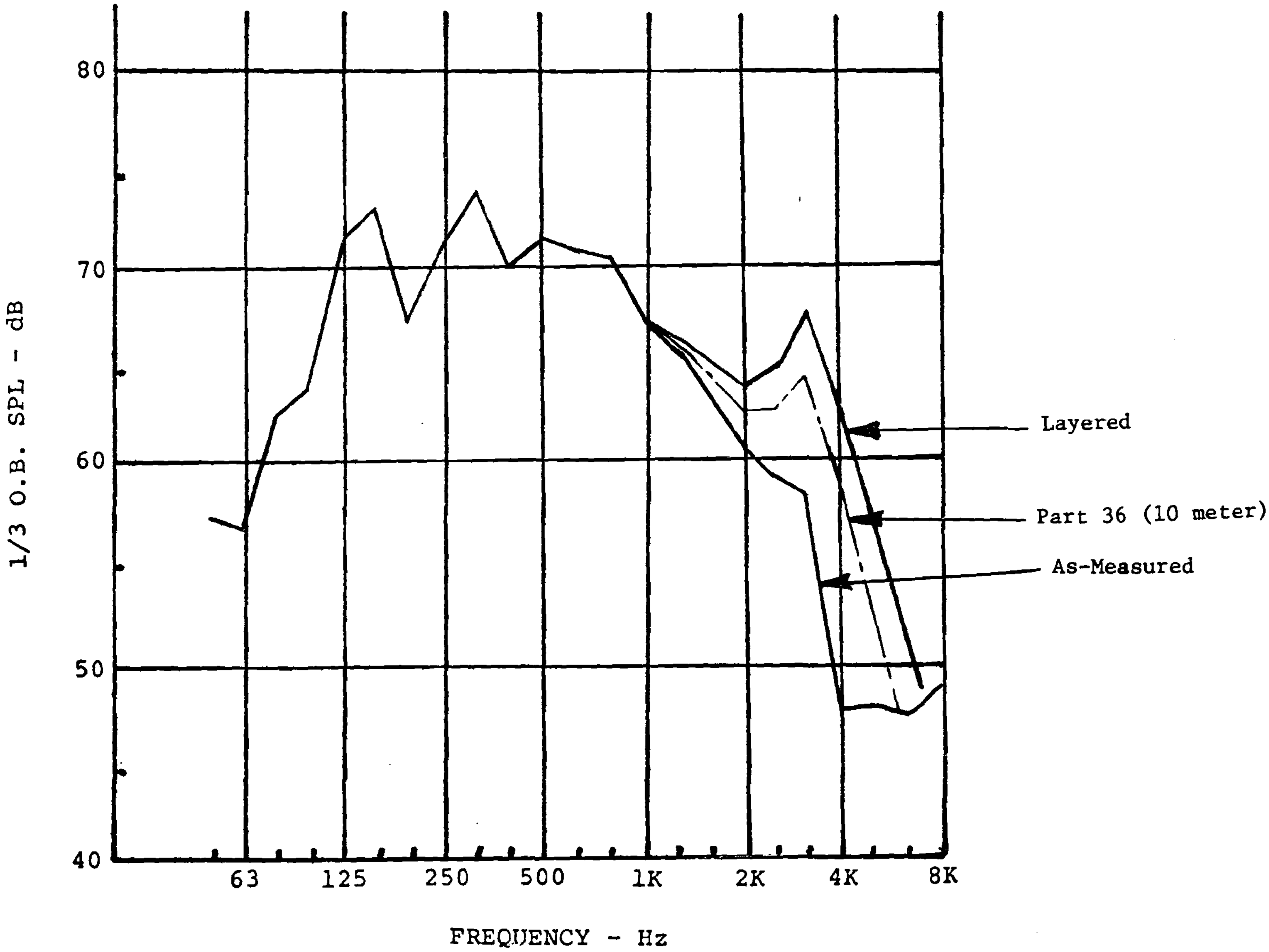
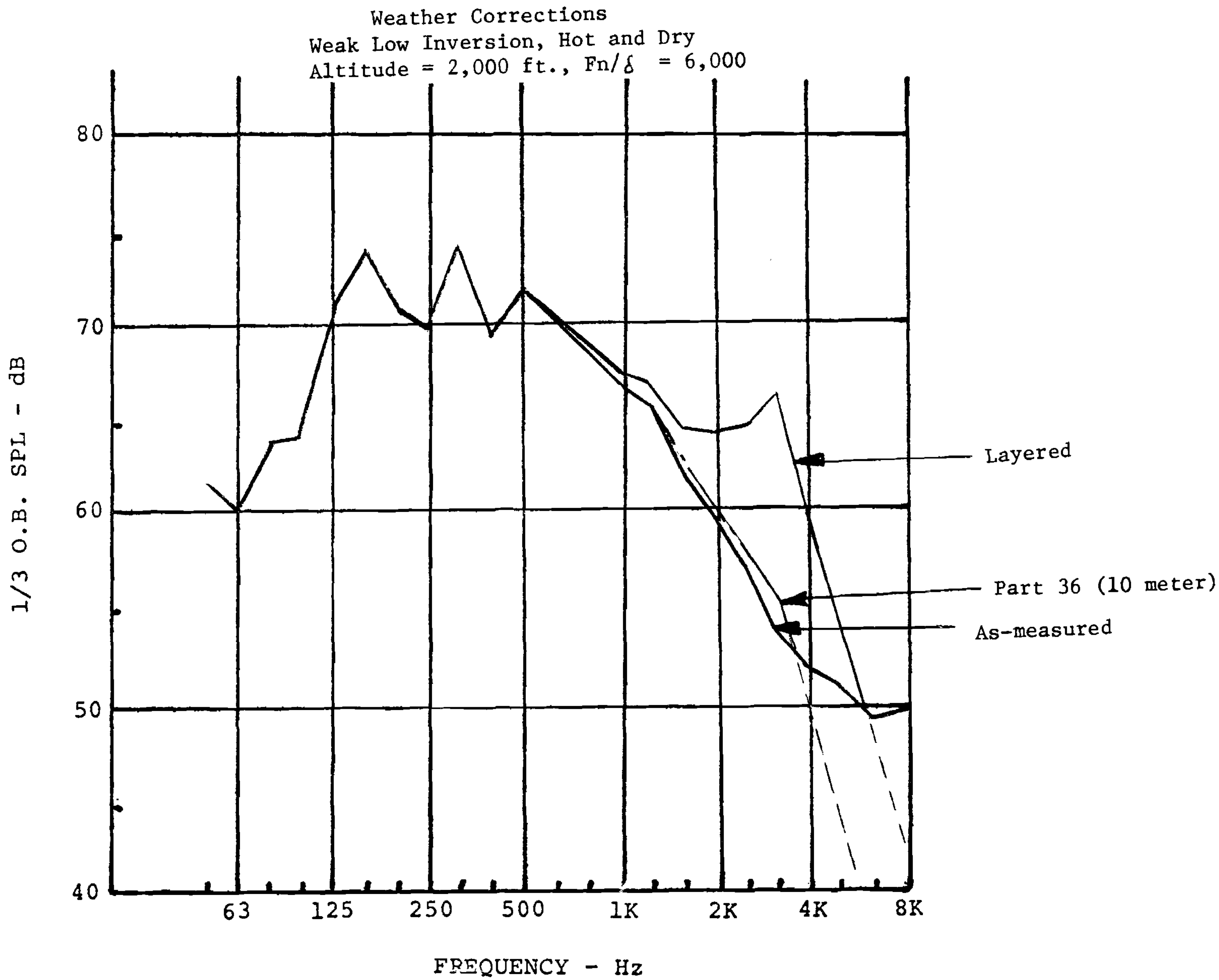


Figure 30 FAA DC-9 PNLTM SPECTRA



5.3 EFFECT OF FLYING AT OR BELOW A HIGH ALTITUDE INVERSION

Table 4 summarizes 500 and 1100 foot altitude flights flown at or under a high inversion and corresponding baseline runs. Figures 31-35 show the meteorological conditions. Negligible effect of the inversion could be found, either in the as-measured or corrected data. The test conditions were relatively cool and moist and the altitude attenuation plot, Figure 36, shows that propagation path tended to be parallel to iso-attenuation lines. This would indicate that the difference between the various methods of correcting for weather should be small. Typical as-measured spectra for a 500 foot flight altitude are shown on Figure 37. The weather corrections are small and are not shown.

Table 4

"EFFECT OF WEATHER AND WEATHER CORRECTION METHOD ON FLYOVER NOISE LEVELS" -- HIGH ALTITUDE vs. NO INVERSION

$Fn/\delta = 6,000$ V = 150 KIAS

ALT = 500'

RUN	LOCATION/WEATHER	10 METER T(°F), RH%	AS-MEAS EPNL	WEATHER CORRECTIONS: SINGLE POINT: PART 36	WEATHER CORRECTIONS: SINGLE POINT: AVG(1)	WEATHER CORRECTIONS: SINGLE POINT: AT ALTITUDE	WEATHER CORRECTIONS: LAYERED ANALYSIS	PART 36 EPNL	LAYERED EPNL	ΔEPNL LAYERED MINUS PART 36	(2) ΔATT/ALT
377	FRESNO, BASELINE	69°, 48%	105.3	.3	.3	.3	.3	105.6	105.6	0	0
276	FRESNO, FLY UNDER HIGH ALTITUDE INVERSION	55°, 50%	104.9	1.0	1.0	1.0	1.1	105.9	106.0	.1	.1
358	FRESNO, FLY UNDER HIGH ALTITUDE INVERSION	50°, 87%	105.9	-.3	-.2	-.1	-.2	105.6	105.7	.1	.2
	ALT = 1100'										
374	FRESNO, BASELINE	67°, 51%	99.2	.1	.3	.4	.2	99.3	99.4	.1	0.2
362	FRESNO, FLY AT KNEE OF HIGH INVERSION	50°, 87%	99.0	-.5	-.4	.2	-.4	98.5	98.6	.1	0.8

(1) AVERAGE OF 10 METER AND FLIGHT ALTITUDE TEMPERATURE AND RH

(2) $\frac{\Delta \text{ATTENUATION}}{\text{ALTITUDE}} = \frac{\text{dB}}{1000 \text{ Ft.}}$ @ 3150 Hz BETWEEN 10 METER AND FLIGHT ALTITUDE CONDITIONS

Figure 31

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

Fresno Baseline

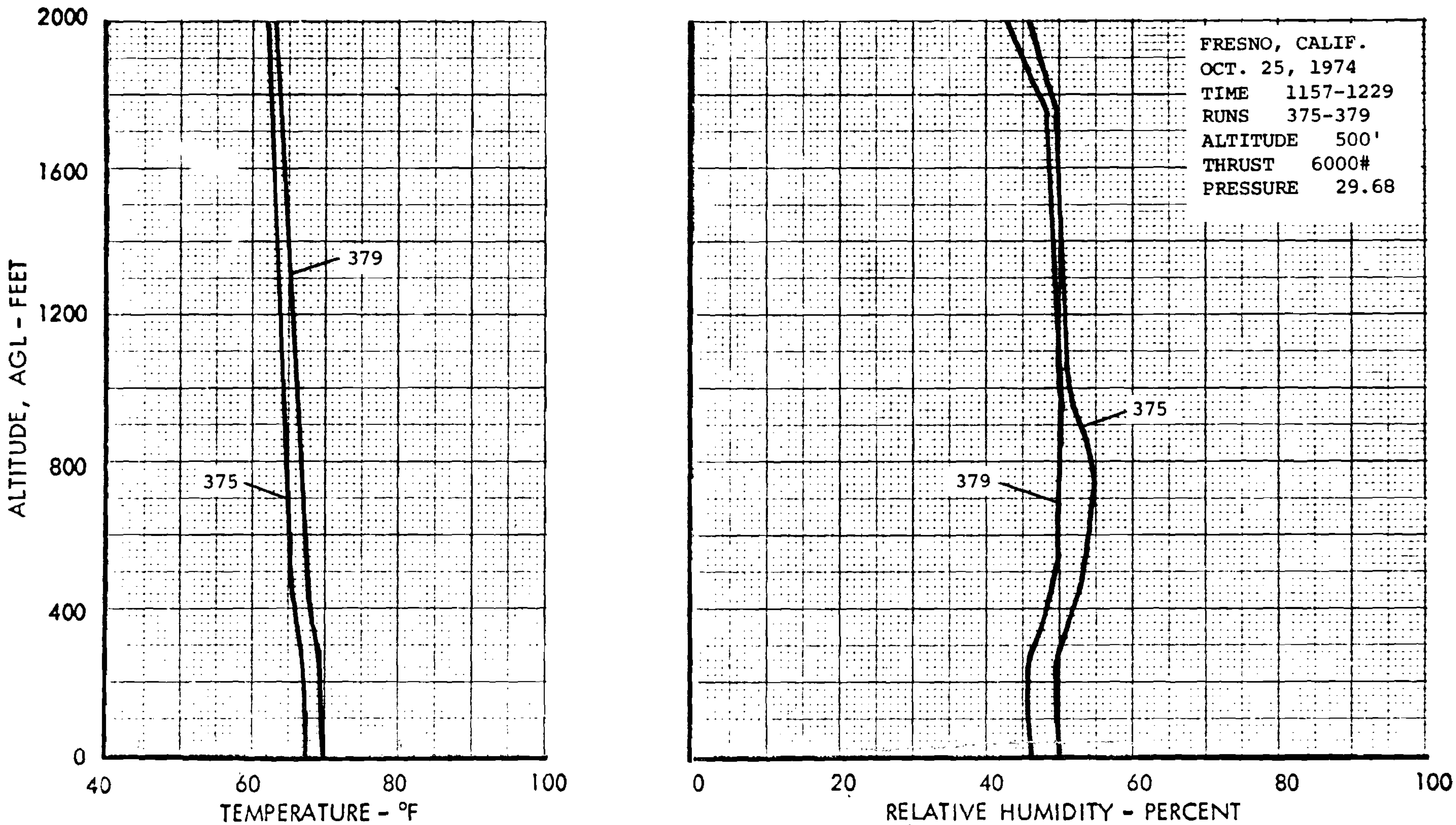


Figure 32

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

High Altitude Inversion

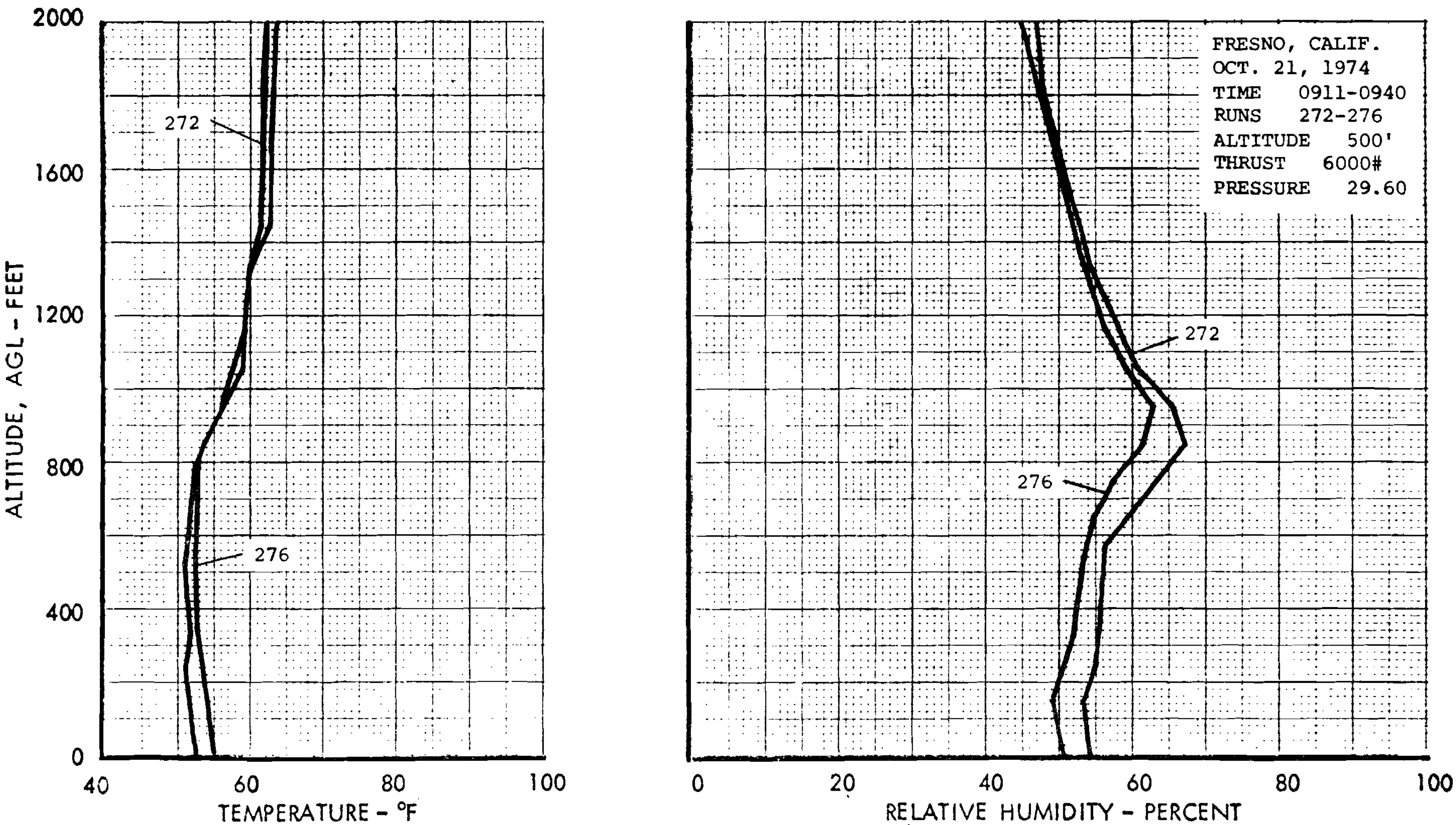


Figure 33

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

High Altitude Inversion

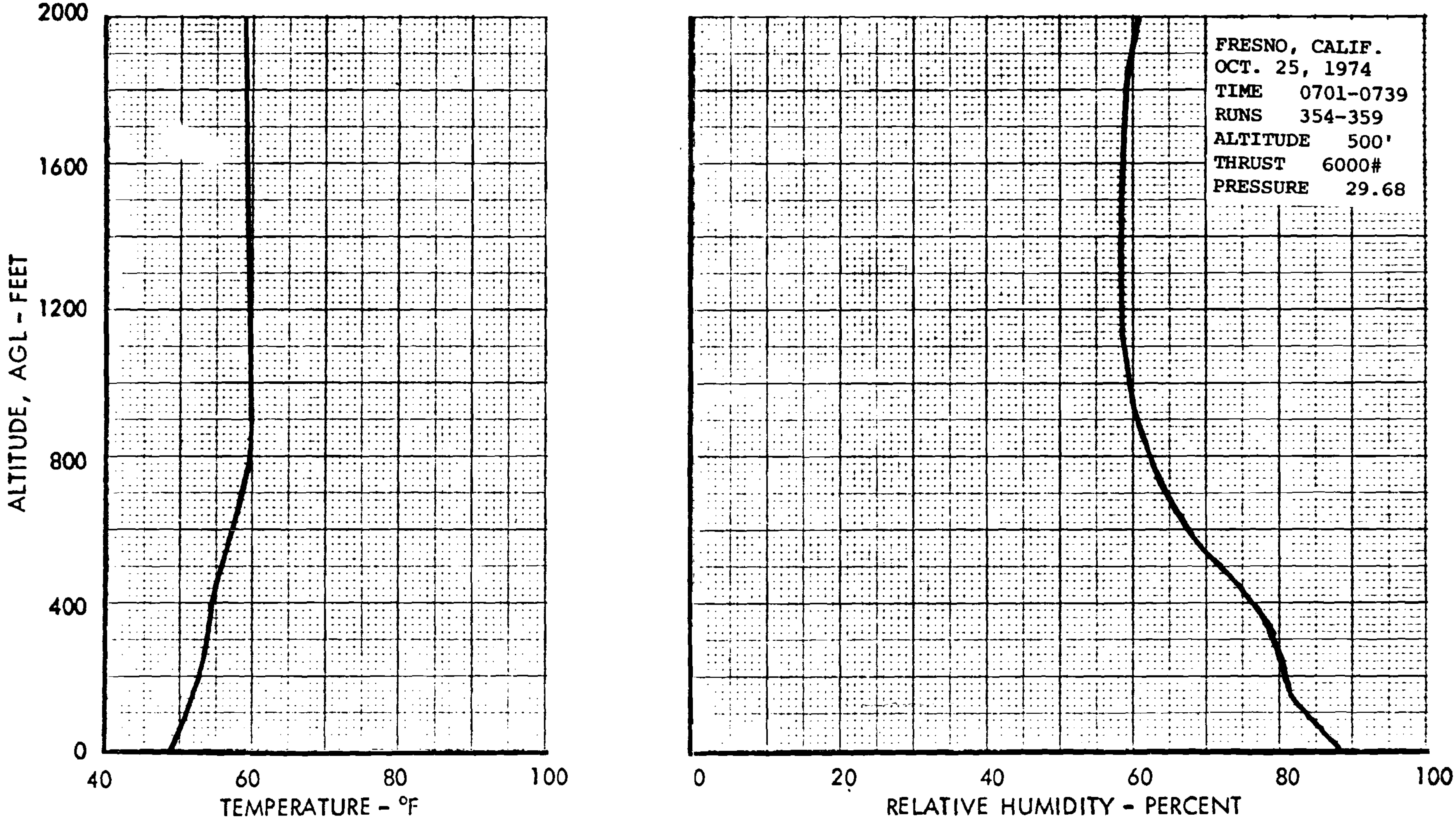


Figure 34

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

Fresno Baseline

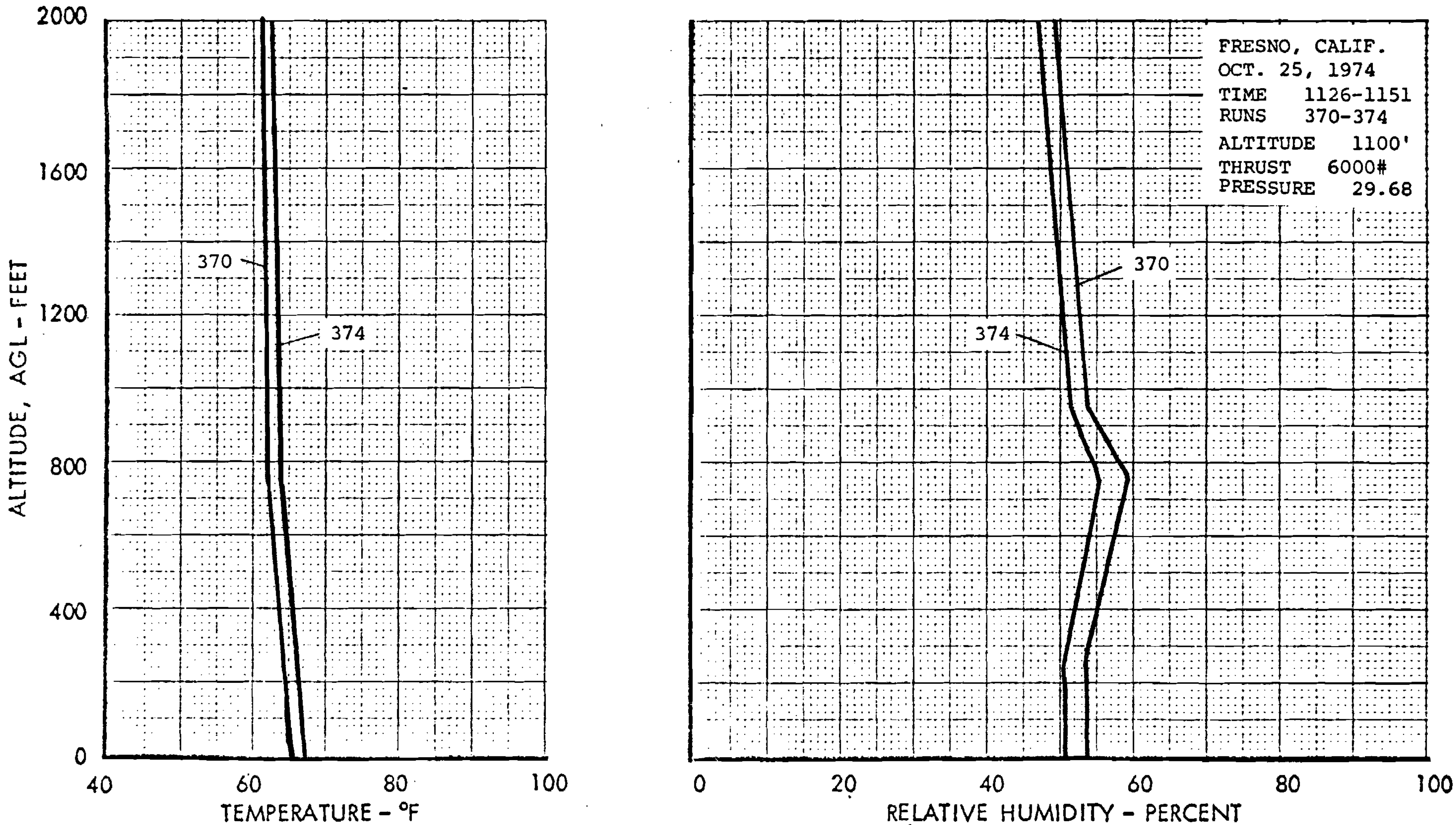
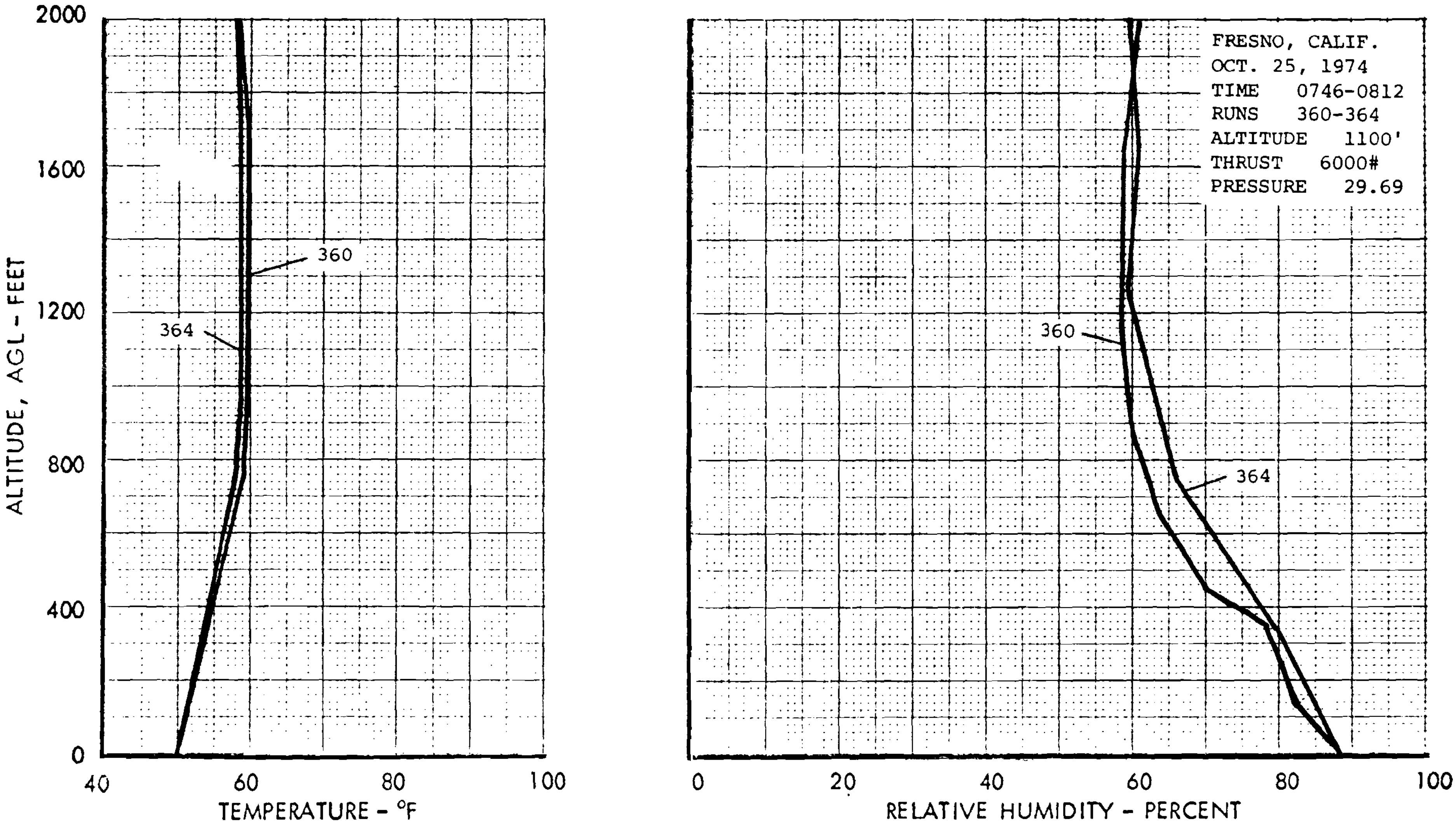


Figure 35

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

High Altitude Inversion



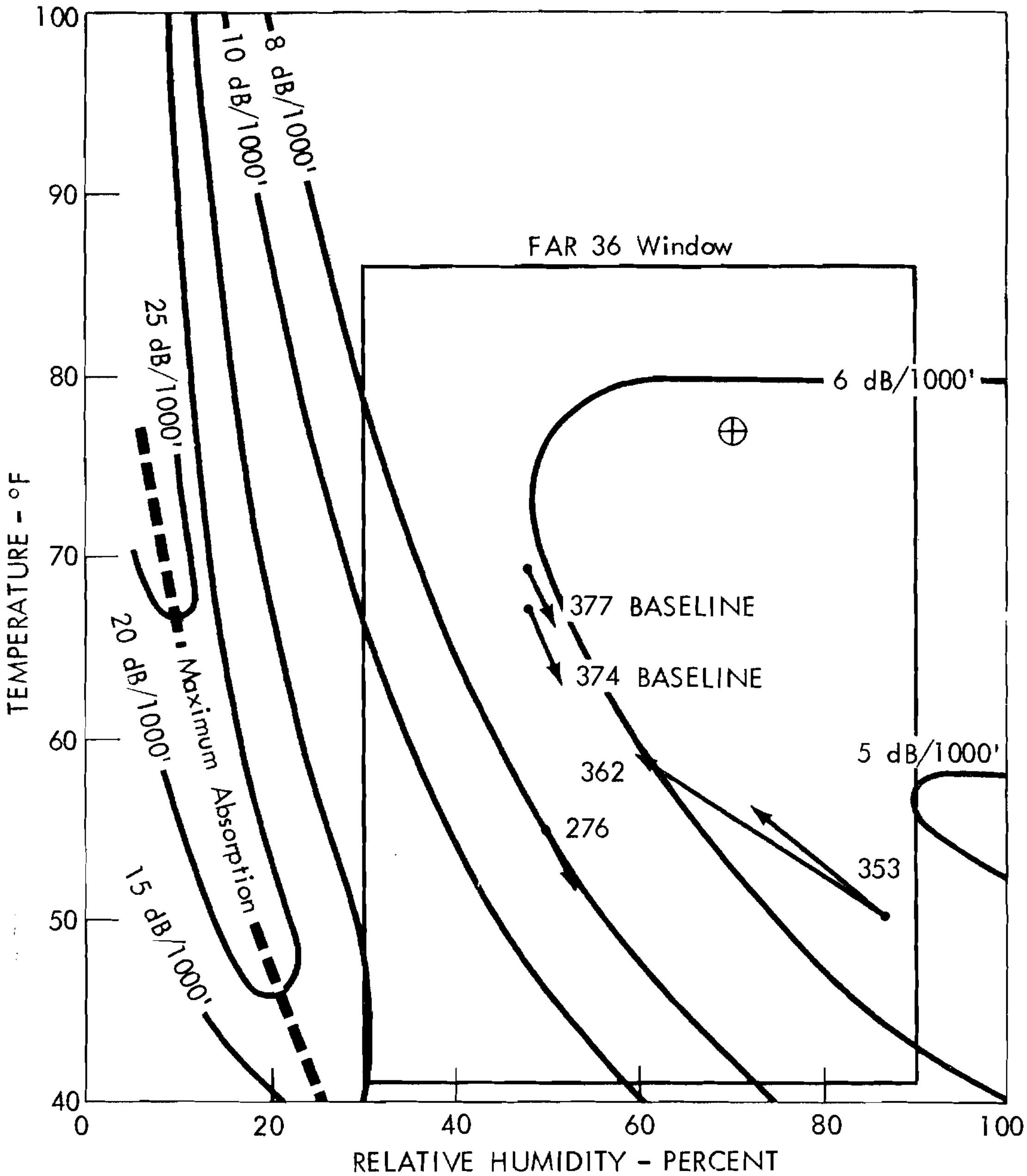
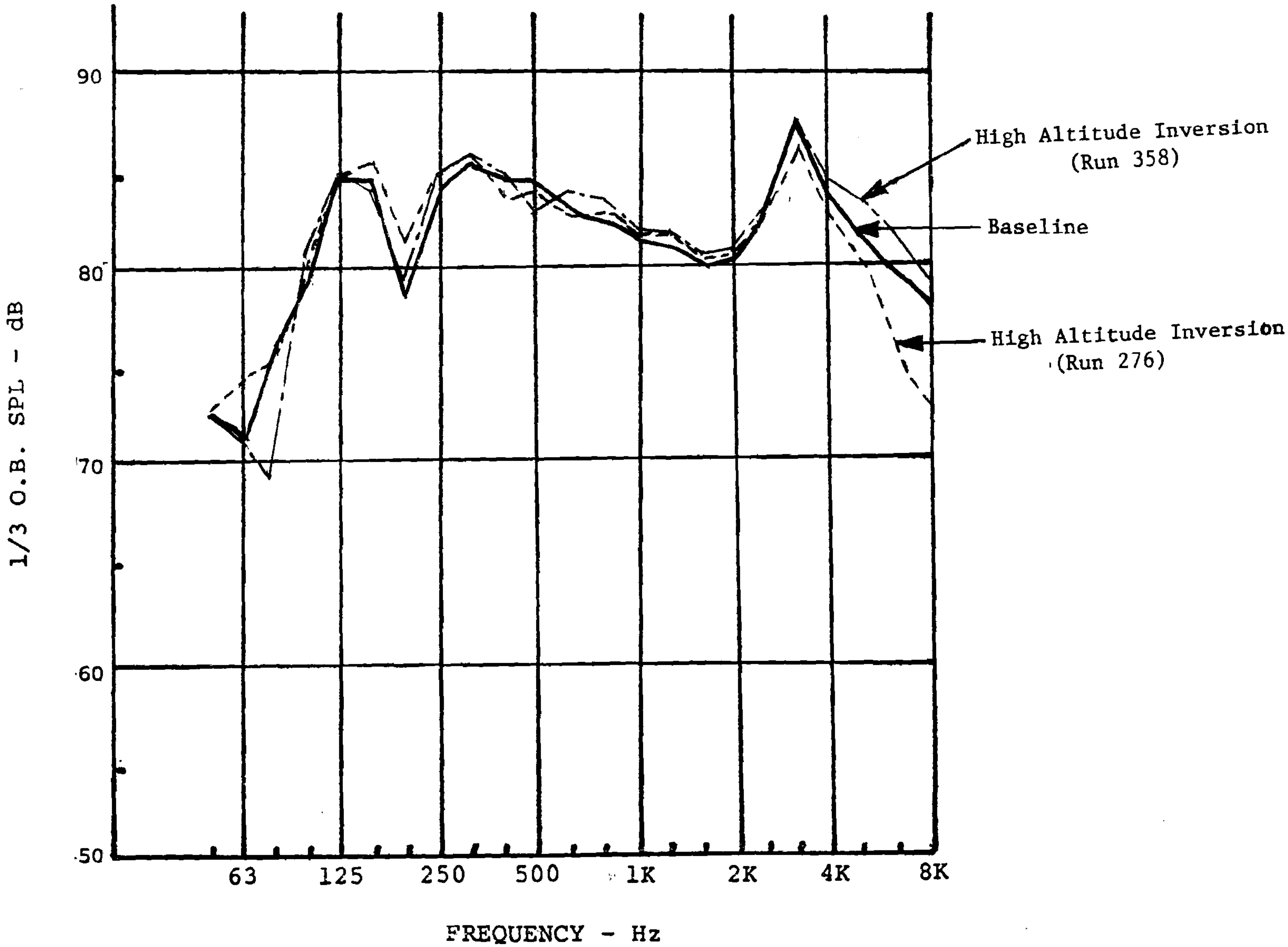


FIG. 36 ALTITUDE ATTENUATION PLOT
HIGH ALTITUDE INVERSIONS
ATMOSPHERIC ABSORPTION - f = 3150 Hz

Figure 37 FAA DC-9 PNLTM SPECTRA

As-Measured
Altitude = 500 ft. Fn/δ = 6,000



5.4 BASELINE NOISE, THRUST, ALTITUDE DATA

Figure 38 shows the baseline data taken at altitude of 500, 1100, and 2000 feet for Fn/δ = 3, 6, and 11,000 lbs. The 2000 foot, 11,000 lb. data appears higher than extrapolations of lower altitude data would warrant. A comparison of the 1100 and 2000 foot 11,000 lb. data is as follows:

As Measured:	OASPL	dBA	PNLTM	EPNL, Part 36:	PNLTM	EPNL
1100'ALT	97.6	93.2	105.8	103.6	105.5	103.3
2000'ALT	93.3	86.9	99.2	99.8	99.4	100.0
Difference ...	4.3	6.3	6.6	3.8	6.1	3.3

The inverse square law gives; $20 \log \frac{2000}{1100} = -5.2$ dB.

The 2000 foot altitude data appears to be at least 0.9 dB too high; however, the reason for the higher noise level has not been determined. The meteorological conditions for the baseline runs are shown on Figures 2, 16, 27, 30, and 39-43.

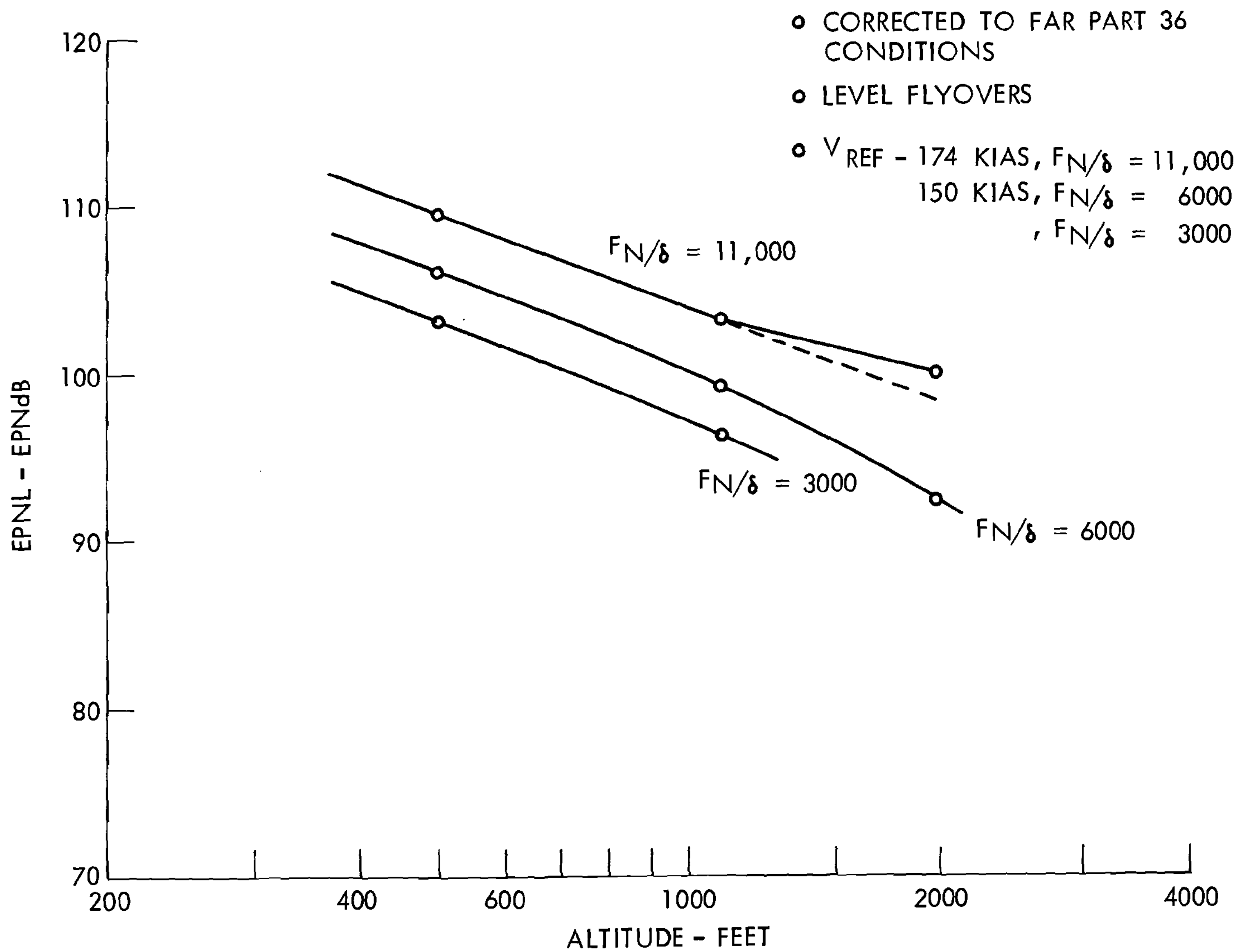


FIG. 38 FAA DC-9 FLYOVER NOISE DATA

Figure 39

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

Fresno Baseline

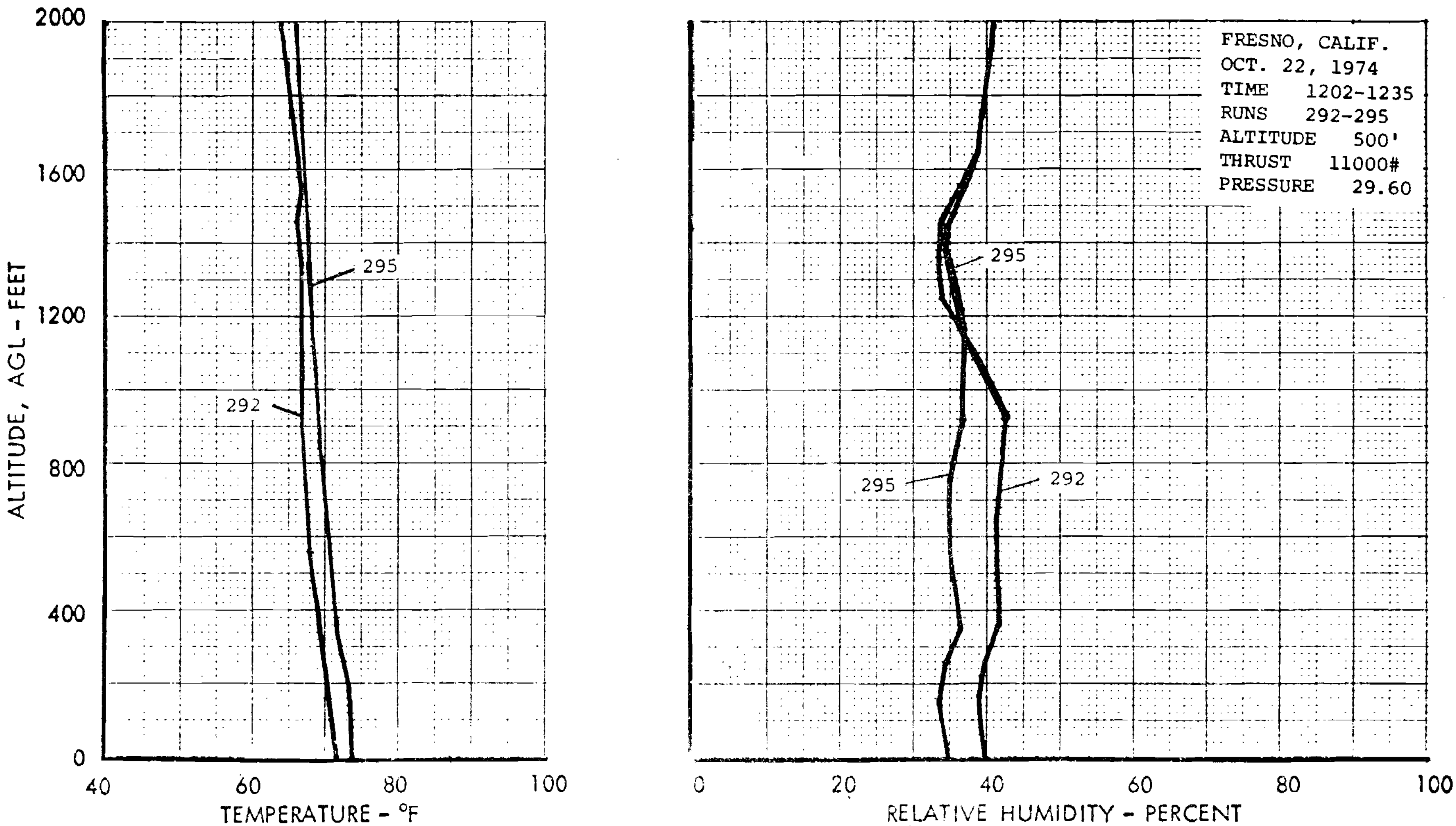


Figure 40

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

Fresno Baseline

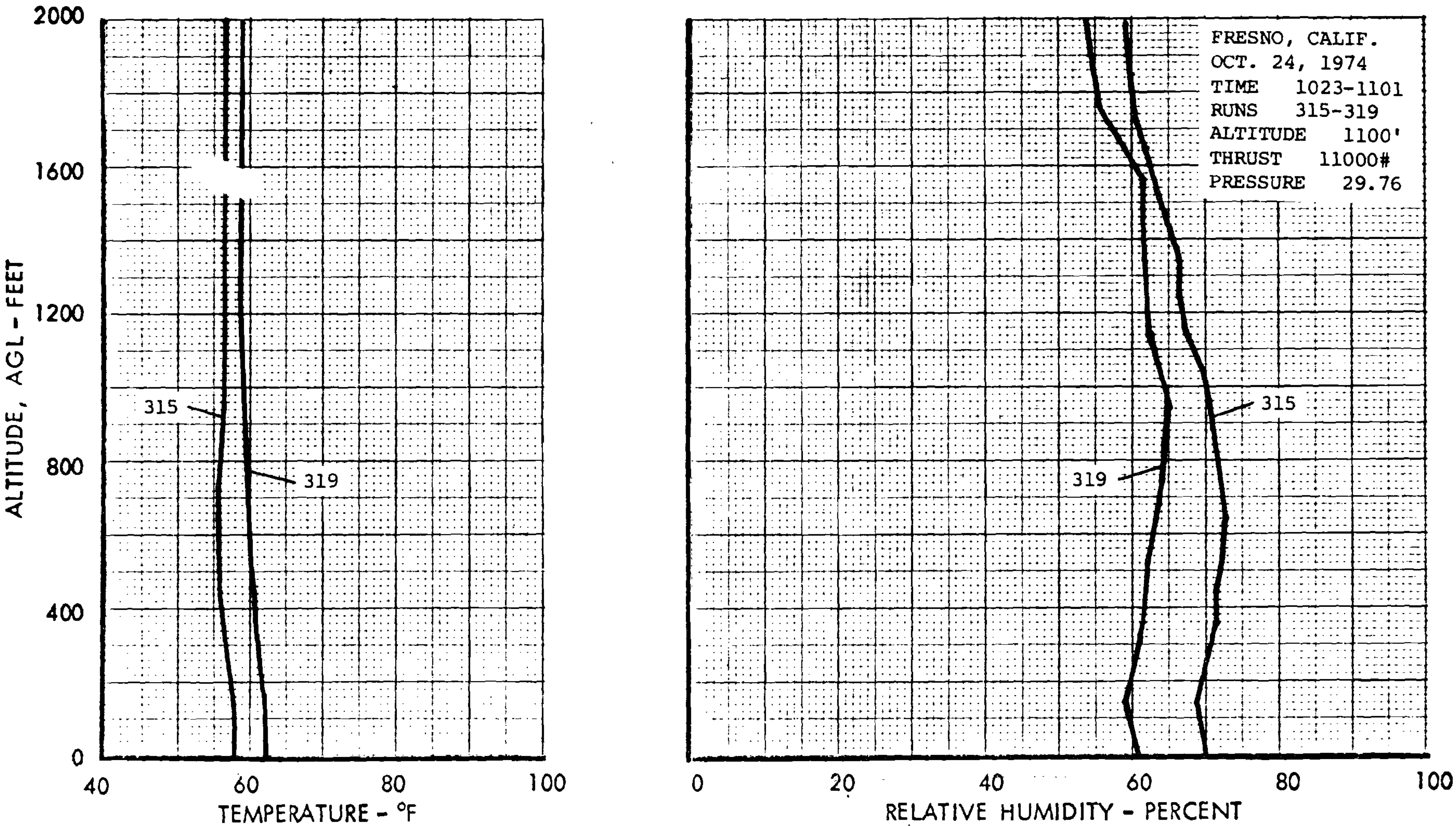


Figure 41

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

Fresno Baseline

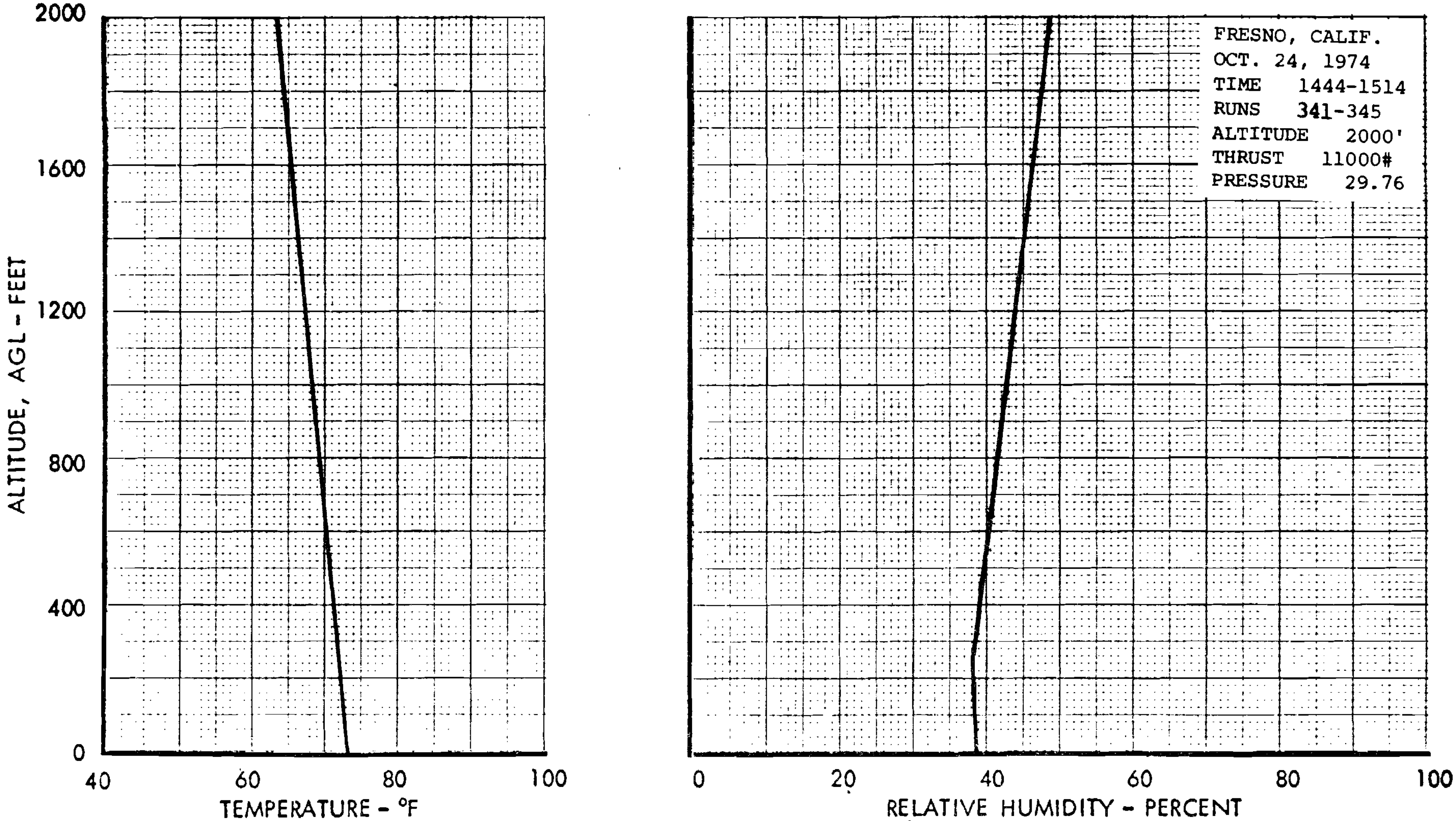


Figure 42

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

Fresno Baseline

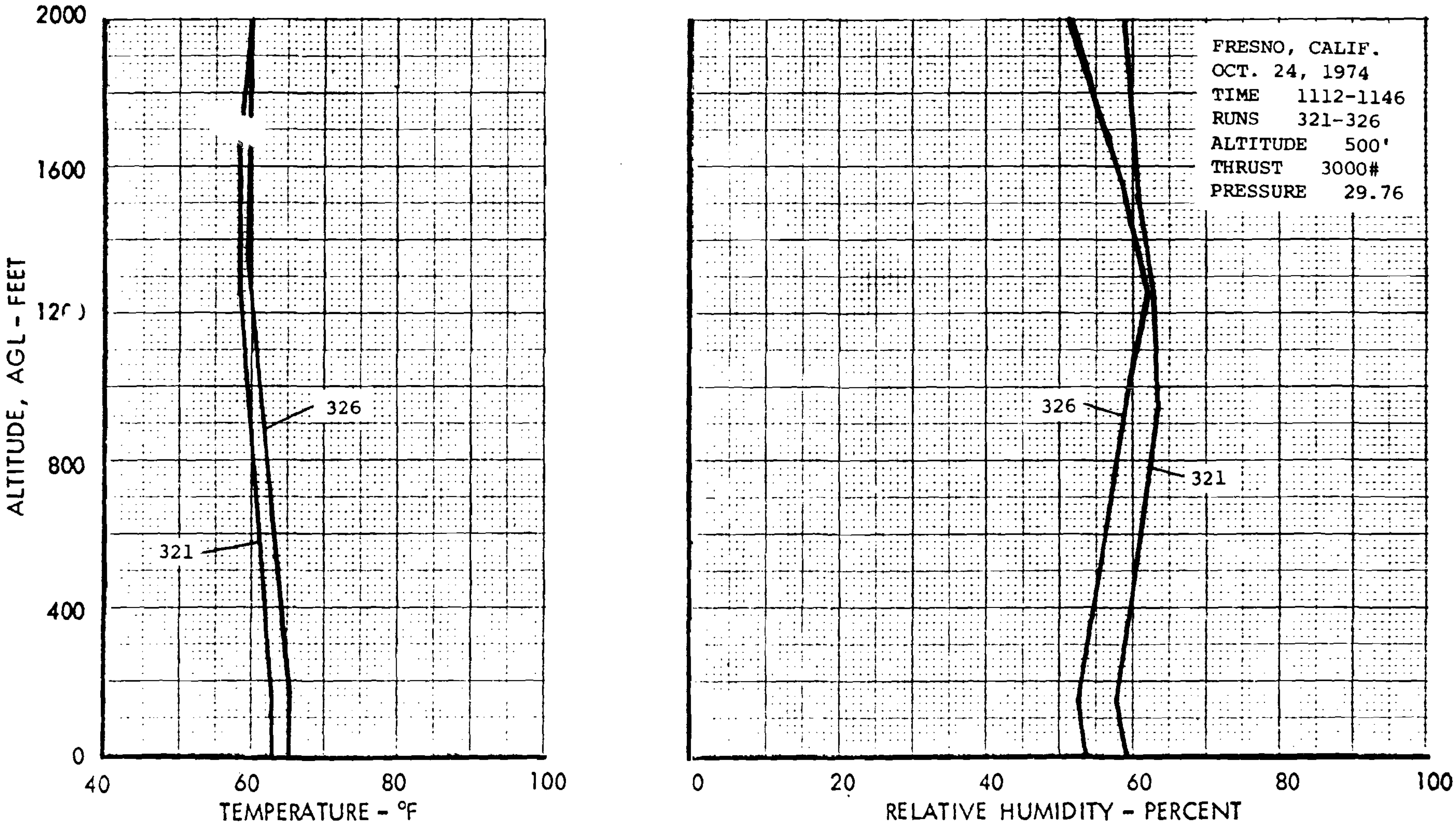
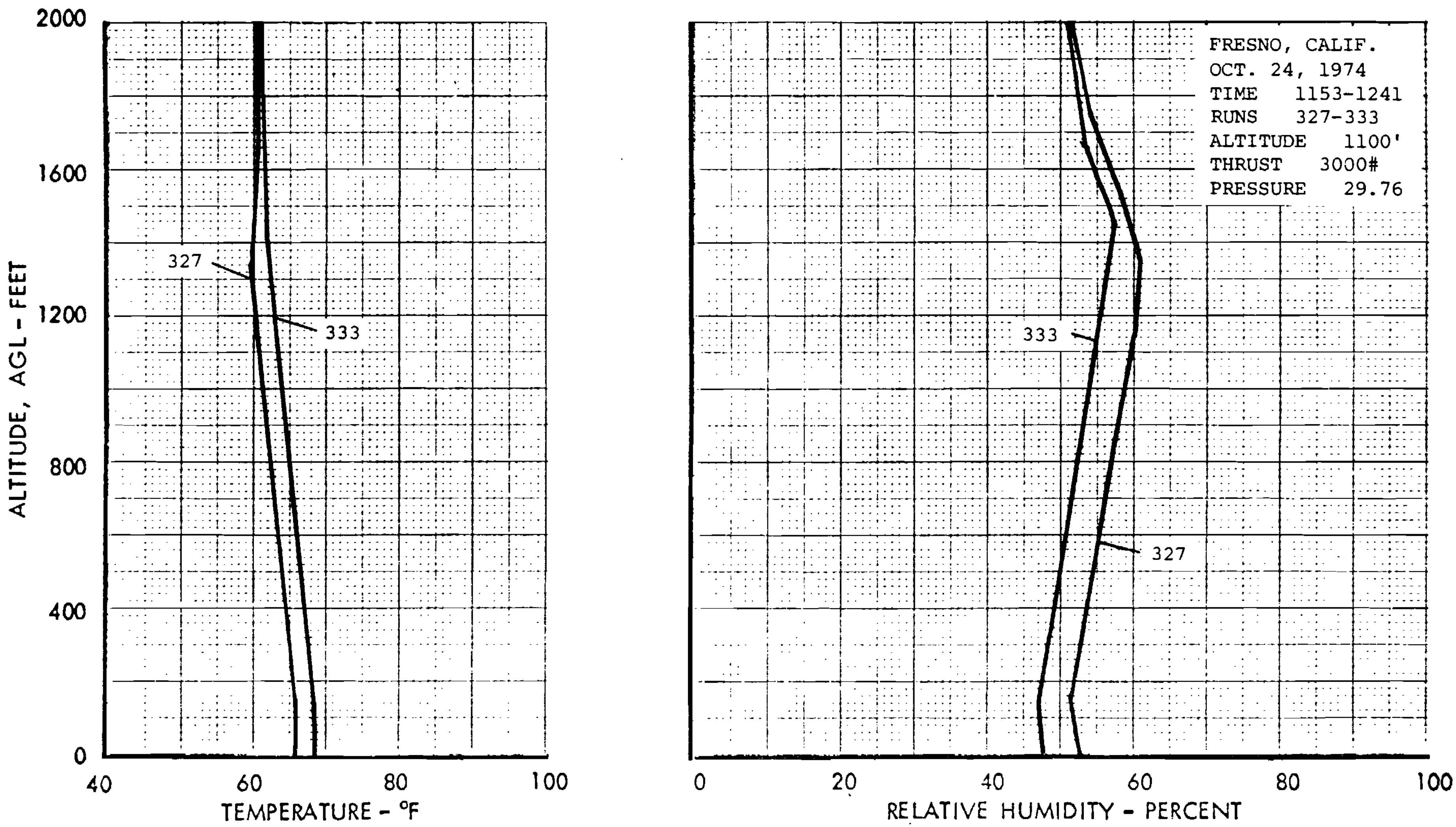


Figure 43

TEMPERATURE AND HUMIDITY PROFILES
FAA DC-9 LEVEL FLYOVER NOISE TESTS

Fresno Baseline



5.5 DATA SUMMARY

A summary of the as-measured data, the acoustic path lengths, and the weather corrections are shown on Table 5. Suspicious data is noted. The data reduction and analysis procedure were as follows:

1. Reduce the data tapes to 1/3 OB spectra and calculate EPNL.

2. Correct the data by 10 log V/V Reference. Note the altitude and thrust settings were held very close during the testing and altitude and thrust corrections were not required.

3. Calculate the propagation path length and radiation angle at the time PNLTM was generated. This calculation is based on the time difference between visual overhead and PNLTM, the altitude and velocity. The path lengths were averaged for each altitude/thrust condition to eliminate randomness in the path lengths caused by human error in noting the time of vertical overhead and the 1/2 second maximum increment resolution on timing.

4. Interpolate the meteorological data tapes to obtain the temperature and humidity profile for each DC-9 run.

5. Adjust the PNLTM spectra for noise floor interference with the high frequency SPL's by applying a roll off to the spectra, starting usually at 6,300 or 5,000 Hz.

6. Calculate the weather corrections:

   (a) Part 36 (10 meter) -- adjust the PNLTM spectra by $SPL_{corr} = SPL_i + (\alpha_i - \alpha_{io}) Pm$,

   SPL_i = each measured 1/3 OB level

   SPL_{corr} = corrected SPL

   α_i = atmospheric absorption coefficient based on 10 meter data -- per SAE ARP-866

   α_{io} = reference values of absorption per SAE-ARP-866 for 77°F and 70 percent RH

   Pm = acoustic path length

   (b) Average: same as 10 meter correction except average of 10 meter and flight altitude temperature and relative humidity are used.

(c) At altitude: same as 10 meter correction except α_i based on T and RH at the flight altitude.

(d) Layered: The atmosphere was divided into 100 feet altitude increments and the temperature and relative humidity determined for each increment, then;

$$(SPL_i)\ corr = SPL_i + \sum_{j=0}^{j = \text{flt. altitude}} (\alpha_i - \alpha_{io}) \left(\frac{Pm}{ALT}\right)_j$$

where the $\sum$ arithmetically sums the absorption in each altitude increment.

Table 5 groups the data by altitude, thrust and similar runs for a given meteorological condition. The meteorological condition is given before each group of runs. The table columns give the run number, the as-measured peak OASPL, dBA, and tone corrected Perceived Noise Level, PNLTM. The as-measured tone correction magnitude and frequency are also given along with the duration correction and as-measured Effective Perceived Noise Level, EPNL. The acoustic path length data includes the time difference between visual overhead and PNLTM, the corresponding propagation angle relative to the flight path direction at the time PNLTM was generated and the averaged propagation angle and path length.

The weather correction magnitude is given for two single point corrections, the Part 36 or 10 meter correction and the correction based on the average temperature and humidity between 10 meters and the flight altitude, and the layered correction. Weather corrected EPNL is obtained by adding the weather correction to the as-measured EPNL. The EPNL's shown are not velocity corrected. The velocity correction is given by footnotes when it is 0.2 EPNdB or larger. Questionable data is noted by parenthesis. This data had either anomalous spikes (probably caused by outside interference) or inconsistent noise floors on the data which gave varying tone and/or weather corrections.

TABLE 5 - FAA - DC-9 FLYOVER NOISE DATA SUMMARY

Altitude = 1,100, Fn/δ = 6,000, V = 150 KIAS

As Measured Data								ACOUSTIC PATH LENGTH				WEATHER CORRECTION		
RUN	Peak OASPL	Peak dBA	PNLTM	Tone Corr.	Tone Freq.	DURATION	EPNL	TPNLTM -TOH(Sec)	PNLTM Rad.Angle	Avg. Angle	Avg.Path Length	Part 36 (10meter)	Avg. of 10m & A/C Alt.	LAYERED
FRESNO BASELINE														
371	89.7	86.5	101.3	.9	3150	-2.5	98.8	4.0 sec	125°	118°	1246'	---	---	---
372	88.9	85.5	101.6	1.7		-2.6	99.0	2.5 sec	109°			.2	---	---
373	88.5	85.7	100.7	.9		-1.9	98.7	3.5 sec	120°			.2	---	---
374	89.7	86.5	101.7	1.3		-2.6	99.2	4.0 sec	125°			.1	.3	.2
YUMA BAS[illegible]														
414	88.4	84.6	99.3	1.4	3150	-2.1	97.3	3. sec	114°	118°	1246'	(.7)?	(.8)	(.8)?
415	89.7	86.4	101.2	1.4		-2.6	98.6	3. sec	114°			1.1	1.4	1.3
416	88.2	84.6	100.0	1.8		-2.8	97.3	2.5 sec	109°			1.3	1.6	1.6
417	88.1	84.9	99.8	1.6		-2.5	97.5	3.5 sec	121°			1.3	1.4	1.5
418	89.4	86.0	100.0	1.8		-2.3	97.6	2.5 sec	109°			1.3	1.7	1.7
FRESNO - HOT, DRY - NO INVERSION														
118	88.8	84.5	99.0	1.3	3150	-3.1	95.9	3.0 sec	117°	118°	1246'	2.5	2.9	2.8
119	88.7	85.1	98.7	1.1		-2.5	96.2	4.5 sec	130°			2.3	2.5	2.4
121	87.7	83.7	98.5	1.8		-2.7	95.8	2.5 sec	120°			3.0	3.4	3.4
122	88.3	84.6	98.6	1.3		-3.1	95.5	3.0 sec	115°			2.6	2.8	3.0
123	87.0	83.2	97.1	1.3		-1.9	95.2	3.0 sec	114°			3.0	3.0	3.5
FRESNO STRONG LOW INVERSION, VERY HOT & DRY ABOVE														
171	88.8	85.0	99.7	1.6	3150	-2.5	97.2	4.0 sec	126°	118°	1246'	(1.2)	(3.1)	(4.7)
174	87.9	83.7	96.7	1.1		-1.9	94.8	4.0 sec	126°			.9	2.2	4.6
175	89.3	84.0	98.0	1.7		-2.2	95.7	3.5 sec	121°			.5	2.0	4.3
176	88.4	84.5	99.1	1.8		-3.3	95.8	3.0 sec	115°			.8	1.9	4.5
177	88.4	84.0	98.0	1.5		-2.9	95.1	3.0 sec	115°			.6	2.3	4.5
178	88.3	84.4	97.9	1.1		-2.2	95.7	4.5 sec	129°			.6	1.9	4.4

( ) = Questionable Data

FAA - DC-9 FLYOVER NOISE DATA SUMMARY

Altitude = 1,100', Fn/δ = 6,000, V = 150 KIAS

AS MEASURED DATA								ACOUSTIC PATH LENGTH				WEATHER CORRECTION		
RUN	Peak OASPL	Peak dBA	PNLTM	Tone Corr.	Tone Freq.	DURATION	EPNL	TPNLTM -TOH(Sec)	PNLTM Rad.Angle	Avg. Angle	Avg. Path Length	Part 36 (10m)	Avg. of 10m & A/C Alt.	LAYERED
FRESNO-STRONG LOW INVERSION, FAR P-36 WINDOW ABOVE AND BELOW														
211	88.8	84.7	98.9	1.4	3150	-2.1	96.8	2.5 sec	109°	118°	1246'	.5	.9	1.9
212	88.5	84.6	99.7	1.6	↓	-2.8	96.9	2.5	109°			.3	.9	1.9
213	88.7	84.9	99.3	1.0	↓	-2.0	97.3	3.5	121°			.2	.7	1.8
214	88.5	84.3	98.9	1.4	↓	-2.3	96.6	2.5	110°			.1	.7	1.8
215	88.6	85.0	99.2	1.5	↓	-2.2	97.0	2.5	110°			.3	.6	1.5
FRESNO-WEAK LOW INVERSION, HOT & DRY														
237	88.6	84.7	99.7	1.7	3150	-2.4	97.2	2.5 sec	110°	118°	1246'	1.3	2.5	3.8
238	88.2	84.3	97.8	1.8	4000	-1.5	96.3	1.5	97°			1.3	2.5	4.2
239	88.0	84.0	97.7	1.3	3150	-1.6	96.1	3.0	115°			.9	2.1	3.3
240	88.2	84.4	97.8	1.1	↓	-1.9	95.9	4.5	130°			.9	1.9	3.4
241	88.5	84.4	99.1	1.8	↓	-2.5	96.6	3.0	115°			.8	1.8	3.5
FRESNO-FLY AT KNEE OF HIGH INVERSION, COOL AND MOIST														
360	89.2	86.0	102.1	1.9	3150	-2.8	99.3	2.5 sec	109°	118°	1246'	-.6	-.3	-.3
361	89.2	85.9	101.2	1.5	↓	-2.4	98.8	3.0	115°			-.4	-.3	-.1
362	89.1	85.6	101.5	1.5	↓	-2.5	99.0	3.0	115°			-.5	-.4	-.4
363	89.0	85.9	101.3	1.3	↓	-2.7	98.6	3.5	121°			-.6	-.2	-.2
364	89.0	85.6	100.7	1.1	↓	-2.2	98.4	3.5	121°			-.2	-.2	-.2
YUMA-WEAK LOW INVERSION - LIGHT WINDS														
385	88.8	85.5	100.4	1.2	3150	-2.2	98.2	2.5	109°	118°	1246'	(-.3)	(.1)	(.9)
386	89.8	85.9	101.3	1.7	↓	-3.0	98.3	(7.5)?	146°			-.1	.5	1.2
388	88.7	85.3	100.3	1.6	↓	-2.4	97.9	5.0	132°			0	.5	1.1

FAA - DC-9 FLYOVER NOISE DATA SUMMARY

Altitude = 1,100', Fn/δ = 6,000, V = 150 KIAS

RUN	Peak OASPL	Peak dBA	PNLTM	Tone Corr.	Tone Freq.	DURATION	EPNL	TPNLTM -TOH(sec)	PNLTM Rad.Angle	Avg. Angle	Avg.Path Length	Part 36 (10m)	Avg. of 10m & A/C Alt.	LAYERED
AS MEASURED DATA								ACOUSTIC PATH LENGTH				WEATHER CORRECTION		
YUMA - LOW WEAK UNVERSION - STRONG WIND SHEAR														
435	(89.7)	(88.3)	(103.3)	(2.8)	(1250)	-3.6	--	3.0 sec	116°	118°	1246'	(.3)	(.5)	(.7)
436	89.4	8[illegible]	100.4	1.3	3150	-2.2	99.1	4.0	125°			.2	.6	.8
437	89.6	85.8	101.6	1.6	↓	-3.0	98.5	3.0	115°			0	.4	.6
438	89.8	86.5	101.8	1.3	↓	-2.4	99.4	4.0	125°			.2	.6	.9
439	88.8	85.9	101.4	1.8	↓	-2.8	98.7	3.0	115°			0	.4	.6
FRESNO - DC-9 FLY OVER DC-8 TURBULENCE								HOT/DRY - NO INVERSION						
202	88.4	84.2	98.4	1.1	3150	-2.6	95.8	3.0 sec	115°	118°	1246'	2.7	--	--
205	--	--	98.8	--	--	--	96.5	--	--			3.3		

Note: Run 205 is without DC-8 turbulence

FAA - DC-9 FLYOVER NOISE DATA SUMMARY

Altitude = 2,000', Fn/δ = 6,000, V = 150 KIAS

AS MEASURED DATA								ACOUSTIC PATH LENGTH				WEATHER CORRECTION		
RUN	Peak OASPL	Peak dBA	PNLTM	Tone Corr.	Tone Freq.	DURATION	EPNL	TPNLTM -TOH(sec)	PNLTM Rad. Angle	Avg. Angle	Avg. Path Length	Part 36 (10m)	Avg. of 10m & A/C Alt.	LAYERED
FRESNO BASELINE														
365	84.0	79.4	93.6	1.3	3150	- .4	93.2	5.5 sec	115°	118°	2265'	-.5	--	--
366	83.0	78.4	93.8	1.9	↓	-1.7	92.1	2.0	(90°)			-.4	--	--
367	84.0	79.8	94.6	1.7	↓	-2.1	92.5	5.0	112°			-.2	--	--
368	83.9	78.9	92.9	1.7	↓	.4	93.4	4.5	109°			-.2	.3	.3
369	84.0	79.7	93.6	2.0	↓	- .9	92.7	3.5	102°			-.3	--	--
FRESNO - HOT & DRY, NO INVERSION														
112	82.2	78.4	91.8	1.6	3150	-2.0	89.7*	6.0 sec	121°	118°	2265'	2.6	5.9	5.5
113	82.5	76.9	89.3	.8	↓	.3	89.6*	6.5	124°			2.4	5.3	5.2
114	82.2	77.2	89.7	1.8	↓	.4	90.1*	4.0	106°			3.1	5.5	5.4
115	83.2	78.1	90.3	1.3	↓	- .9	89.4*	7.5	127°			1.2	3.5	3.2
116	82.8	77.0	89.7	1.8	↓	- .5	89.2*	5.5	117°			2.6	5.2	4.7
117	83.1	77.1	89.4	1.7	↓	- .1	89.4*	5.0	113°			2.1	4.5	3.9
FRESNO-STRONG LOW INVERSION, MORE TEMPERATE														
216	83.3	77.8	90.7	1.3	3150	- .3	90.4	7.0 sec	124°	118°	2265'	-.5	.1	1.5
217	82.9	77.2	89.6	1.6	↓	(2.2)	(91.8)	3.5	102°			O	1.8	3.7
218	82.5	77.2	89.8	1.3	↓	.5	90.3	7.0	124°			-.4	.2	1.3
219	82.8	77.6	91.0	2.0	↓	-.3	90.7	4.0	106°			-.2	1.4	3.3
220	82.6	76.8	89.4	1.5	↓	.8	90.2	5.5	116°			-.1	1.7	3.6
FRESNO - SMALL LOW INVERSION, HOT & DRY														
242	82.1	76.9	88.6	.7	315	.2	88.8	6.0 sec	123°	118°	2265'	.2	1.3	4.2
243	82.2	77.2	89.3	.9	↓	.2	89.5	7.5	125°			.1	.4	2.8
244	81.9	76.4	88.4	.7	↓	.9	89.4	7.5	127°			.2	1.0	3.7
245	81.9	76.8	88.8	.8	↓	.5	89.3	8.0	129°			.2	.9	3.2
246	82.1	76.9	88.8	.8	↓	.7	89.4	8.0	129°			(.7) ?	(3.8)	--

* add 0.2 for V = 150 KIAS

FAA - DC-9 FLYOVER NOISE DATA SUMMARY

Altitude = 2,000', Fn/δ = 6,000, V = 150 KIAS

	AS MEASURED DATA							ACOUSTIC PATH LENGTH				WEATHER CORRECTION		
RUN	Peak OASPL	Peak dBA	PNLTM	Tone Corr.	Tone Feq.	DURATION	EPNL	TPNLTM -TOH(sec)	PNLTM Rad.Angle	Avg. Angle	Avg. Path Length	Part 36 (10m)	Avg. of 10m & A/C Alt.	LAYERED
YUMA - LOW WEAK INVERSION, LIGHT WINDS														
389	84.0	79.0	92.5	1.6	3150	.2	92.6	4.5 sec	109°	118°	2265'	-.5	.5	1.8
390	82.7	76.6	90.9	.8	160	1.1	92.0	8.0	128°			0	(1.4)*	(3.2)
391	82.5	78.	.8	.8	315	1.7	92.4	6.5	120°			-.1	(1.2)	(3.1)
392	83.0	78.6	91.1	.8	315	.9	92.0	12.0	141°			-.2	(1.1)	(3.0)
393	82.9	78.9	93.0	2.2	3150	-.6	92.4	4.0	106°			-.5	.4	1.7
YUMA - LOW WEAK INVERSION, STRONG WIND SHEAR														
440	83.4	78.8	92.7	2.1	3150	-.4	92.3	5.0 sec	112°	118°	2265'	-.1	.4	1.0
441	83.3	78.8	92.2	1.8	↓	-.2	92.0	5.0	116°			-.5	.1	.8
442	83.2	79.1	92.2	1.4		0	92.2	6.5	121°			-.4	.2	.9
443	82.5	78.5	93.5	2.7		-1.4	92.0	4.0	106°			-.7	.2	.8
444	83.1	78.9	92.7	1.9		-.5	92.1	4.5	109°			-.2	.4	1.0
FRESNO-DC-9 FLY OVER DC-8 TURBULENCE, HOT/DRY,								NO INVERSION						
203	82.7	77.8	90.3	.9	315	.6	(90.8)	7.5	126°	118°	2265'	1.3	--	--
204	83.7	78.1	91.1	1.6	3150	-1.3	89.9	7.5	126°			1.5	--	--

NOTE: Run 204 is w/o DC-8 Turbulence

* Noise Floor Problem

FAA - DC-9 FLYOVER NOISE DATA SUMMARY

Altitude = 500', Fn/δ = 6,000, V = 150 KIAS

AS MEASURED DATA								ACOUSTIC PATH LENGTH				WEATHER CORRECTION		
RUN	Peak OASPL	Peak dBA	PNLTM	Tone Corr.	Tone Freq.	DURATION	EPNL	TPNLTM -TOH(sec)	PNLTM Rad.Angle	Avg. Angle	Avg. Path Length	Part 36 (10m)	Avg.of 10m & A/C Alt.	LAYERED
FRESNO BASELINE														
375	96.6	94.8	111.2	1.4	3150	-5.5	105.8	2.5 sec	136	133°	690'	.4	--	--
376	96.1	94.1	110.5	1.4	↓	-5.0	105.4	2.0	128			.4	--	--
377	96.6	94.4	110.8	1.4	↓	-5.5	105.3	2.0	128			.3	.3	.3
378	96.3	94.6	110.9	1.4	↓	-5.1	105.8	2.5	135			.4	--	--
379	96.1	94.5	110.7	1.3	↓	-5.0	105.7	2.5	137			.7	--	--
FRESNO - FLY UNDER HIGH INVERSION														
272	96.2	93.6	109.2	1.1	3150	-4.5	104.7	2.0 sec	129°	131°	657'	1.2	1.2	1.4
273	97.2	95.3	111.1	1.2	↓	-5.9	105.1	2.0	128°			.8	.8	.9
274	96.2	93.9	109.9	1.3	↓	-5.2	104.6	2.0	130°			1.1	1.1	1.2
275	97.0	95.2	111.5	1.5	↓	-6.3	105.2	2.5	129°			1.1	1.1	1.3
276	96.0	93.7	109.4	1.0	↓	-4.6	104.9	2.5	137°			1.0	1.0	1.1
FRESNO - FLY UNDER HIGH INVERSION, COOL, MOIST														
354	97.1	94.9	110.5	.9	3150	-5.1	105.4	2.0	130°	131°	657'	-.3	-.3	-.3
355	97.0	94.9	110.8	1.2	↓	-5.4	105.4	2.0	128°			-.1	-.5	0
356	97.3	95.7	112.1	1.4	↓	-5.8	106.3	2.5	138°			-.3	-.3	-.3
358	97.3	95.2	111.3	1.5	↓	-5.4	105.9	2.0	126°			-.3	-.2	-.2
359	96.8	94.8	110.5	1.2	↓	-5.1	105.4	2.5	128°			-.7	-.7	-.7

FAA - DC-9 FLYOVER NOISE DATA SUMMARY

Altitude = Varies, Fn/δ = 11,000 lb., V = 174 KIAS

AS MEASURED DATA								ACOUSTIC PATH LENGTH				WEATHER CORRECTION		
RUN	Peak OASPL	Peak dBA	PNLTM	Tone Corr.	Tone Freq.	DURATION	EPNL (Vel Corr)	TPNLTM -TOH(sec)	PNLTM Rad. Angle	Avg. Angle	Avg. Path Length	Part 36 (10m)	Avg. of 10m & A/C Alt.	LAYERED
FRESNO BASELINE, ALT = 500'														
292	104.1	100.2	113.2	.9	100	-4.8	108.4, -.1	2.0 sec	132°	140°	782'	1.1	--	--
293	103.2	99.2	112.1	.8	5000	-3.9	108.2, -.1	3.0	145°			--	0	0
294	104.1	99.8	113.2	.7	315	-5.0	108.2, +.1	2.5	142°			1.1	--	--
295	103.6	99.7	[illegible].9	.7	315	-4.1	108.8, -.1	2.5	138°			1.3	--	--
FRESNO BASELINE, ALT = 1100'														
315	97.4	94.4	106.6	0	100	-2.9	103.6, .1	3.5 sec	124°	129°	1416'	-.2	--	--
316	97.1	92.7	105.0	.8	5000	-1.8	103.2, 0	4.0	130°			-.3	0	-.1
317	98.0	94.0	106.3	.8	315	-2.1	104.1, .1	4.5	134°			-.2	--	--
318	97.9	92.4	106.3	.9	125	-1.7	103.4, -.1	4.5	133°			-.1	--	--
319	97.4	92.5	104.7	.7	4000	-1.1	103.7,	3.5	124°			-.7	--	--
FRESNO BASELINE, ALT = 2000'														
341	91.8	85.7	97.8	.8	125	1.6	99.4	9.5 sec	138°	143°	3300'	.2	0	0
342	94.5	88.3	100.1	.8	160	.3	100.4	12	147°			.1	--	--
343	94.3	88.3	100.6	1.0	125	-.9	99.7	10	141°			.4	--	--
344	93.6	86.2	99.4	.8	200	.3	99.7	11.5	145°			.1	--	--
345	92.3	86.1	98.2	.7	125	1.5	99.7	10.0	141°			.2	--	--

FAA - DC-9 FLYOVER NOISE DATA SUMMARY

Altitude = Varies, Fn/δ = 3,000, V = 150 KIAS

RUN	AS MEASURED DATA							ACOUSTIC PATH LENGTH				WEATHER CORRECTION		
	Peak OASPL	Peak dBA	PNLTM	Tone Corr.	Tone Freq.	DURATION	EPNL	TPNLTM -TOH(sec)	PNLTM Rad.Angle	Avg. Angle	Avg. Path Length	Part 36 (10m)	Avg.of 10m & A/C Alt	LAYERED
	FRESNO BASELINE, ALT = 500'													
321	93.9	93.1	108.3	1.2	2500	-5.5	102.8	2.0 sec	128°	130°	639'	.1	--	--
322	93.9	93.1	108.0	.8	6300	-5.3	102.6	2.0	129°			.2	.2	.2
324	93.9	93.1	108.2	1.1	2500	-5.4	102.7	2.0	131°			.4	--	--
325	94.3	93.6	108.5	1.1	2500	-5.9	102.7	2.0	131°			.3	--	--
326	93.6	92.8	107.6	1.0	6300	-5.2	102.4	2.0	129°			.1	--	--
	FRESNO BASELINE, ALT = 1100'													
327	86.3	84.6	99.3	1.0	2500	-2.5	96.8	3.0	116°	120°	1272'	.3	--	--
328	85.2	83.7	98.2	1.0	2500	-2.6	95.6	3.5	119°			.4	--	--
329	86.2	85.0	99.5	.8	300	-3.4	96.1	3.0	115°			.3	--	--
330	86.1	84.0	98.7	1.1	2500	-3.0	95.7	4.5	130°			.5	--	--
331	85.8	84.3	98.6	1.0	300	-3.6	95.0	3.5	121°			.4	--	--
332	84.4	83.0	97.8	1.3	2500	-2.6	95.2	2.5	107°			.3	--	--
333	85.2	83.5	98.0	1.1	300	-2.6	95.4	4.0	125°			.6	.6	.4

6.0 REFERENCES

1. 'JB' McCollough and Larry K. Carpenter, FAA-ARD-75-69 "Airborne Meteorological Instrumentation System and Data Reduction" April 1975.

2. Christine M. Smith, HS AHAD-R-GEN-214 (2 Volumes) "Atmospheric Attenuation of Aircraft Noise" September 1973.

3. Final Report Contract FAA-RD-71-99, "Experimental Atmospheric Absorption Coefficients", November 1971.

4. Society of Automotive Engineers, Aerospace Recommended Practice ARP-866 "Standard Values of Atmospheric Absorption As A Function Of Temperature and Humidity For Use In Evaluating Aircraft Flyover Noise" August 1964.

5. FAA, Federal Aviation Regulations, Part 36, "Noise Standards: Aircraft Type Certification".

APPENDIX A

NOISE MEASUREMENT SYSTEM SPECIFICATIONS

TABLE A-1

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.	+0 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.	$\pm$ 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.	41-49 dB

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

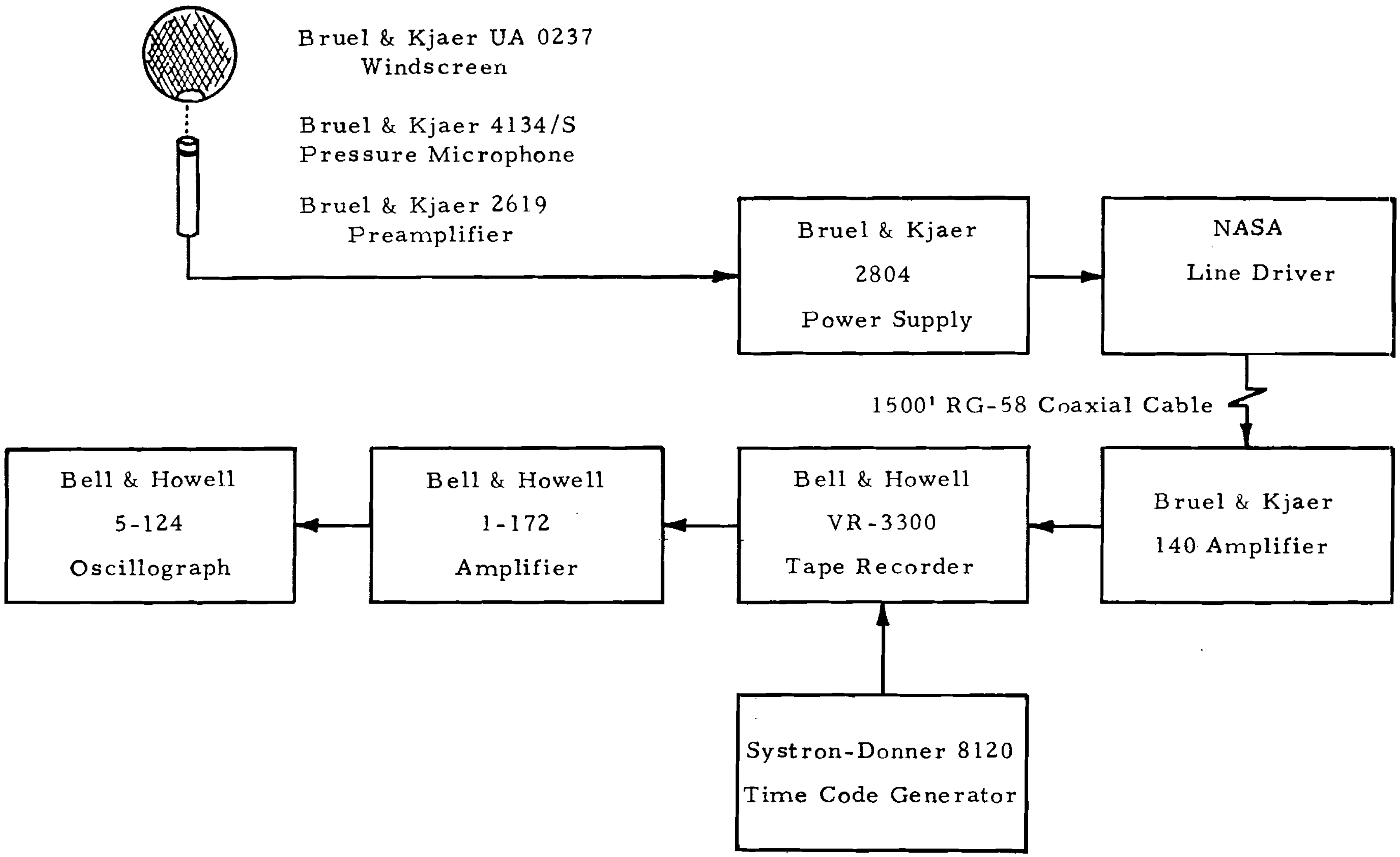


Figure A-1 Instrumentation Block Diagram

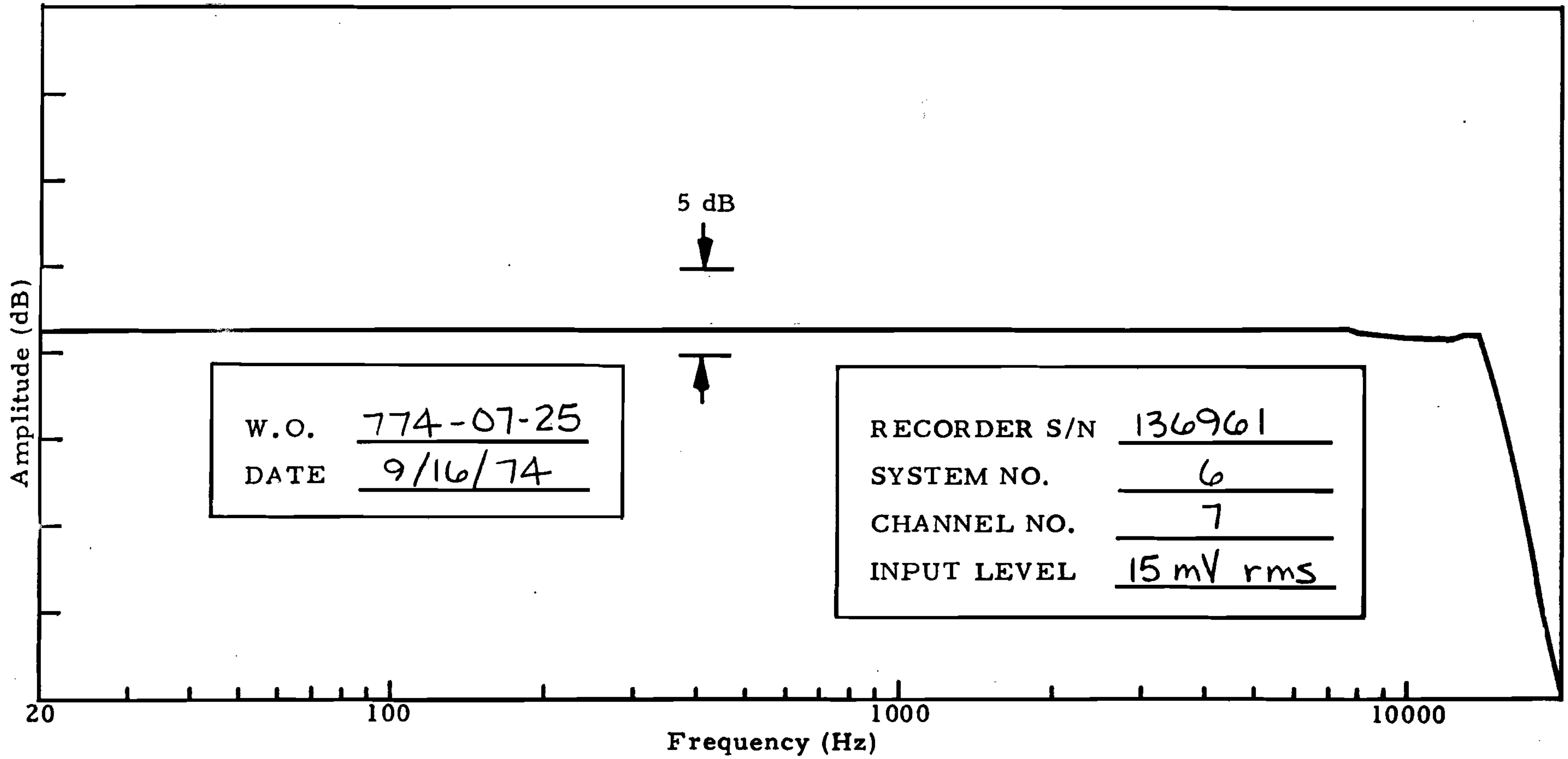


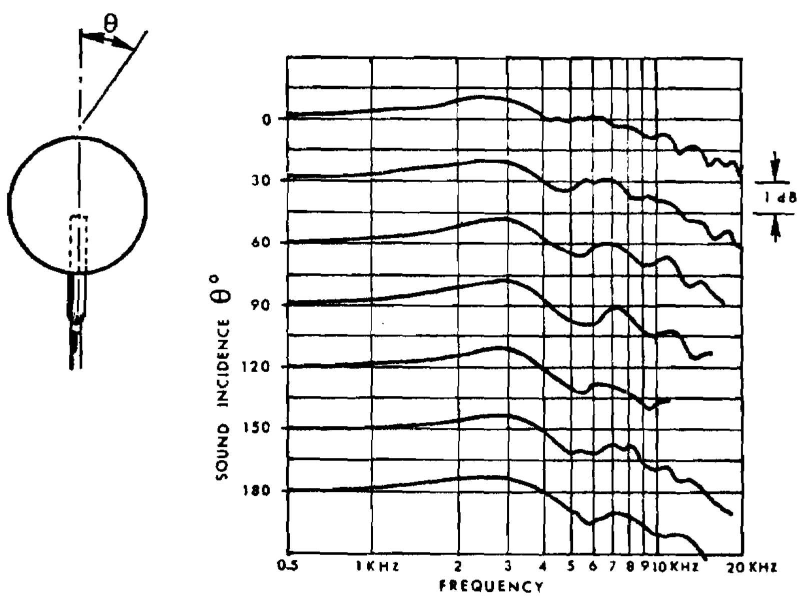
Figure A-1 Typical Microphone Channel Frequency Response -

MICROPHONE, BRUEL AND KJAER, MODEL 4134

Specifications

Diameter:	1/2 inch
Polarization Voltage:	200 volts
Open Circuit Sensitivity:	12.5 mV per N/m^2 at 250 Hz
Frequency Response (pressure):	10 Hz to 5 kHz ± 0.5 dB 5 Hz to 10 kHz ± 1.5 dB 4 Hz to 20 kHz ± 2.0 dB

Free-field frequency response corrections for a microphone with the UA0237 windscreen are shown in the following curves.



Dynamic Range: (open circuit)	Lower limit determined by preamplifier noise. Upper limit 164 dB (ref. 2×10^{-5} N/m^2)
Capacitance:	18 pF (polarized)

Temperature Range:	-50 to +60° C, temperature coefficient better than 0.006 dB/°C
Influence of Ambient Pressure:	-0.1 dB/100 mm Hg
Influence of Humidity:	Less than 0.1 dB in absence of condensation

PREAMPLIFIER, BRUEL AND KJAER, MODEL 2619

Specifications

Gain:	1 : 1 (0.05 dB typical attenuation)
Frequency Response:	2 Hz - 200 kHz[1]
Input Impedance:	4000 megohms
Output Impedance:	25 ohms
Temperature Range:	-20 to +60° C
Output Signal:	1 volt rms to approximately 5 kHz (1500-ft. cable) 0.1 volt rms to approximately 40 kHz (1500-ft. cable)
Polarizing Voltage:	+200 volts
Noise:	Less than 50 μV with 1/2-inch microphone
Distortion:	Less than 1% for normal operating conditions
Power:	120 Vdc, 28 Vdc

[1] The frequency response cited is the maximum obtainable for the preamplifier only. In the system configuration, the low frequency response is effectively controlled by source (microphone) capacitance and the high frequency response is a function of signal amplitude and output cable capacitance.

POWER SUPPLY, BRUEL AND KJAER, MODEL 2804

Specifications

Outputs:	Polarization voltage 200 volts, power supply 120 Vdc and 28 Vdc, auxiliary 28 Vdc, heater 6 - 12 Vdc (external battery)
Battery Voltage:	3.5 volts to 5 volts
Battery Life when Driving 2619 Preamplifier:	Approximately 40 hours
Noise and Ripple:	Adds no additional noise to Model 2619 preamplifier
Gain (with custom line driver):	1 : 1
Cross-talk Attenuation:	Better than 100 dB to 20 kHz
Temperature Range:	0° to $+40^{\circ}$C
Maximum Relative Humidity:	95%
<u>Custom Line Driver</u>	
Output Impedance:	50 ohms
Output Level:	1 volt rms minimum
Frequency Response:	Flat to at least 10 kHz with 1500-ft. coaxial cable
Power:	9-volt battery, 4 mA current drain

SIGNAL CONDITIONER, BRUEL AND KJAER, MODEL 140

Specifications

Number of Channels:	Four (4)
Gain:	10 dB steps from -20 to +40
Frequency Response:	2 - 40 000 Hz ± 0.4 dB
Output Impedance:	25 ohms
Maximum Output Voltage:	7 volts rms
Power:	110 - 220 volts, 50 to 400 Hz

SOUND LEVEL METER, GENERAL RADIO, MODEL 1551-C

(Modified for Use as Amplifier)

Specifications

Frequency Response:	The A, B, and C weighting characteristics are those specified in ANSI Standard S1.4-1961 and IEC Publication 123, 1961. The (20 kHz) response characteristic affords flat response from 20 Hz to 20 kHz
Gain:	-20 to +80 dB, in 5-dB steps
Input Impedance:	25 megohms in parallel with 50 pF
Output Level:	Nominal output voltage for full-scale meter reading is 1.4 volts rms, open circuit
Output Impedance:	7000 ohms
Power:	Two, 1 1/2-volt (D) cells and one, 67 1/2-volt battery

MAGNETIC TAPE RECORDER, BELL AND HOWELL, MODEL VR-3300

Specifications

Number of Channels: 7 or 14

Tape Speeds: 60, 30, 15, 7-1/2, 3-3/4, and 1-7/8 ips

Tape Speed Accuracy: ± 0.25% when operated with 60 Hz

Power: 105 - 125 volts, 48 - 63 Hz

Flutter: (Cumulative peak-to-peak)

Tape Speed (ips)	Bandpass	% Flutter	Bandpass	% Flutter
60	0.2 - 312 Hz	0.30	0.2 Hz - 10 kHz	0.50
30	0.2 - 312 Hz	0.40	0.2 Hz - 5 kHz	0.65
15	0.2 - 312 Hz	0.50	0.2 Hz - 2.5 kHz	0.70
7-1/2	0.2 - 312 Hz	0.65	0.2 Hz - 1.25 kHz	0.80
3-3/4	0.2 - 312 Hz	0.80	0.2 Hz - 0.625 kHz	1.00
1-7/8	0.2 - 312 Hz	1.20		

Operating Temperature: 0 to 50° C

Direct Record/Reproduce System

Frequency Response and Signal-to-Noise Ratio:

Tape Speed (ips)	Frequency Response at ± 3 dB Points Referred to 1.0 kHz as 0 dB	SNR Over Frequency Response Bandwidth Specified	SNR 300 Hz to Upper Band Edge Specified
60	100 Hz to 300 kHz	-30 dB	-32 dB
30	100 Hz to 150 kHz	-30 dB	-32 dB
15	100 Hz to 75 kHz	-30 dB	-32 dB
7-1/2	100 Hz to 37.5 kHz	-30 dB	-32 dB
3-3/4	100 Hz to 18.7 kHz	-28 dB	-32 dB
1-7/8	100 Hz to 9.4 kHz	-28 dB	-30 dB

Input Level: 1 volt rms nominal (0 dB) to produce normal recording level

Input Sensitivity: 0.25 to 10 volts rms; adjustable with input potentiometer for normal record level

Input Impedance: 20 kohms minimum, unbalanced to ground

Output Level: 1 volt rms nominal (0 dB) across a 600 ohm minimum and 3000 pF maximum load impedance (at normal recording level)

Output Impedance: Less than 100 ohms unbalanced to ground

Distortion: 1% ± 0.1% 3rd harmonic distortion of a one-kHz signal and less than 0.6% intermodulation distortion for $f_1 \pm f_2$ products

Bias Frequency: 1.0 MHz

FM Record/Reproduce System

Frequency response, carrier, signal/noise ratio and total harmonic distortion:

Tape Speed (ips)	Center Frequency (kHz)	Information Frequency (kHz)	Full Scale SNR (RMS Signal/ RMS Noise) *	Harmonic Distortion (%)
60	108.0	0 - 20 ± 0.5 dB	45 dB	1.5
30	54.0	0 - 10 ± 0.5 dB	45 dB	1.5
15	27.0	0 - 5 ± 0.5 dB	44 dB	1.5
7-1/2	13.5	0 - 2.5 ± 0.5 dB	44 dB	1.5
3-3/4	6.75	0 - 1.25 ± 0.5 dB	38 dB	1.5
1-7/8	3.375	0 - .625 ± 0.5 dB	38 dB	1.5

* Including FM to FM crosstalk.

Input Level: 1 volt rms nominal (0 dB) to produce full-scale modulation (± 40% deviation) of the carrier.

MAGNETIC TAPE RECORDER, BELL AND HOWELL, MODEL VR-3300

(continued)

Input Sensitivity:	0.5 to 10 volts rms; adjustable with input potentiometer for full-scale modulation (± 40% deviation) of the carrier.
Input Impedance:	10 kohms minimum, unbalanced to ground
Output Level:	1 volt rms nominal (0 dB) across a 10-kohm load impedance, for full-scale modulation
Termination Impedance:	Operates into a 10-kohm load, with 1000 pF shunt capacitance
Phase Shift:	Linear within 5% of best straight line through dc for frequencies in the passband
DC Linearity:	± 0.5% of full scale
AC Linearity:	± 0.5% of full scale
Drift:	Less than 1.0% of full scale in an eight-hour period at constant temperature within ± 10° F
Transient Response:	Adjustable on low-pass filter in FM reproduce amplifier for flat frequency response or optimum transient response. Frequency response specified above exhibits high frequency rolloff at approximately 1/2 band edge frequency when system is adjusted for optimum transient response

TIME CODE GENERATOR, SYSTRON-DONNER, MODEL 8120

Specifications

Time Base:	Crystal controlled oscillator with stability of ± 1 in 10^5 within 0 to 60° C and an aging rate of ± 1 part in 10^7/24 hours after 72 hours. Provisions included for use of an external 1-MHz time base
Display:	Six-digit in-line planar readout to indicate time of day or elapsed time in hours, minutes, and seconds (three additional digits if Days / ID Number option is included)
Code Format:	Modified IRIG B format in terms of hours, minutes, and seconds (Days / ID Number optional)
Modulated Code:	The modulated code is generated on a precise 1-kHz carrier with an adjustable amplitude from 0 to 10 volts peak-to-peak from a low impedance 15 mA peak source and an adjustable modulation ratio (mark-to-space) from 2 : 1 to 6 : 1. Connector is rear panel BNC type
DC Level Shift Code:	The dc level shift code is generated with an adjustable amplitude from 1 to + 10 volts into a 600-ohm load. Connector is rear panel BNC type
Pulse Rates:	Simultaneous rates of 1 PPS, 10 PPS, 100 PPS, and 1 KPPS are provided with leading edge "on time." Levels are 0 to +5 volts nominal from a 6-kohm source (TTL) compatible. Connector is Amphenol 57-40500 (mating connector supplied)
Parallel BCD Outputs:	Updated time is provided as twenty parallel BCD lines representing hours, minutes, and seconds (twelve additional lines for Days / ID Number or Milliseconds options)
Code:	8-4-2-1

Logic:	Binary "1" = 5 (± 0.5) volts, 6-kohm source Binary "0" = 0 (± 0.5) volts, 10 mA sink
Connector:	Amphenol 57-40500. Mating connector supplied
Environment:	0° C to 50° C at up to 95% relative humidity
Power:	115/230 volts (± 10%), 48 to 62 Hz

GALVANOMETER AMPLIFIER, BELL AND HOWELL, MODEL 1-172

Specifications

Number of Channels:	Six (6)
Gain:	Controlled by plug-in feedback network resistor boards
Frequency Response (ac position):	1 Hz to 10 kHz $\pm$ 3 dB
Input Impedance:	1 megohm, shunted by 45 pF
Input Configuration:	Single ended
Maximum Input Voltage:	400 Vdc or peak ac without damage
Ambient Temperature:	0 to 50° C
Linearity:	$\pm$ 0.25% of full scale from best straight line to $\pm$ 80 milliamperes or $\pm$ 6.8 volts from amplifier, whichever is less
Power:	105 to 125 volts, 60 Hz

OSCILLOGRAPH, BELL AND HOWELL, MODEL 5-124

Specifications

Data Channels:	Eighteen (18)
Galvanometer Model:	7 - 361
Frequency Response:	0 - 5000 Hz $\pm$ 5%
Optical Arm:	11.5 inches at zero deflection
Recording Media:	7-inch paper
Trace Width:	Less than 0.01 inch
Maximum Writing Speed:	50 000 inches per second
Record Speeds:	0.25, 1, 4, 16, and 64 ips
Power:	105 to 125 volts, 50/60 Hz

PISTONPHONE, BRUEL & KJAER, MODEL 4220

Specifications

Accuracy:	$\pm$ 0.2 dB
Sound Pressure Level:	124 dB (ref. 2×10^{-5} N/m^2)
Frequency:	250 Hz $\pm$ 1%
Distortion:	Less than 3%
Temperature Range:	0 to +60°C (including batteries)
Humidity:	Relative humidities of up to 100% will not influence the calibration
Power:	7 Mallory RM-3 (R) mercury cells

SOUND LEVEL CALIBRATOR, HEWLETT-PACKARD, MODEL 15117A

Specifications

Acoustic Output

Sound Pressure Level:	94, 104 114, and 124 dB (Ref. 2×10^{-5} N/m^2)
Accuracy:	± 0.3 dB
Frequency:	1 kHz ± 2%

Electrical Output

Voltage:	1.0 volt open circuit
Accuracy:	± 0.1 dB
Output Impedance:	600 ohms
Distortion:	Less than 0.3%
Frequency:	1 kHz ± 2%

General

Temperature Range:	0 - +50°C (including battery)
Humidity:	Up to 95% relative humidity at 40° C
Power:	11.5 volts dc to 13.5 volts dc, current up to 6 mA depending upon sound pressure level

MICROPHONE CALIBRATION APPARATUS, BRUEL & KJAER, MODEL 4142

Specifications

The following specifications apply to the determination of microphone frequency response, using the Model UA0033 electrostatic actuator supplied with the calibration apparatus.

Frequency Range:	20 - 20,000 Hz
Accuracy:	± 0.5 dB (estimate)
Polarization Voltage:	800 volts
Power:	115 volts, 60 Hz

RANDOM NOISE GENERATOR, GENERAL RADIO, MODEL 1382

Specifications

Spectrum: Either (a) white noise (constant energy per hertz bandwidth) ± 1 dB, 20 Hz to 25 kHz, with 3-dB points at approximately 10 Hz and 50 kHz; (b) pink noise (constant energy per octave bandwidth) ± 1 dB, 20 Hz to 20 kHz; or (c) ANSI noise, as specified in ANSI Standard S1.4-1961

Waveform:

Voltage	Gaussian Probability Density Function	Amplitude-Density Distribution of 1382
0	0.0796	0.0796 ± 0.005
$\pm\sigma$	0.0484	0.0484 ± 0.005
$\pm 2\sigma$	0.0108	0.0108 ± 0.003
$\pm 3\sigma$	0.000898	0.000898 ± 0.0002
$\pm 4\sigma$	0.0000274	0.0000274 ± 0.00002

These data measured in a "window" of $0.2\,\sigma$, centered on the indicated values, σ is the standard deviation or rms value of the noise voltage.

Output Voltage: Greater than 3 volts rms maximum, open-circuit for any bandwidth

Output Impedance: 600 ohms

Amplitude Control: Continuous adjustment from full output to approximately 60 dB below that level

Power Required: 100 to 125 volts, 50 to 400 Hz