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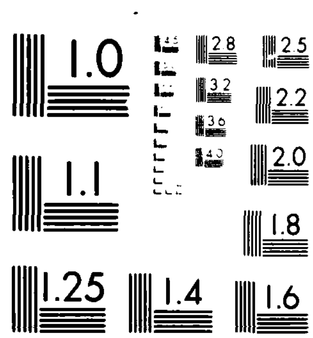
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Washington, D.C. 20591

Analysis of Data Processing Errors Inherent Part 36 of the Federal Aviation Regulations (FAR) Aircraft Noise Certification

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September 1980

Final Report

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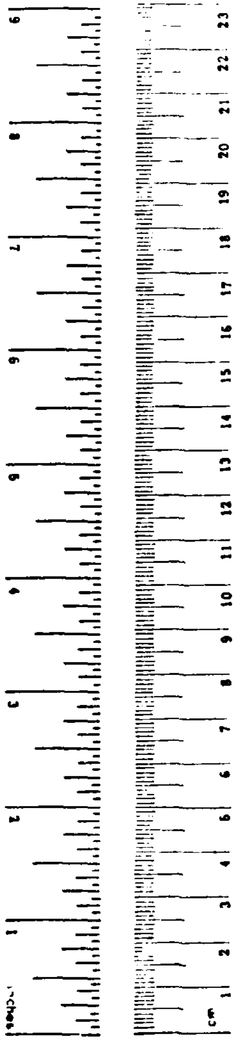
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

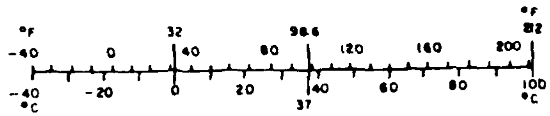
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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



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ABBREVIATIONS AND SYMBOLS

A36.X - Appendix A, Part 36. Federal Aviation Regulations

ANSI - ANSI S1.26-1978, Method for the Calculation of the Absorption of Sound by the Atmosphere (American National Standard)

D - Distance between airplane and microphone

L - Layered atmosphere model

PNLT - Tone corrected Perceived Noise Level

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

SPL(i) - Sound pressure level in the ith 1/3 octave band

$SPL_c(i)$ - Corrected SPL value

$SPL_m(i)$ - Measured SPL value

STD - 1 measurement, Standard day (77°F, 70% RH)

1PT - 1 point, 10 meters height

$1PT_{FP}$ - 1 point, Height of airplane

2PT - Average of above two points

$\alpha(i)$ - Atmospheric sound absorption, dB/1000 ft. or dB/100 M. in ith 1/3 octave band

$\alpha_m(i)$ - Atmospheric absorption/unit distance under measured weather conditions during recording (using 10 M method with SAE standards)

$\alpha_{x_{SAE_L}}(i)$ - Atmospheric absorption/unit distance under conditions of profile being considered (using layered method with SAE standards)

$\alpha_{x_y}(i)$ - Atmospheric absorption/unit measurement under conditions of profile being considered (using one of the 4 methods with either SAE or ANSI standards)

$\alpha_{STD}(i)$ - Atmospheric absorption/unit measurement under conditions of 77°F, 70% RH (using single point method with either SAE or ANSI standards)

1.0 INTRODUCTION

Recent changes have been made to FAR Part 36 with the purpose of improving the accuracy and fairness of noise certification procedures for aircraft. Certain of these changes have necessitated increasing the complexity of the measurements and calculations. The purpose of this study is to make an unbiased, analytical analysis of present regulations to aid in judging whether the regulations as now stated fulfill the purposes for which they are intended, and whether the accuracies currently required for test data measurement and correction are mutually consistent.

Of particular interest is an evaluation of the inherent assumptions of Part 36 concerning the aircraft-to-microphone sound path. In effect, Part 36 requires the measured acoustic data to be averaged for a period of 1.5 seconds and the value of this moving average to be reported each 0.5 second. Because of the speed and height of the aircraft, and because of directivity differences between the various aircraft noise sources, the measured one-third octave band amplitudes may not result from sound propagated along the assumed aircraft-to-microphone sound path. This study evaluates the errors introduced by this method of processing and compares the magnitude of these errors with the accuracy requirements imposed by the data correction requirements of Part 36.

The errors of concern fall in three categories: the measurement of aircraft position, the atmospheric correction of measured airplane noise, and the effect of data sampling and averaging requirements on noise measurement accuracy.

Recommendations are made concerning these three categories.

2.0 AIRCRAFT POSITION

External tracking systems to meet noise certification requirements have been developed by the major airplane manufacturers. The use of these systems comprises a substantial part of the expense of the certification testing.

The certification EPNL values for takeoff and approach are most strongly influenced by the measurements near the point of closest approach by the airplane to the test measurement point. Verification of position and altitude at a single point can be made rather easily with a camera on a tripod at considerably less expense than that incurred by continuous tracking.

Recent generation transport aircraft have on-board navigational systems of high precision, and coordination of ground data with aerial data has become highly developed.

A possible source of system errors during certification testing is the difference between the visual position of the moving aircraft and the point at which the sound which reached the microphone was emitted at a given time.

2.1 Requirements

FAR 36 requires that the airplane flight path be determined by an FAA approved method independent of normal flight instrumentation such as radar tracking, theodolite triangulation, laser trajectography or photographic scaling. The aircraft position must be measured during the entire time the plane is within 10 dB of PNLTM by an FAA approved method which is independent of flight instrumentation.

Air speed, position, and engine performance parameters must be recorded at an approved sampling rate sufficient to correct to the noise certification conditions. The lateral position relative to the extended centerline of the runway, the configuration, and the gross weight must be reported.

The aircraft position, performance, and noise measurement data must be corrected to the following reference atmospheric conditions: sea level pressure of 2116 p.s.f. (76 cm. mercury), ambient temperature of 77°F (25 degrees Centigrade), relative humidity of 70% and zero wind.

The measured flight path must be corrected by the difference between the applicants predicted flight path for the certification reference conditions and the measured flight path at the test conditions. Corrections relating to flight path or performance may be derived from approved data other than certification test data. An estimate must be made of individual errors inherent in each operation employed in obtaining the final data.

The minimum sample size acceptable for each of the three certification measurements, takeoff, approach, and sideline must be large enough to establish statistically for each a 90% confidence limit which does not exceed ±1.5 EPNdB.

2.2 Tracking Systems

An airplane tracking system should be useable in any weather conditions that do not otherwise prevent noise-certification testing. Light clouds or fog may prevent satisfactory operation of devices using optical wavelength radiation when temperature inversion or high relative humidity would not otherwise prevent a valid test.

The accuracy of distance measurements should be compatible with the accuracy of results required. Fraunhaufer diffraction can be a serious limitation in angular and distance discrimination in devices using electromagnetic radiation. In general, for telescopes, radar and other devices, the minimum angular resolution is the Rayleigh criterion,

$$\theta = 1.22\lambda/a,$$

where λ is the wavelength of the radiation and a is the effective diameter of the circular aperture of a telescope objective lens or of a radar antenna. The smaller λ and the larger a, the better θ.

Some installations are external to the airplane, and some require its modification.

A number of tracking systems have been developed and used by the major aircraft manufacturers. All have merit when reliability, cost, complexity and other factors are considered. Each has disadvantages. They fall in the following categories:

1. *Theodolite*
2. *Camera*
3. *Radar, Centimeter and Optical (Laser)*

2.2.1 *Theodolite*

A theodolite is basically a mounted telescope with cross-hairs used to establish the spatial parameters of an airplane in flight. Installations range from rather simple portable units to complex high-accuracy ones. Scales on the azimuth and elevation axes are read manually or photographed with a camera timed from a signal in the flight test recording system so that airplane position can be correlated with recorded noise data. The scales may be read electronically. In some installations, the target is recorded photographically, together with the telescope cross-hairs.

Tracking imperfections are the main source of error, and corrections from photographs of the target are possible though time-consuming.

With proper design optical resolution errors should be within 0.1 dB as shown by the Rayleigh criterion.

Tracking an airplane with a theodolite may be difficult when visibility is poor, as in the presence of haze, morning or evening sunlight.

There is considerable scope for further development.

2.2.2 *Camera*

A camera for airplane position measurement is mounted on the ground or in the test airplane. The shutter is controlled by the recording system timing signal and may provide 5 to 10 exposures per second. For a ground-mounted camera, the photograph is scaled to find the slant height from the measurement station to the airplane. The position of the airplane in the photograph determines lateral distance from overhead. Several cameras would be required to monitor the takeoff flight path from threshold to 6 miles from brake release and also for the approach from 4 miles to threshold.

An airplane-mounted downward looking camera, with good control over focus and aperture providing adequate contrast in the pictures, should be at least as good as a tripod-mounted camera on the ground. Aiming the camera is not a problem, since it would be rigidly mounted in the airplane and aimed by the attitude of the airplane. A roll of 10° would generate an airplane to ground distance measurement error of 0.13 dB and correction could be made for this.

The reference point on the airplane must be clearly established. Markers on the ground must be well-defined. (Each location where an airplane-mounted camera is used must be calibrated.)

Whether a ground-mounted or airplane-mounted camera is used, data reduction involves scaling distance from photographs. The process is fundamentally the same whether it is done with an optical comparator, a traveling microscope, or projection on a calibrated screen.

To measure the reliability of this method, a series of 9 photographs of airplanes taken during takeoff conditions at altitudes ranging from 825 feet to 2003 feet were read six times each with a BISHOP GRAPHICS, INC. PEAK 10X DE-LUXE optical comparator. The airplane models were C141 (seven) and T38 (two). These photos ranged in intensity from light medium to dark against a white background. The results showed twice the standard error (i.e. 96% of measurements) within ±0.1 EPNdB.

There do not appear to be basic limitations on the attainment of high accuracy with this method, though there may be scope for further sophistication in hardware development.

2.2.3 Radar

Centimeter radar (electro-magnetic carrier signal a few cm. in wavelength), although it has been used with difficulty for airplane certification, is generally not suited for short-range measurements (a mile or less). Lobes in the radiation pattern and pulse tails cause confusion, especially at low angles. Equipment is generally expensive to acquire and maintain.

Tracking radar such as the Bell EEM having fractional millimeter wavelengths (33 GHz) has slant range accuracy of 15 feet at shorter range and 1% at longer distances, with dynamic angular errors of 0.3 milliradian (rms) at an Angular Tracking Rate of 60°/sec. A corner reflector a square foot in area mounted on the airplane enhances its performance compared to skin tracking with its multitude of targets and potential for error. This type of equipment appears to be adequate for certification purposes.

Laser radar such as the MALT SYSTEM (Sylvania Electronic Systems) has range accuracy in the order of 1 foot with tracking accuracy of less than 0.1 milliradian for an angular sweep rate of 28.6°/sec. A retroreflector mounted on the airplane is advisable for positive tracking. Haze and fog impair the performa... of laser radar, but otherwise it is well-suited to certification work.

3.0 ATMOSPHERIC CORRECTION

In earlier versions of FAR PART 36 the correction for atmospheric absorption to reference day conditions was based on meteorological data taken at a single point near the ground. Since the humidity and temperature which strongly influence sound absorption in the air, are typically functions of altitude, this represents an inaccurate value for the absorption integrated over the sound path. In the revision of FAR PART 36 of March, 1978, this error source was reduced by the new requirements of paragraph A36.9(d)(3). These call for the calculation of sound absorption corrections by summing up the absorption between the airplane location and the test microphone in stratified layers of atmosphere not more than 100 feet thick, whenever the absorption coefficient over the flight path in the 3150 Hz one-third octave band varies by more than 0.7 dB/1000 feet from the 10 meter value.

FAR PART 36 applies corrections for atmospheric absorption to that sample of the noise time-history that gives peak tone-corrected PNL (PNLT). The effects of the corrections on that sample are added to the calculated EPNL. Comparisons have been made among four atmospheric correction methods designated as follows.

3.1 Atmospheric Correction Methods

1) 10 M - one set of atmospheric measurements (temperature and relative humidity) at the test microphone site 10 meters off the ground.

2) AP - one set of atmospheric measurements at the height of the airplane.

3) 2 Pt. Ave. - the average of the two sets of atmospheric measurements taken at 10 M and at the height of the airplane.

4) Layered - atmospheric measurements taken at 100 feet intervals measured vertically from the ground level to the airplane height.

In this study, corrections were calculated using the spectrum of the peak PNLT sample, as the comparisons to be made would be reflected equally in changes in peak PNLT and in changes in EPNL. The atmospheric corrections calculated in each of these four ways were therefore used to correct peak PNLT for takeoff and landing of five different airplane models. These corrections were done for 10 different atmosphere profiles, using FAR PART 36 procedures, with the following equation:

$$SPL_c(i) = SPL_m(i) + \alpha_m(i) \cdot D - \alpha_{x_{SAE_L}}(i) \cdot D + \alpha_{x_y}(i) \cdot D - \alpha_{STD}(i) \cdot D$$

(See List of Symbols)

The results of these calculations, together with the associated atmospheric profiles are shown in Tables 3-1 to 3-10 and Figures 3-1 to 3-9. These tables give the differences between the value of peak PNLT calculated using each of the correction methods and that calculated with the layered atmosphere method, using SAE (ARP 866A) absorption values. The layered method using the SAE standard was used as the reference condition as being the most accurate method and the most widely-used standard.

The PNLT range of differences and the mean differences from atmospheric corrections with the SAE layered atmosphere model are shown in Tables 3-11 through 3-16.

3.2 Atmospheric Attenuation Criteria

FAR 36 A36.1(c)(3) requires that the "relative humidity and ambient temperature over the portion of the sound propagation path between the aircraft and a point 10 m.above the ground at the noise measuring station (be) such that the sound attenuation in the one-third octave band centered at 8 kHz is not greater than 12 dB/100 m. and the relative humidity is between 20% and 95%, inclusively." A36.9(d)(2) states that "if the atmospheric absorption coefficients do not vary over the sound propagation path by more than ±0.7 dB/1000 ft. in the 3150 Hz one-third octave band from the value of the absorption coefficients derived from the meteorological measurements obtained at 10 m. above the surface of the noise measuring station" then the layered correction need not be used. To show how the weather profiles considered in this study comply with these requirements, Tables 3-17 to 3-19 show temperature and relative humidity measurements at 10 m , and the maximum and minimum values measured along the sound path between the ground and the airplane. Also shown is the variation in absorption coefficient/1000 ft. in the 3.15 kHz band for conditions along the sound path, and the average and maximum values of the absorption coefficient/100 m. in the 8 kHz band along the path, as A36.1(c)(3) does not state whether an average value of the 8 kHz absorption coefficient is to be used.

3.3 Meteorological Measurement Error

The precise measurements of temperature and relative humidity for the atmospheric correction of airplane certification noise level measurements to standard reference conditions are required. To determine the effect of small errors in temperature and relative humidity on noise level measurements, a weather condition was selected (Figure 3-7) near the lower humidity limit and near the upper limit of sound attenuation in the 8 kHz 1/3-octave band as specified in A36.1(c)(3). Using the four atmospheric correction methods, atmospheric measurements at a height of 10 m., at the height of the airplane in flight, the average of the previous two, and the layered atmosphere model, takeoff noise levels for six airplanes flying at approximately 1500 feet (450 m.) were corrected to standard conditions of 77°F and 70% RH. Then, these same corrections were made with increments in temperature of ±2°F and in relative humidity of ±2%, as shown in Tables 3-20 to 3-25. For these results, the range and the standard deviation are shown for each method. These corrections were made also for two rather more extreme weather conditions, Figures 3-3 and 3-8. Only the range of noise levels is shown for each of the latter two conditions since only the variations +2°F, +2% RH and -2°F, -2% RH were used. When the temperature and relative humidity variations have opposite signs, their effects tend to cancel at these low humidities and high temperatures. Both SAE and ANSI sound absorption values were used for these calculations.

These results show that errors in temperature and relative humidity measurement of the above magnitudes can result in noise measurement errors exceeding 0.5 EPNdB. For Profile 5, errors are least for atmospheric measurements at a height of 10 m. above the ground and nearly equal for the average of these measurements at 10 m. and at the airplane height, and for the layered atmosphere model calculation method. Errors are higher for noise spectra with more high frequency content.

TABLE 3-1. PNLT TEMPERATURE AND RELATIVE HUMIDITY CORRECTIONS COMPARED TO LAYERED ATMOSPHERE (SAE): NMM

(Normal lapse rate; Moderate temperature; Moist)

WEATHER SET	AIRPLANE		ΔPNLT (SAE,T,RH CORR.)			ΔPNLT (ANSI,T,RH CORR.)			
	MODEL	HEIGHT	10 M.	Ap.Hgt.	2Pt.Ave.	10 M.	Ap.Hgt.	2Pt.Ave.	Layered
NMM	DC-8	161	0.0	-0.1	0.0	0.1	0.1	0.1	0.1
	707-120B	159	0.0	0.0	0.0	0.2	0.2	0.2	0.2
	727-200	138	0.0	0.0	0.0	0.2	0.2	0.2	0.2
	DC-9	128	0.0	0.0	0.0	0.2	0.2	0.2	0.2
	DC-10	160	0.0	0.0	0.0	0.2	0.2	0.2	0.3
	LANDING, 150 Meters								
	707-320	449	-0.2	0.6	0.2	0.3	0.9	0.6	0.5
	727-200	439	0.0	0.2	0.1	0.2	0.4	0.3	0.2
	DC-9	455	0.0	0.1	0.0	0.1	0.2	0.2	0.1
	747	458	-0.2	0.4	0.1	0.1	0.5	0.3	0.2
	DC-10	454	-0.2	0.4	0.1	0.2	0.6	0.4	0.3
	L1011	492	-0.4	0.8	0.2	0.0	0.7	0.3	0.2
	TAKEOFF, 460 Meters								
	707-320	755	-0.7	1.8	0.7	0.1	1.8	0.7	0.5
	727-200	751	-0.1	0.3	0.1	0.1	0.5	0.3	0.2
	737	721	-0.2	0.6	0.1	0.1	0.8	0.5	0.2
	747	764	-0.5	1.3	0.2	-0.4	1.3	0.2	0.0
	DC-10	750	-0.3	0.6	0.1	-0.2	0.7	0.1	0.0
	TAKEOFF, 750 Meters								

WEATHER CONDITION (1)

NMM (Normal lapse rate; moderate temperature; moist)

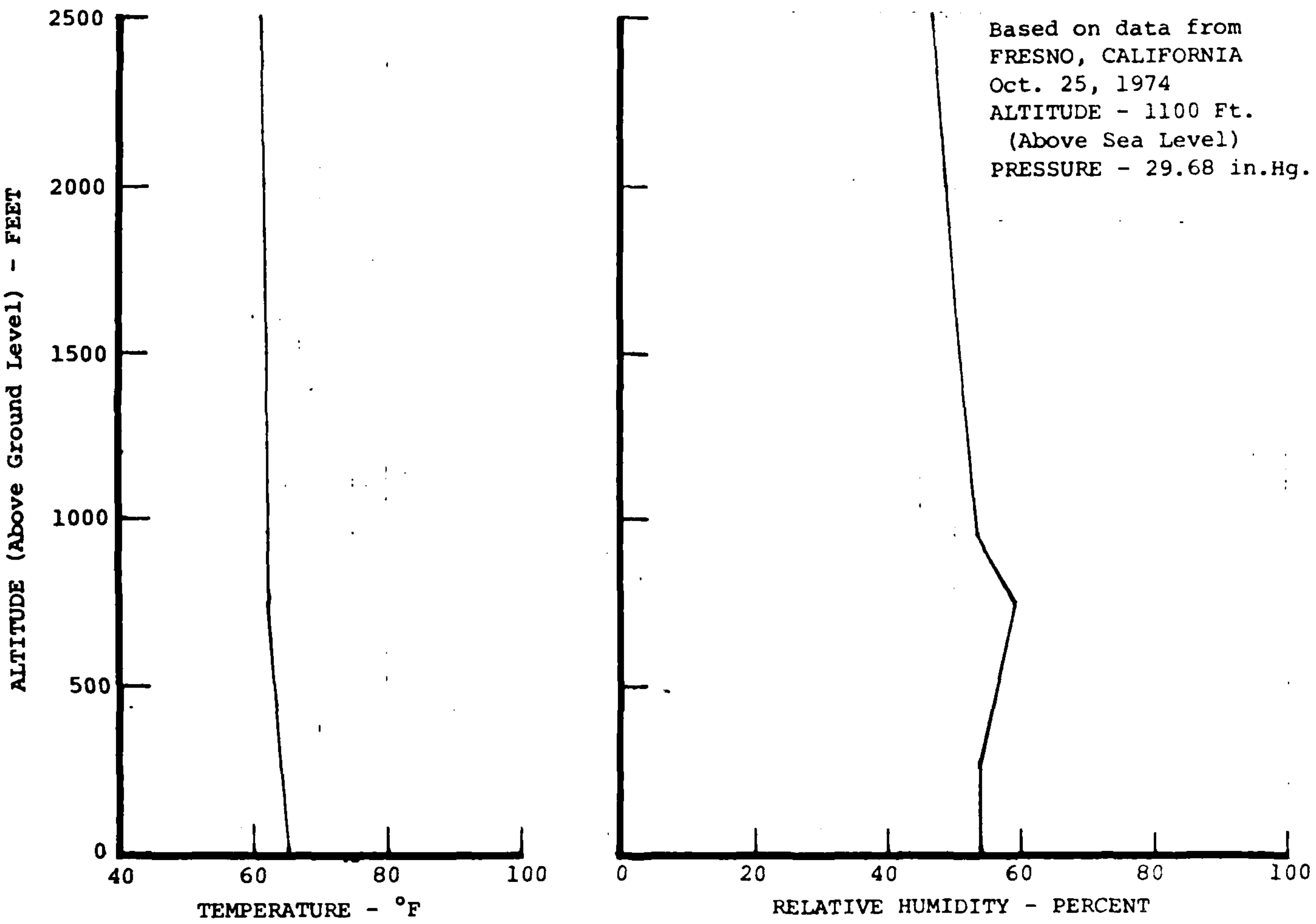

Figure 3-1. Atmospheric Profile

TABLE 3-2 PNLT TEMPERATURE AND RELATIVE HUMIDITY CORRECTIONS COMPARED TO LAYERED ATMOSPHERE (SAE): NMD

(Normal lapse rate; Moderate temperature; Dry)

WEATHER SET	AIRPLANE		ΔPNLT (SAE,T,RH CORR.)			Δ PNLT(ANSI,T,RH CORR.)			
	MODEL	HEIGHT	10 M.	Ap.Hgt	2Pt.Ave.	10 M.	Ap.Hgt.	2Pt.Ave.	Layered
NMD	DC-8	161	-0.1	0.0	-0.1	0.1	0.2	0.1	0.2
	707-120B	159	0.0	0.1	0.0	0.2	0.2	0.2	0.2
	727-200	138	-0.1	0.0	0.0	0.2	0.2	0.2	0.2
	DC-9	128	-0.1	0.0	0.0	0.2	0.2	0.2	0.2
	DC-10	160	-0.1	0.1	0.0	0.2	0.2	0.2	0.2
	LANDING, 150 Meters								
	707-320	449	-0.2	-0.1	-0.1	0.4	0.3	0.3	0.4
	727-200	439	0.0	0.0	0.0	0.3	0.2	0.2	0.1
	DC-9	455	0.0	0.0	0.0	0.2	0.1	0.2	0.2
	747	458	-0.1	-0.1	-0.1	0.3	0.1	0.2	0.2
	DC-10	454	-0.1	-0.1	-0.1	0.3	0.1	0.2	0.3
	L1011	492	-0.3	-0.1	-0.2	-0.1	-0.1	-0.1	0.1
	TAKEOFF, 460 Meters								
	707-320	755	-0.2	-0.2	-0.3	1.0	0.2	0.6	0.8
	727-200	751	0.1	-0.1	0.0	0.3	0.1	0.2	0.3
	737	721	0.1	-0.2	0.0	0.4	0.0	0.2	0.3
	747	764	0.0	-0.4	-0.2	0.3	-0.4	-0.1	0.1
	DC-10	750	0.0	-0.2	-0.1	0.2	-0.2	0.0	0.1
	TAKEOFF, 750 Meters								

WEATHER CONDITION (2)

NMD (Normal lapse rate; moderate temperature; dry)

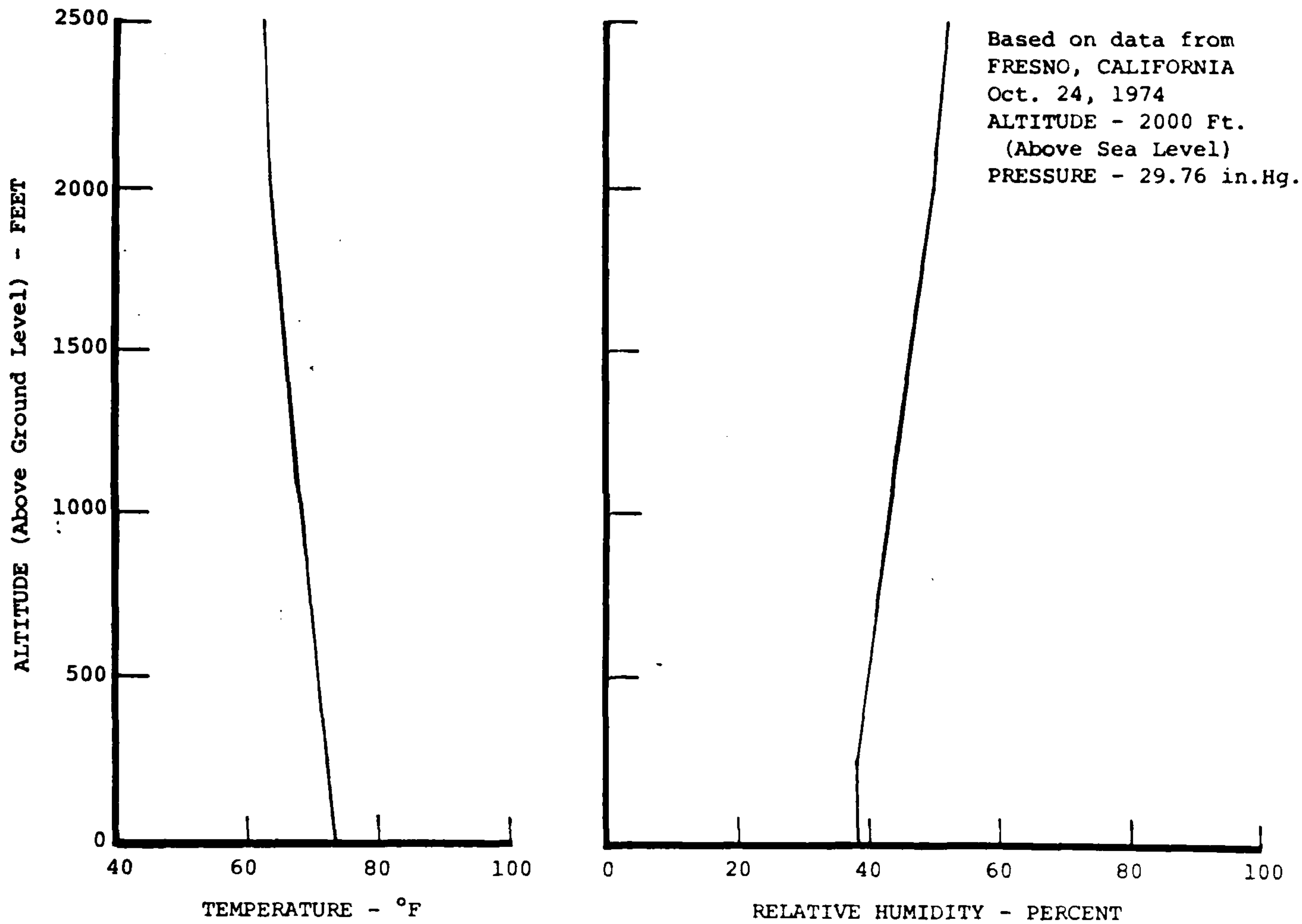

Figure 3-2. Atmospheric Profile

TABLE 3-3 PNLT TEMPERATURE AND RELATIVE HUMIDITY CORRECTIONS COMPARED TO LAYERED ATMOSPHERE (SAE): NHD

(Normal lapse rate; Hot temperature; Dry)

WEATHER SET	AIRPLANE		ΔPNLT (SAE,T,RH CORR.)			Δ PNLT (ANSI,T,RH CORR.)			
	MODEL	HEIGHT	10 M.	Ap.Hgt	2Pt.Ave.	10 M.	Ap.Hgt.	2Pt.Ave.	Layered
NHD	DC-8	161	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	707-120B	159	0.1	0.0	0.0	0.1	0.1	0.1	0.1
	727-200	138	0.0	0.0	0.0	0.1	0.0	0.1	0.1
	DC-9	128	0.1	0.0	0.0	0.1	0.0	0.1	0.0
	DC-10	160	0.1	0.0	0.0	0.0	-0.1	0.0	0.0
	LANDING, 150 Meters								
	707-320	449	-0.5	1.4	0.4	-0.6	1.4	0.3	-0.1
	727-200	439	-0.1	0.5	0.2	0.1	0.7	0.4	0.2
	DC-9	455	0.0	0.2	0.1	0.1	0.4	0.3	0.2
	747	458	-0.4	1.0	0.3	-0.5	0.8	0.1	-0.2
	DC-10	454	-0.4	1.0	0.3	-0.4	1.1	0.3	0.0
	L1011	492	-0.6	1.6	0.5	-0.7	1.6	0.1	-0.4
	TAKEOFF, 460 Meters								
	707-320	755	-2.5	7.8	2.0	-2.8	10.2	1.1	-0.8
	727-200	751	-0.3	1.6	0.4	-0.1	3.3	0.7	0.3
	737	721	-0.5	3.9	0.8	-0.3	6.1	1.0	0.2
	747	764	-1.8	7.9	1.5	-1.4	16.7	1.5	-0.2
	DC-10	750	-0.8	5.4	0.7	-0.8	11.0	0.9	0.1
	TAKEOFF, 750 Meters								

WEATHER CONDITION (3)

NHD (Normal lapse rate; hot temperature; dry)

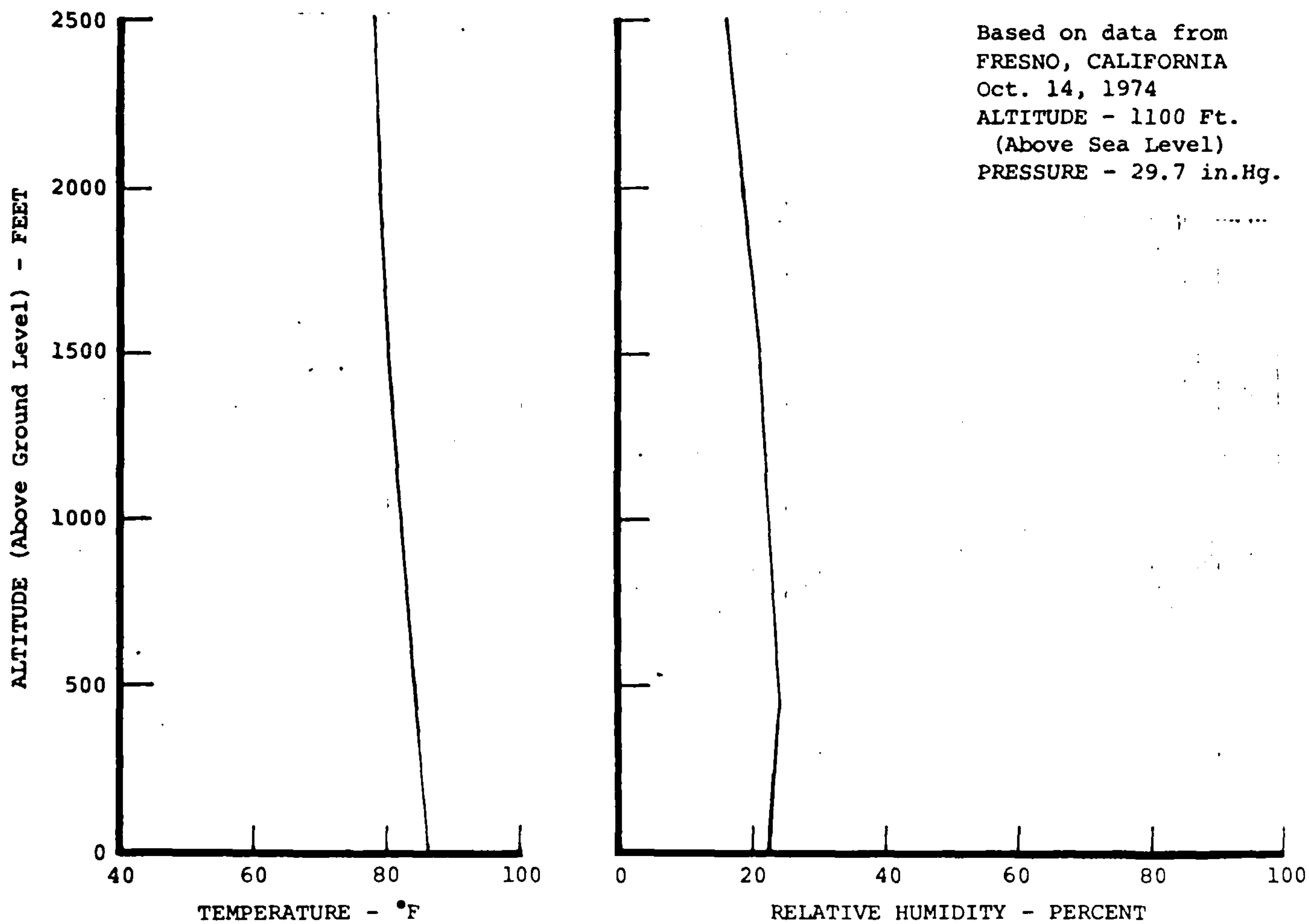

Figure 3-3. Atmospheric Profile

TABLE 3-4. PNLT TEMPERATURE AND RELATIVE HUMIDITY CORRECTIONS COMPARED TO LAYERED ATMOSPHERE (SAE): IMM

(Inversion; Moderate temperature; Moist)

WEATHER SET	AIRPLANE		ΔPNLT(SAE,T,RH CORR.)			ΔPNLT(ANSI,T,RH CORR.)			
	MODEL	HEIGHT	10 M.	Ap.Hgt.	2Pt.Ave.	10 M.	Ap.Hgt.	2Pt.Ave.	Layered
IMM	DC-8	161	-0.3	0.3	0.0	-0.2	0.4	0.1	0.1
	707-120B	159	-0.3	0.4	0.0	-0.2	0.5	0.1	0.1
	727-200	138	-0.3	0.4	0.0	-0.2	0.5	0.1	0.1
	DC-9	128	-0.3	0.4	0.0	-0.2	0.5	0.2	0.1
	DC-10	160	-0.4	0.5	0.0	-0.2	0.5	0.1	0.1
	LANDING, 150 Meters								
	707-320	449	-1.6	2.6	0.4	-1.4	2.6	0.4	0.2
	727-200	439	-0.5	0.9	0.1	-0.5	1.2	0.2	0.2
	DC-9	455	-0.3	0.5	0.0	-0.2	0.7	0.2	0.2
	747	458	-1.3	2.0	0.2	-1.2	1.7	0.1	0.0
	DC-10	454	-1.3	1.9	0.2	-1.2	2.1	0.2	0.1
	L1011	492	-1.8	3.1	0.3	-1.5	3.2	0.2	-0.1
	TAKEOFF, 460 Meters								
	707-320	755	-4.3	4.0	-0.3	-4.1	3.2	-1.3	-0.5
	727-200	751	-0.7	0.7	-0.1	-0.5	1.3	0.1	0.3
	737	721	-1.1	1.3	-0.2	-1.0	1.6	-0.1	0.2
	747	764	-2.5	3.6	-0.5	-2.3	5.3	-0.8	-0.2
	DC-10	750	-1.4	1.9	-0.3	-1.4	2.1	-0.3	0.1
	TAKEOFF, 750 Meters								

WEATHER CONDITION (4)

IMM (Inversion; moderate temperature; moist)

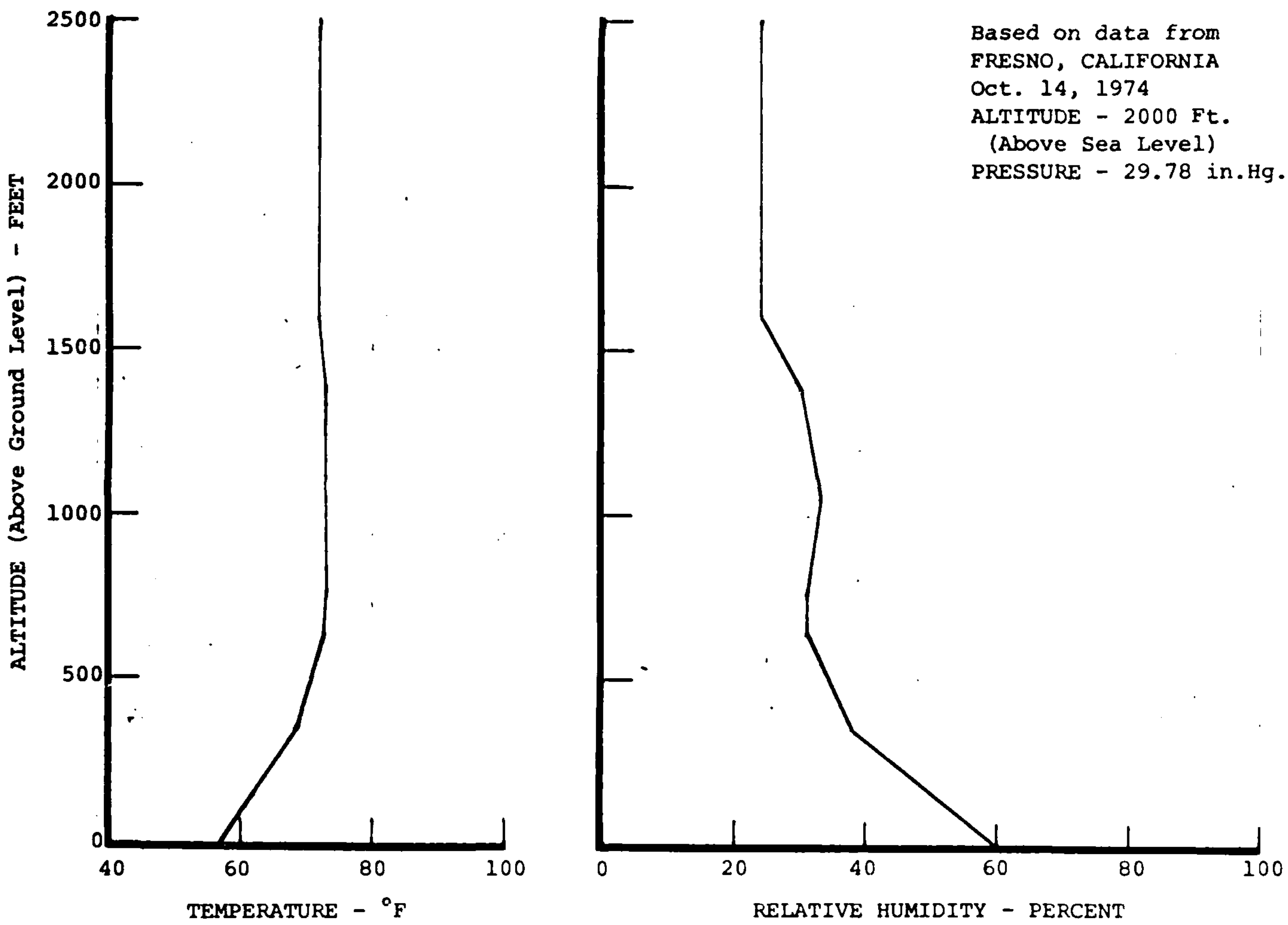

Figure 3-4. Atmospheric Profile

TABLE 3-5. PNLT TEMPERATURE AND RELATIVE HUMIDITY CORRECTIONS COMPARED TO LAYERED ATMOSPHERE (SAE): IMM

(Inversion; Moderate temperature; Moist)

WEATHER SET	AIRPLANE		ΔPNLT (SAE,T,RH CORR.)			Δ PNLT (ANSI,T,RH CORR)			
	MODEL	HEIGHT	10 M.	Ap.Hgt.	2Pt.Ave.	10 M.	Ap.Hgt.	2Pt.Ave.	Layered
IMM	DC-8	161	-0.5	0.3	-0.1	-0.5	0.3	-0.1	0.0
	707-120B	159	-0.5	0.4	-0.1	-0.4	0.4	0.0	0.1
	727-200	138	-0.5	0.4	-0.1	-0.4	0.5	0.0	0.1
	DC-9	128	-0.5	0.4	-0.1	-0.4	0.4	0.0	0.1
	DC-10	160	-0.6	0.5	-0.1	-0.5	0.8	0.0	0.1
	LANDING, 150 Meters								
	707-320	449	-1.7	2.4	0.2	-1.6	2.4	0.2	0.0
	727-200	439	-0.6	0.9	0.1	-0.5	1.1	0.2	0.2
	DC-9	455	-0.3	0.4	0.0	-0.2	0.7	0.1	0.2
	747	458	-1.4	1.9	0.1	-1.4	1.5	-0.1	-0.1
	DC-10	454	-1.4	1.8	0.1	-1.3	1.9	0.1	0.0
	L1011	492	-1.8	2.9	0.2	-1.6	3.0	0.0	-0.2
	TAKEOFF, 460 Meters								
	707-320	755	-4.3	6.2	0.2	-4.4	5.9	-0.5	-0.7
	727-200	751	-0.7	1.3	0.0	-0.6	2.2	0.2	0.3
	737	721	-1.2	2.8	0.0	-1.1	2.8	0.1	0.2
	747	764	-2.6	6.1	0.1	-2.4	11.2	-0.3	-0.2
	DC-10	750	-1.5	3.9	0.0	-1.4	6.4	0.0	0.1
	TAKEOFF, 750 Meters								

WEATHER CONDITION (5)

IMD (Inversion; moderate temperature; dry)

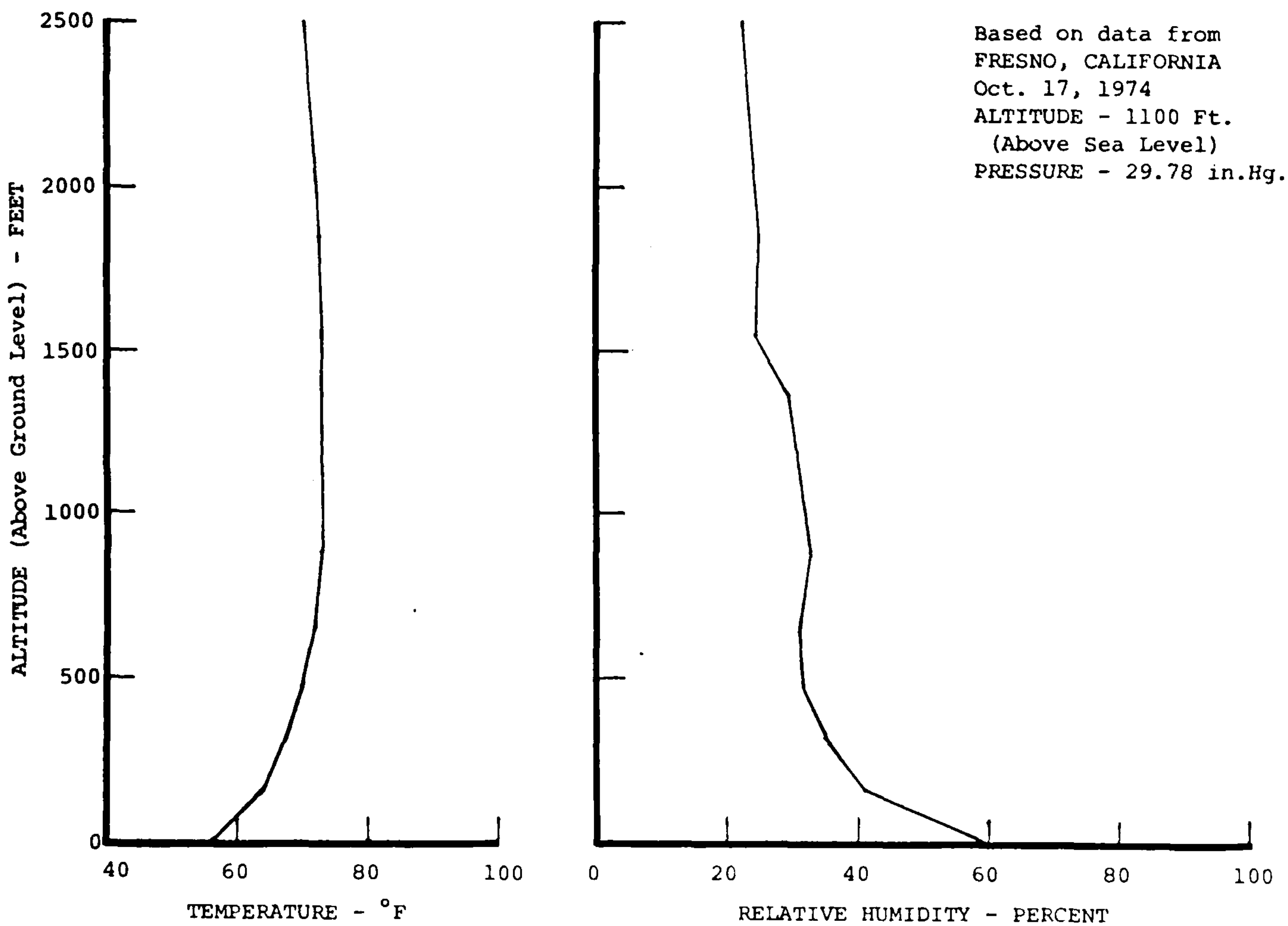

Figure 3-5. Atmospheric Profile

TABLE 3-6 PNLT TEMPERATURE AND RELATIVE HUMIDITY CORRECTIONS COMPARED TO LAYERED ATMOSPHERE (SAE): ICM

(Inversion; Cool temperature; Moist)

WEATHER SET	AIRPLANE		ΔPNLT (SAE,T,RH CORR.)			ΔPNLT (ANSI,T,RH CORR.)			
	MODEL	HEIGHT	10 M.	Ap.Hgt.	2Pt.Ave.	10 M.	Ap.Hgt.	2Pt.Ave.	Layered
ICM	DC-8	161	0.0	0.0	0.0	0.1	0.2	0.1	0.1
	707-120B	159	0.0	0.1	0.1	0.2	0.3	0.2	0.2
	727-200	138	0.0	0.0	0.0	0.2	0.3	0.2	0.2
	DC-9	128	0.0	0.1	0.0	0.2	0.3	0.2	0.2
	DC-10	160	0.0	0.1	0.1	0.3	0.3	0.3	0.3
	LANDING, 150 Meters								
	707-320	449	-0.4	0.4	0.0	0.0	0.8	0.4	.5
	727-200	439	-0.1	0.2	0.0	0.0	0.3	0.1	0.2
	DC-9	455	-0.1	0.1	0.0	0.0	0.2	[illegible]	0.1
	747	458	-0.4	0.2	-0.1	-0.2	0.5	0.2	0.2
	DC-10	454	-0.4	0.2	-0.1	-0.1	0.5	0.2	0.3
	L1011	492	-0.6	0.4	-0.1	-0.2	0.7	0.2	0.3
	TAKEOFF, 460 Meters								
	707-320	755	-0.7	1.5	0.2	0.0	1.7	0.6	0.6
	727-200	751	-0.2	0.2	0.0	0.0	0.5	0.2	0.2
	737	721	-0.3	0.5	0.0	-0.2	0.7	0.4	0.5
	747	764	-0.7	1.0	0.0	-0.8	1.2	-0.1	0.0
	DC-10	750	-0.4	0.5	0.0	-0.4	0.5	0.0	0.0
	TAKEOFF, 750 Meters								

WEATHER CONDITION (6)

ICM (Inversion; cool temperature; moist)

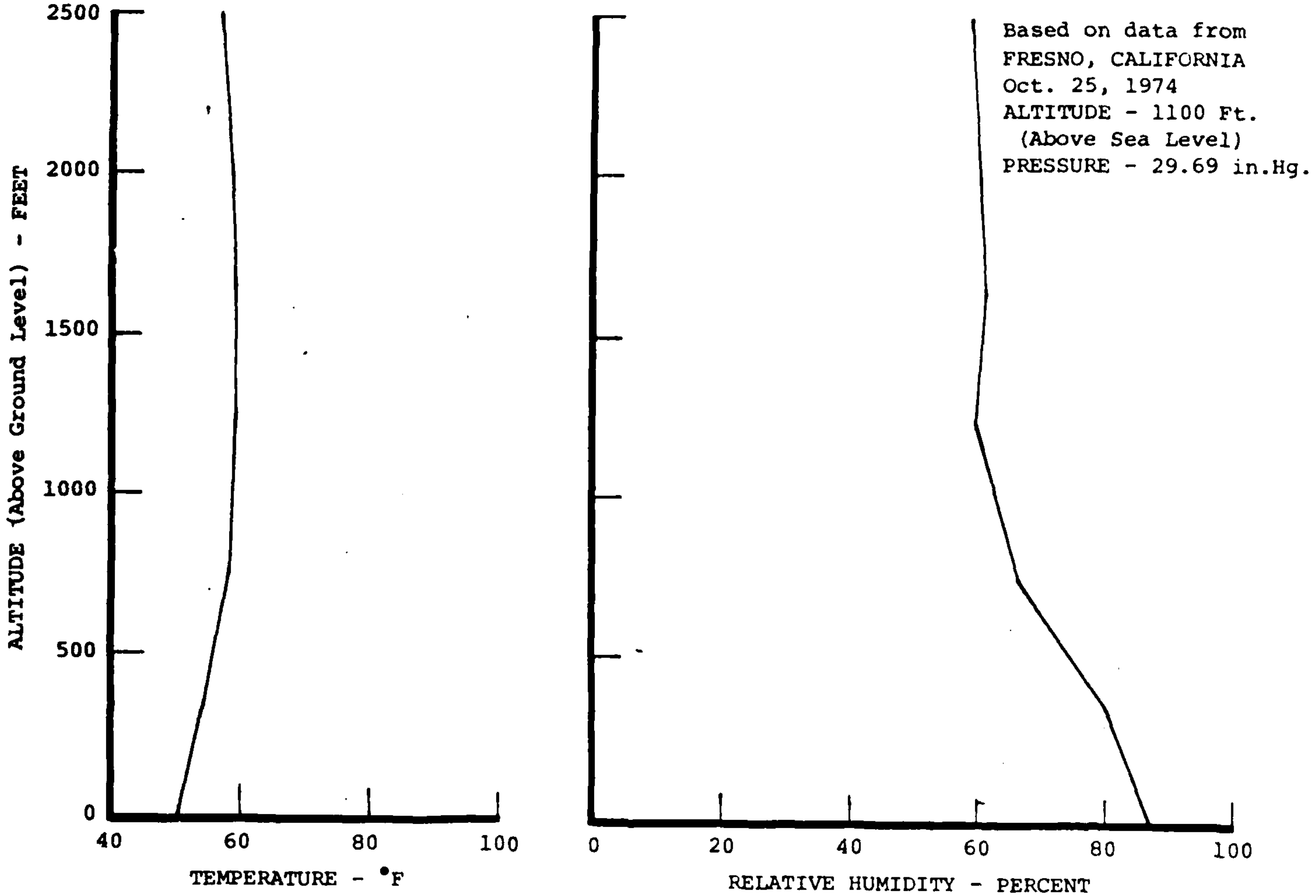

Figure 3-6. Atmospheric Profile

TABLE 3-7. PNLT TEMPERATURE AND RELATIVE HUMIDITY CORRECTIONS COMPARED TO LAYERED ATMOSPHERE (SAE): I_wHD

(Weak inversion; Hot temperature; Dry)

WEATHER SET	AIRPLANE		ΔPNLT(SAE,T,RH CORR.)			ΔPNLT (ANSI,T,RH CORR.)			
	MODEL	HEIGHT	10 M.	Ap.Hgt	2Pt.Ave.	10 M.	Ap.Hgt.	2Pt.Ave.	Layered
I_wHD	DC-8	161	-0.6	0.5	-0.1	-0.4	0.5	0.0	0.1
	707-120B	159	-0.6	0.6	0.0	-0.4	0.6	0.1	0.1
	727-200	138	-0.6	0.6	-0.1	-0.4	0.0	0.1	0.1
	DC-9	128	-0.7	0.6	0.0	-0.4	0.6	0.1	0.1
	DC-10	160	-0.9	0.8	0.0	-0.6	1.0	0.0	0.1
	LANDING, 150 Meters								
	707-320	449	-3.8	2.8	-0.9	-3.3	1.9	-1.2	-0.5
	727-200	439	-1.1	1.0	-0.3	-0.9	1.0	-0.2	0.1
	DC-9	455	-0.6	0.5	-0.1	-0.4	0.6	0.0	0.1
	747	458	-3.0	2.1	-0.7	-2.7	1.1	-1.1	-0.6
	DC-10	454	-2.8	2.1	-0.7	-2.5	1.6	-0.9	-0.3
	L1011	492	-2.7	3.4	-1.0	-2.4	2.5	-1.1	-0.5
	TAKEOFF, 460 Meters								
	707-320	755	-8.6	37.0	9.6	-8.3	39.4	7.7	-2.0
	727-200	751	-1.2	19.9	1.9	-1.0	27.9	2.4	0.1
	737	721	-2.1	27.5	5.3	-1.6	32.4	4.8	0.2
	747	764	-3.7	36.5	6.5	-3.5	46.0	7.4	-0.7
	DC-10	750	-2.3	31.3	4.7	-2.0	38.7	4.5	-0.3
	TAKEOFF, 750 Meters								

WEATHER CONDITION (7 & 10)

$I_w HD_1$, $I_w HD_2$ } (Weak inversion; hot temperature; dry)

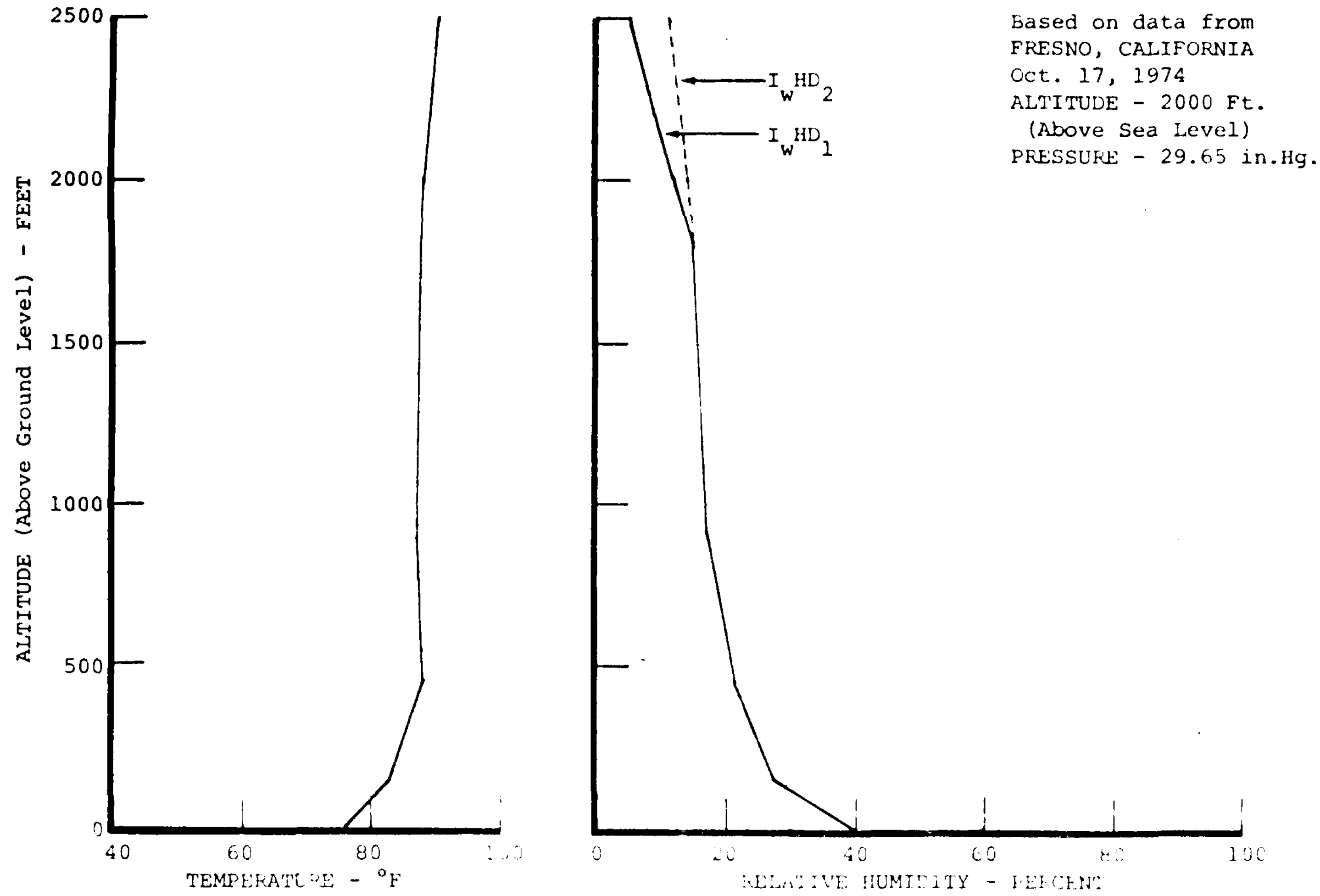

Figure 3-7. Atmospheric Profile

TABLE 3-8. PNLT TEMPERATURE AND RELATIVE HUMIDITY CORRECTIONS COMPARED TO LAYERED ATMOSPHERE (SAE): I_sHD

(Strong inversion; Hot temperature; Dry)

WEATHER SET	AIRPLANE		ΔPNLT (SAE,T,RH CORR.)			Δ PNLT (ANSI,T,RH CORR.)			
	MODEL	HEIGHT	10 M.	Ap.Hgt	2Pt.Ave.	10 M.	Ap.Hgt.	2Pt.Ave.	Layered
I_sHD	DC-8	161	-1.2	0.5	-0.4	-1.1	0.3	-0.4	-0.2
	707-120B	159	-1.2	0.6	-0.3	-1.1	0.4	-0.4	-0.1
	727-200	138	-1.1	0.6	-0.3	-1.0	0.4	-0.3	-0.1
	DC-9	128	-1.2	0.6	-0.3	-1.0	0.4	-0.4	-0.1
	DC-10	160	-1.5	0.7	-0.4	-1.4	0.8	-0.5	0.2
	LANDING, 150 Meters								
	707-320	449	-5.8	11.3	0.4	-5.6	12.4	-0.3	-1.0
	727-200	439	-1.9	8.2	0.3	-1.8	7.1	0.0	-0.1
	DC-9	455	-1.0	2.5	0.1	-0.8	2.6	0.0	0.0
	747	458	-5.3	8.4	0.4	-5.2	8.3	-0.6	-1.3
	DC-10	454	-3.8	8.8	0.4	-3.6	11.7	-0.4	-0.9
	L1011	492	-3.7	13.5	0.5	-3.6	16.1	-0.4	-0.7
	TAKEOFF, 460 Meters								
	707-320	755	-9.3	0.0	-6.8	-9.1	-3.0	-8.0	-2.6
	727-200	751	-1.5	-0.1	-1.0	-1.2	0.0	-0.9	0.2
	737	721	-2.4	-0.3	-1.8	-2.0	0.0	-1.7	0.3
	747	764	-4.6	-0.4	-3.4	-4.2	-0.7	-3.4	-0.5
	DC-10	750	-2.6	-0.2	-2.1	-2.3	0.0	-1.9	0.1
	TAKEOFF, 750 Meters								

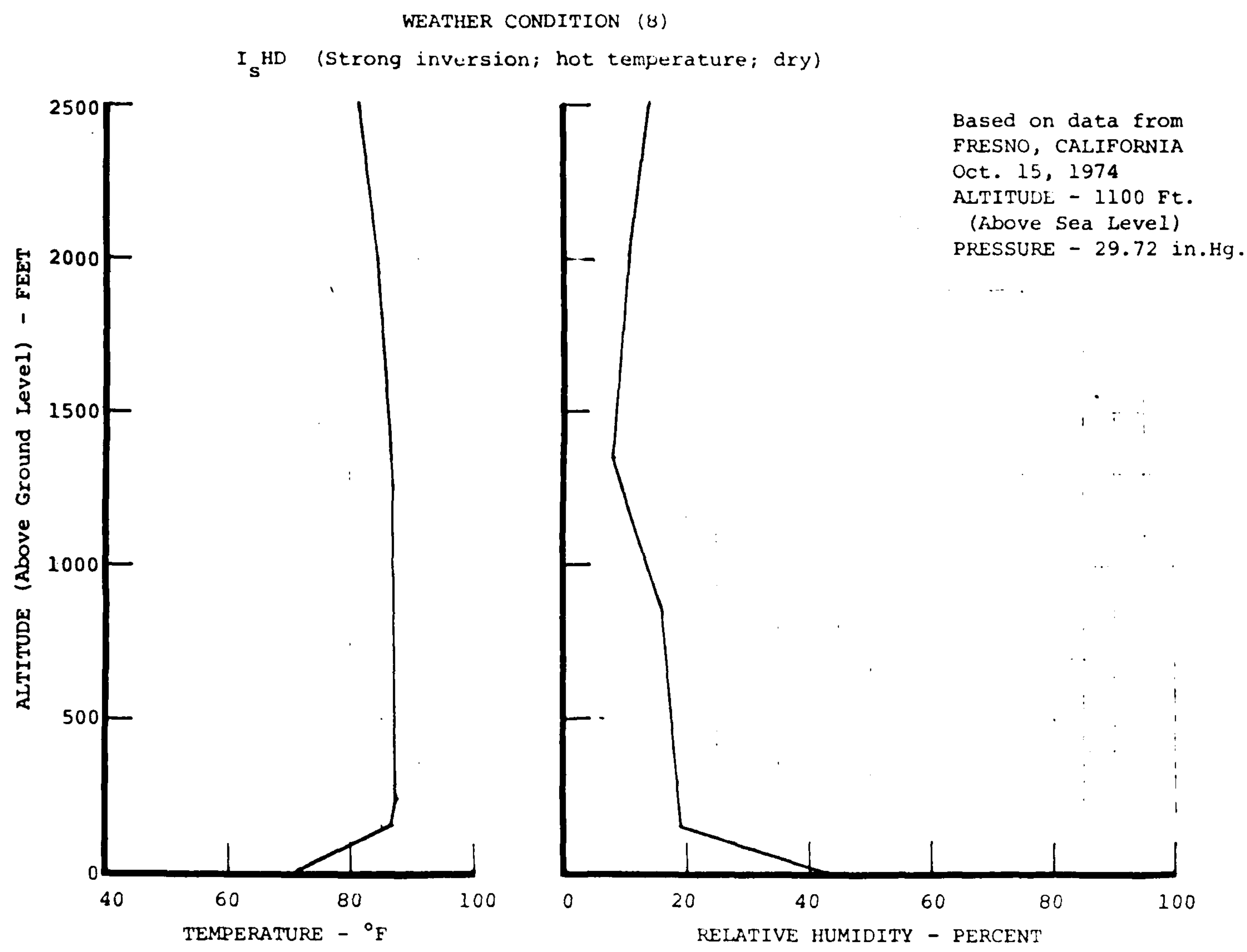

Figure 3-8. Atmospheric Profile

TABLE 3-9. PNLT TEMPERATURE AND RELATIVE HUMIDITY CORRECTIONS COMPARED TO LAYERED ATMOSPHERE (SAE): I_hCM
(High altitude inversion; Cool temperature; Moist)

WEATHER SET	AIRPLANE		ΔPNLT (SAE,T,RH CORR.)			Δ PNLT (ANSI,T,RH CORR.)			
	MODEL	HEIGHT	10 M.	Ap.Hgt.	2Pt.Ave.	10 M.	Ap.Hgt.	2Pt.Ave.	Layered
I_hCM	DC-8	161	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	707-120B	159	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	727-200	138	0.0	0.0	0.0	0.1	0.1	0.1	0.1
	DC-9	128	0.0	0.0	0.0	0.1	0.1	0.1	0.1
	DC-10	160	0.0	0.0	0.0	0.1	0.1	0.1	0.1
	LANDING, 150 Meters								
	707-320	449	1.1	-0.4	0.3	1.2	-0.1	0.5	0.2
	727-200	439	0.4	0.0	0.1	0.5	0.1	0.3	0.1
	DC-9	455	0.2	0.0	0.1	0.3	0.1	0.2	0.1
	747	458	0.8	-0.4	0.2	0.6	-0.3	0.2	-0.1
	DC-10	454	0.8	-0.4	0.2	0.8	-0.2	0.3	0.1
	L1011	492	1.3	-0.5	0.4	1.3	-0.5	0.3	-0.1
	TAKEOFF, 460 Meters								
	707-320	755	1.5	2.8	2.1	1.1	2.3	1.7	0.0
	727-200	751	0.2	0.5	0.3	0.4	0.9	0.6	0.2
	737	721	0.5	1.0	0.7	0.6	1.2	0.9	0.1
	747	764	0.9	2.4	1.6	0.9	2.4	1.6	-0.2
	DC-10	750	0.4	1.4	0.7	0.5	1.2	0.8	0.0
	TAKEOFF, 750 Meters								

WEATHER CONDITION (9)

I_HCM (High altitude inversion; cool; moist)

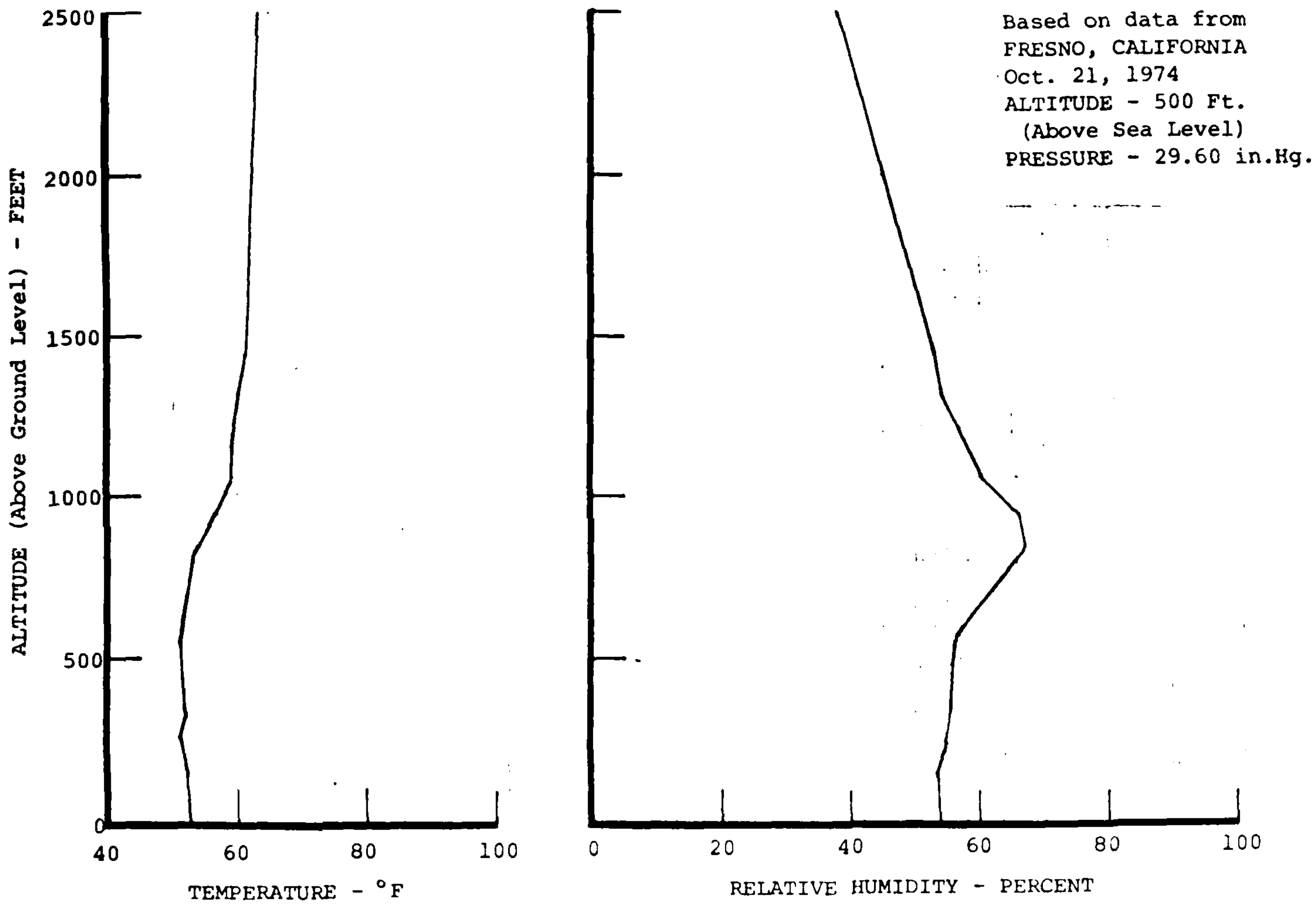

Figure 3-9. Atmospheric Profile

TABLE [illegible]. DIFFERENCES IN PNLT ATMOSPHERIC CORRECTIONS [illegible]
[illegible] Average Height [illegible]

	RANGE OF DIFFERENCES IN PNLT*									
WEATHER CONDITION**	1	2	3	4	5	6	7	8	9	10
WEATHER SET	NMM	NMC	NHC	IMM	INM	ICM	I_wHC_1	I_sHC	[illegible]	I_wHC_2
Atmospheric Measurement Height 10 Meters	0.0	0.1	0.1	0.1	[illegible]	[illegible]	[illegible]	0.4	0.0	[illegible]
Atmospheric Measurement Height of Airplane in Flight Path	0.1	0.1	0.0	0.2	0.2	[illegible]	[illegible]	[illegible]	0.0	0.3
2-Point Average: Height 10 Meters Height of Airplane	0.0	[illegible]	0.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	MEAN OF DIFFERENCES IN PNLT*									
WEATHER CONDITION**	[illegible]	[illegible]	3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WEATHER SET	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Atmospheric Measurement Height 10 Meters	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Atmospheric Measurement Height of Airplane in Flight Path	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2-Point Average: Height 10 Meters Height of Airplane	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*Differences [illegible]
**[illegible]

TABLE 3-12. DIFFERENCES IN PNLT ATMOSPHERIC CORRECTIONS (ANSI: S1.26-1978) Average Height: 150 M.

	RANGE OF DIFFERENCES IN PNLT*									
WEATHER CONDITION**	1	2	3	4	5	6	7	8	9	10
WEATHER SET	NMM	NMD	NHD	IMM	IMM	ICM	I_wHD_1	I_sHD	I_hCM	I_wHD_2
Atmospheric Measurement Height 10 Meters	0.1	0.1	0.1	0.0	0.1	0.2	0.2	0.4	0.1	0.2
Atmospheric Measurement Hgt. of Airplane in Flight Path	0.1	0.0	0.2	0.1	0.5	0.1	0.5	0.5	0.1	0.5
2-Point Average: Height 10 M./Hgt. of Airplane	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.1
Layered Atmosphere Model	0.2	0.0	0.1	0.0	0.1	0.2	0.0	0.4	0.1	0.0

	MEAN OF DIFFERENCES IN PNLT*									
WEATHER CONDITION**	1	2	3	4	5	6	7	8	9	10
WEATHER SET	NMM	NMD	NHD	IMM	IMM	ICM	I_wHD_1	I_sHD	I_hCM	I_wHD_2
Atmospheric Measurement Height 10 Meters	0.2	0.2	0.1	-0.2	-0.4	0.2	-0.4	-1.1	0.1	-0.4
Atmospheric Measurement Hgt. of Airplane in Flight Path	0.2	0.2	0.0	0.5	0.5	0.3	0.7	0.5	0.1	0.7
2-Point Average: Height 10M./Hgt. of Airplane	0.2	0.2	0.1	0.1	0.0	0.2	0.1	-0.4	0.1	0.1
Layered Atmosphere Model	0.2	0.2	0.0	0.1	0.1	0.2	0.1	-0.1	0.1	0.1

*Differences from corrections with layered atmosphere (LAM).
**See Figures 3-1 to 3-9.

TABLE 3-13. DIFFERENCES IN PNLT ATMOSPHERIC CORRECTIONS (SAE: ARP 866A) Average Height: [illegible] M.

	RANGE OF DIFFERENCES IN PNLT*									
WEATHER CONDITION**	1	2	3	4	5	6	7	8	9	10
WEATHER SET	NMM	NMD	NHD	IMM	IMM	ICM	[illegible]	I_sHD	I_hCM	I_wHD$_2$
Atmospheric Measurement Height 10 Meters	0.4	0.3	0.6	1.5	1.5	0.5	[illegible]	4.8	1.1	3.2
Atmospheric Measurement Height of Airplane in Flight Path	0.7	0.1	1.4	2.6	2.5	0.3	2.9	11.0	0.5	2.9
2-Point Average: Height 10 Meters Height of Airplane	0.2	0.2	0.4	0.4	0.2	0.1	[illegible]	0.4	0.3	0.9

	MEAN OF DIFFERENCES IN PNLT*									
WEATHER CONDITION**	1	2	3	4	5	6	7	8	9	10
WEATHER SET	NMM	NMD	NHD	IMM	IMM	ICM	[illegible]	I_sHD	I_hCM	I_wHD$_2$
Atmospheric Measurement Height 10 Meters	-0.2	-0.1	[illegible]	[illegible]	-1.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Atmospheric Measurement Height of Airplane in Flight Path	[illegible]	-0.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2-Point Average: Height 10 Meters Height of Airplane	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*Differences from corrections with layered atmosphere [illegible].
**See Figures 3-1 to 3-9.

TABLE 3-14. DIFFERENCES IN PNLT ATMOSPHERIC CORRECTIONS
(ANSI: S1.26-1978) Average Height: 460 M.

	RANGE OF DIFFERENCES IN PNLT*									
WEATHER CONDITION**	1	2	3	4	5	6	7	8	9	10
WEATHER SET	NMM	NMD	NHD	IMM	IMM	ICM	I_wHD_1	I_sHD	I_hCM	I_wHD_2
Atmospheric Measurement Height 10 Meters	0.3	0.5	0.8	1.3	1.4	0.2	2.9	4.8	1.0	2.9
Atmospheric Measurement Hgt. of Airplane in Flight Path	0.7	0.4	1.2	2.5	2.3	0.6	1.9	13.5	0.6	[illegible]
2-Point Average: Height 10 M./Hgt. of Airplane	0.4	0.4	0.3	0.3	0.3	0.3	1.2	0.6	0.3	1.2
Layered Atmosphere Model	0.4	0.3	0.6	0.3	0.4	0.4	0.7	1.3	0.3	0.7

	MEAN OF DIFFERENCES IN PNLT*									
WEATHER CONDITION**	1	2	3	4	5	6	7	8	9	10
WEATHER SET	NMM	NMD	NHD	IMM	IMM	ICM	I_wHD_1	I_sHD	I_hCM	I_wHD_2
Atmospheric Measurement Height 10 Meters	0.2	0.2	-0.3	-1.0	-1.1	-0.1	-2.0	-3.4	0.8	-2.0
Atmospheric Measurement Hgt. of Airplane in Flight Path	0.6	0.1	1.0	1.9	1.8	0.5	1.5	9.7	-0.2	1.5
2-Point Average: Height 10M./Hgt. of Airplane	0.4	0.2	0.3	0.2	0.1	0.2	-0.8	-0.3	0.3	-0.8
Layered Atmosphere Model	0.3	0.2	-0.1	0.1	0.0	0.3	-0.3	-0.7	0.1	-0.3

*Differences from corrections with layered atmosphere (SAE).
**See Figures 3-1 to 3-9.

TABLE 3-15. DIFFERENCES IN PNLT ATMOSPHERIC CORRECTIONS
(SAE: ARP 866A) Average Height: 750 M.

	RANGE OF DIFFERENCES IN PNLT*									
WEATHER CONDITION**	1	2	3	4	5	6	7	8	9	10
WEATHER SET	NMM	NMD	NHD	IMM	IMM	ICM	I_wHD_1	I_sHD	I_hCM	I_wHD_2
Atmospheric Measurement Height 10 Meters	0.6	0.3	2.2	3.6	3.6	0.5	7.4	7.8	1.3	6.7
Atmospheric Measurement Height of Airplane in Flight Path	1.5	0.3	6.3	3.3	4.9	1.3	17.1	0.4	2.3	8.5
2-Point Average: Height 10 Meters Height of Airplane	0.6	0.3	1.6	0.4	0.2	0.2	7.7	5.8	1.8	0.3

	MEAN OF DIFFERENCES IN PNLT*									
WEATHER CONDITION**	1	2	3	4	5	6	7	8	9	10
WEATHER SET	NMM	NMD	NHD	IMM	IMM	ICM	I_wHD_1	I_sHD	I_hCM	I_wHD_2
Atmospheric Measurement Height 10 Meters	-0.4	0.0	-1.2	-2.0	-2.1	-0.5	-3.6	-4.1	0.7	-3.1
Atmospheric Measurement Height of Airplane in Flight Path	0.9	-0.2	5.3	2.3	4.1	0.7	30.4	-0.2	1.0	7.5
2-Point Average: Height 10 Meters Height of Airplane	0.2	-0.1	1.1	-0.3	0.1	0.0	5.6	-3.0	1.1	-0.2

*Differences from corrections with layered atmosphere (SAE).
**See Figures 3-1 to 3-9.

TABLE 3-16. DIFFERENCES IN PNLT ATMOSPHERIC CORRECTIONS (ANSI: S1.26-1978) Average Height: 750 M.

	RANGE OF DIFFERENCES IN PNLT*									
WEATHER CONDITION**	1	2	3	4	5	6	7	8	9	10
WEATHER SET	NMM	NMD	NHD	IMM	IMM	ICM	$I_w HD_1$	$I_s HD$	$I_h CM$	$I_w HD_2$
Atmospheric Measurement Height 10 Meters	0.5	0.8	2.7	3.6	3.8	0.8	7.3	7.9	0.7	6.2
Atmospheric Measurement Hgt. of Airplane in Flight Path	1.3	0.6	13.4	4.0	9.0	1.2	18.1	3.0	1.5	14.8
2-Point Average: Height 10 M./Hgt. of Airplane	0.6	0.7	0.8	1.4	0.7	5.3	5.3	7.1	1.1	2.1
Layered Atmosphere Model	0.5	0.7	1.1	0.8	1.0	0.6	2.2	2.9	0.4	2.1

	MEAN OF DIFFERENCES IN PNLT*									
WEATHER CONDITION**	1	2	3	4	5	6	7	8	9	10
WEATHER SET	NMM	NMD	NHD	IMM	IMM	ICM	$I_w HD_1$	$I_s HD$	$I_h CM$	$I_w HD_2$
Atmospheric Measurement Height 10 Meters	-0.1	0.4	-1.1	-1.9	-2.0	-0.3	-3.3	-3.8	0.7	-2.8
Atmospheric Measurement Hgt. of Airplane in Flight Path	1.0	-0.1	9.5	2.7	5.7	0.9	36.9	-0.7	1.6	11.8
2-Point Average: Height 10M./Hgt. of Airplane	0.4	0.2	1.0	-0.5	-0.1	0.2	5.4	-3.2	1.1	-0.7
Layered Atmosphere Model	0.2	0.3	-0.1	0.0	-0.1	0.3	-0.5	-0.5	0.0	-0.4

*Differences from corrections with layered atmosphere (SAE).
**See Figures 3-1 to 3-9.

TABLE 3-17. ATMOSPHERIC DATA FOR NOISE ATTENUATION CALCULATIONS INCLUDING TEMPERATURE, RELATIVE HUMIDITY AND NOISE ATTENUATION CRITERIA (Airplane Height: 150 m.)

ATMOSPHERIC CONDITIONS							1/3 OCTAVE NOISE ATTENUATION 10M. to AIRPLANE		
WEATHER CONDITION (See Fig. 3-1 to 3-9)	HEIGHT 10M.		10M. to AIRPLANE				$\Delta\alpha$ MAX/1000 FT 3150 Hz	α AVE/100 M 8000 Hz	α MAX/100 M 8000 Hz
			MIN		MAX				
	T°F	RH	T°F	RH	T°F	RH			
1	64	55	63	54	65	56.5	0.10	7.40	6.93
2	73.5	38	71	38	73.5	40	0.32	8.63	8.12
3	85.5	22.5	84	22.5	86	24	0.20	11.03	11.17
4	60.5	54	57	35	71	60	1.74	9.04	10.03
5	62.5	49	56	31	70.5	60	2.25	9.95	10.86
6	51	85	50	74	56	87	0.14	6.52	6.22
7	82.5	31	76	20	88	40	3.34	10.09	11.82
8	83.5	29	71.5	17	87.5	43	4.67	12.36	13.81
9	52.5	54	51.3	53.5	52.5	56	0.13	9.66	9.76
10	82.5	31	76	20	88	40	3.34	10.09	11.82
CRITERIA A 36.1(c)(2),(3)			36	20	95	95	0.7 dB/1000 FT A 36.9(d)(2)	12 dB/100 M. A 36.1(c)(3)	

TABLE 3-18. ATMOSPHERIC DATA FOR NOISE ATTENUATION CALCULATIONS INCLUDING TEMPERATURE, RELATIVE HUMIDITY AND NOISE ATTENUATION CRITERIA (Airplane Height: 460 m.)

ATMOSPHERIC CONDITIONS							1/3 OCTAVE NOISE ATTENUATION 10M. to AIRPLANE		
WEATHER CONDITION (See Fig. 3-1 to 3-9)	HEIGHT 10M.		10M. to AIRPLANE						
			MIN		MAX				
	T°F	RH	T°F	RH	T°F	RH	Δ∝ MAX/1000 FT 3150 Hz	∝ AVE/100 M 8000 Hz	∝ MAX/100 M 8000 Hz
1	64	55	62	51.5	65	59	0.86	7.67	7.73
2	73.5	38	66	38	73.5	46	0.32	8.62	8.12
3	85.5	22.5	80	21	86	24	1.84	11.59	12.75
4	60.5	54	57	27.5	73	60	3.97	9.95	12.12
5	62.5	49	56	25.5	73	60	3.98	10.44	12.48
6	51	85	50	59.5	59	87	0.90	7.05	7.09
7	82.5	31	76	15.5	88	40	6.91	12.69	15.08
8	83.5	29	71.5	8	87.5	43	16.84	16.33	23.13
9	52.5	54	51.3	52	61	67	2.34	8.69	9.76
10	82.5	31	76	15.5	88	40	6.91	12.69	15.08
CRITERIA A 36.1(c)(2),(3)			36	20	95	95	0.7 dB/1000 FT A 36.9(d)(2)	12 dB/100 M. A 36.1(c)(3)	

TABLE 3-19. ATMOSPHERIC DATA FOR NOISE ATTENUATION CALCULATIONS INCLUDING TEMPERATURE, RELATIVE HUMIDITY AND NOISE ATTENUATION CRITERIA (Airplane Height: 750 m.)

ATMOSPHERIC CONDITIONS							1/3 OCTAVE NOISE ATTENUATION 10M. to AIRPLANE		
WEATHER CONDITION (See Fig. 3-1 to 3-9)	HEIGHT 10M.		10M. to AIRPLANE						
			MIN		MAX		Δ∝ MAX/1000 FT 3150 Hz	∝ AVE/100 M 8000 Hz	∝ MAX/100 M 8000 Hz
	T°F	RH	T°F	RH	T°F	RH			
1	64	55	61	47	65	59	1.69	8 8	8.50
2	73.5	38	62.2	38	73.5	52	0.32	8.53	8.12
3	85.5	22.5	78	16	86	24	5.82	12.70	16.29
4	60.5	54	57	24	73	60	5.17	11.19	13.20
5	62.5	49	56	22	73	60	6.32	11.58	14.53
6	51	85	50	59.5	59	87	1.48	7.31	7.64
7	82.5	31	76	5	90.5	40	24.27	15.06	22.05
8	83.5	29	71.5	8	87.5	43	16.84	18.20	23.13
9	52.5	54	51.3	38	63	67	2.34	8.96	10.53
10	82.5	31	76	11	90.5	40	10.98	14.16	18.89
CRITERIA A 36.1(c)(2),(3)			36	20	95	95	0.7 dB/1000 FT A 36.9(d)(2)	12 dB/100 M. A 36.1(c)(3)	

TABLE 3-20 CALCULATED NOISE LEVELS FOR VARIATION IN TEMPERATURE AND RELATIVE HUMIDITY

MODEL 727-200, Height 439 M., Takeoff Condition

VARIATION IN TEMPERATURE AND RELATIVE HUMIDITY	SAE ABSORPTION DATA				ANSI ABSORPTION DATA			
	LOCATION OF ATMOSPHERIC MEASUREMENTS							
	A	B	C	D	A	B	C	D
	Height 10 Meters	Airplane Height	2-Pt.Ave of A&B	Layered Atmos.	Height 10 Meters	Airplane Height	2-Pt.Ave of A&B	Layered Atmos.
ATMOSPHERIC PROFILE 5								
0°, 0%	106.2	107.7	106.9	106.8	106.3	107.9	107.0	107.0
+2°,+0%	106.1	107.5	106.7	106.7	106.2	107.7	106.9	106.9
-2°,+0%	106.3	107.9	107.0	107.0	106.4	108.2	107.1	107.1
+0°,+2%	106.1	107.3	106.7	106.7	106.2	107.5	106.8	106.8
+0°,-2%	106.3	108.3	107.1	107.1	106.4	108.5	107.2	107.2
+2°,+2%	106.1	107.2	106.6	106.6	106.2	107.4	106.7	106.7
+2°,-2%	106.2	107.9	106.9	106.9	106.3	108.2	107.1	107.1
-2°,+2%	106.2	107.5	106.8	106.8	106.3	107.7	106.9	106.9
-2°,-2%	106.4	108.8	107.3	107.2	106.4	108.8	107.4	107.4
RANGE	0.3	1.5	0.7	0.6	0.2	1.1	0.7	0.6
STANDARD DEVIATION	0.1	0.5	0.2	0.2	0.1	0.5	0.2	0.2
ATMOSPHERIC PROFILE 3								
0°, 0%	106.7	107.3	107.0	106.8	106.9	107.5	107.2	107.0
+2°,+2%	106.4	106.9	106.6	106.5	106.7	107.0	106.8	106.7
-2°,-2%	107.2	108.2	107.6	107.4	107.3	108.4	107.8	107.5
RANGE	0.8	1.3	1.0	0.9	0.6	1.4	1.0	0.8
ATMOSPHERIC PROFILE 8								
0°, 0%	104.9	115.0	107.1	106.8	105.0	113.9	106.8	106.7
+2°,+2%	104.8	109.2	106.2	106.1	105.0	108.6	106.1	106.0
-2°,-2%	105.0	119.0	108.4	108.1	105.1	119.4	107.8	107.7
RANGE	0.2	9.8	2.2	2.0	0.1	10.8	1.7	1.7

TABLE 3-21 CALCULATED NOISE LEVELS FOR VARIATION IN TEMPERATURE AND RELATIVE HUMIDITY

MODEL 707-320, Height 449 M., Takeoff Condition

VARIATION IN TEMPERATURE AND RELATIVE HUMIDITY	SAE ABSORPTION DATA				ANSI ABSORPTION DATA			
	LOCATION OF ATMOSPHERIC MEASUREMENTS							
	A	B	C	D	A	B	C	D
	Height 10 Meters	Airplane Height	2-Pt.Ave of A&B	Layered Atmos.	Height 10 Meters	Airplane Height	2-Pt.Ave of A&B	Layered Atmos.
ATMOSPHERIC PROFILE 5								
0°, 0%	111.3	115.4	113.2	113.0	111.4	115.4	113.2	113.0
+2°,+0%	110.9	114.8	112.8	112.6	111.1	114.8	112.8	112.7
-2°,+0%	111.6	116.1	113.7	113.5	111.6	116.1	113.6	113.5
+0°,+2%	111.0	114.4	112.6	112.5	111.2	114.4	112.6	112.6
+0°,-2%	111.5	116.6	113.9	113.7	111.6	116.7	113.8	113.6
+2°,+2%	110.7	113.9	112.2	112.1	111.0	113.9	112.3	112.3
+2°,-2%	111.2	115.9	113.4	113.2	111.3	116.0	113.4	113.2
-2°,+2%	111.4	115.0	113.1	112.9	111.4	115.0	113.0	112.9
-2°,-2%	111.9	117.3	114.4	114.2	111.9	118.1	114.3	114.1
RANGE	1.0	3.4	2.2	2.1	0.9	4.2	2.0	1.8
STANDARD DEVIATION	0.4	1.2	0.7	0.7	0.3	1.4	0.7	0.6
ATMOSPHERIC PROFILE 3								
0°, 0%	112.5	114.4	113.4	113.0	112.4	114.4	113.3	112.9
+2°,+2%	111.4	113.2	112.3	111.9	111.7	112.9	112.3	112.0
-2°,-2%	114.1	116.5	115.2	114.7	113.6	116.7	115.0	114.4
RANGE	2.7	3.3	2.9	2.8	1.9	3.8	2.7	2.4
ATMOSPHERIC PROFILE 8								
0°, 0%	107.2	124.3	113.4	113.0	107.4	125.4	112.7	112.0
+2°,+2%	107.1	117.9	111.1	110.7	107.3	118.8	110.3	109.9
-2°,-2%	107.4	129.1	116.6	116.2	107.5	129.0	115.9	115.0
RANGE	0.3	12.2	5.5	5.5	0.2	10.2	5.6	5.1

TABLE 3-22 CALCULATED NOISE LEVELS FOR VARIATION IN TEMPERATURE AND RELATIVE HUMIDITY

MODEL DC-9, Height 455 M., Takeoff Condition

VARIATION IN TEMPERATURE AND RELATIVE HUMIDITY	SAE ABSORPTION DATA				ANSI ABSORPTION DATA			
	LOCATION OF ATMOSPHERIC MEASUREMENTS							
	A	B	C	D	A	B	C	D
	Height 10 Meters	Airplane Height	2-Pt.Ave of A&B	Layered Atmos.	Height 10 Meters	Airplane Height	2-Pt.Ave of A&B	Layered Atmos.
ATMOSPHERIC PROFILE 5								
0°, 0%	100.0	100.7	100.3	100.3	100.1	101.0	100.4	100.5
+2°,+0%	100.0	100.6	100.3	100.3	100.1	100.9	100.4	100.4
-2°,+0%	100.0	100.8	100.4	100.4	100.1	101.1	100.5	100.5
+0°,+2%	99.9	100.6	100.2	100.2	100.0	100.8	100.3	100.4
+0°,-2%	100.0	101.0	100.4	100.4	100.1	101.2	100.6	100.6
+2°,+2%	99.9	100.5	100.2	100.2	100.0	100.7	100.3	100.3
+2°,-2%	100.0	100.8	100.4	100.3	100.1	101.1	100.5	100.5
-2°,+2%	100.0	100.7	100.3	100.3	100.1	100.8	100.4	100.4
-2°,-2%	100.1	101.1	100.5	100.5	100.1	101.4	100.6	100.7
RANGE	0.2	0.6	0.3	0.3	0.1	0.7	0.3	0.4
STANDARD DEVIATION	0.1	0.2	0.1	0.1	0.0	0.2	0.1	0.1
ATMOSPHERIC PROFILE 3								
0°, 0%	100.3	100.5	100.4	100.3	100.4	100.7	100.6	100.5
+2°,+2%	100.1	100.3	100.2	100.2	100.3	100.5	100.4	100.4
-2°,-2%	100.5	100.9	100.7	100.6	100.6	101.2	100.9	100.7
RANGE	0.4	0.6	0.5	0.4	0.3	0.7	0.5	0.3
ATMOSPHERIC PROFILE 8								
0°, 0%	99.3	102.8	100.4	100.3	99.5	102.9	100.3	100.3
+2°,+2%	99.3	101.3	100.0	99.9	99.5	101.3	100.0	100.0
-2°,-2%	99.4	106.3	101.1	100.9	99.5	104.9	100.9	100.8
RANGE	0.1	5.0	1.1	1.0	0.0	3.6	0.9	0.8

TABLE 3-23 CALCULATED NOISE LEVELS FOR VARIATION IN TEMPERATURE AND RELATIVE HUMIDITY

MODEL 747, Height 458 M., Takeoff Condition

VARIATION IN TEMPERATURE AND RELATIVE HUMIDITY	SAE ABSORPTION DATA				ANSI ABSORPTION DATA			
	LOCATION OF ATMOSPHERIC MEASUREMENTS							
	A	B	C	D	A	B	C	D
	Height 10 Meters	Airplane Height	2-Pt.Ave of A&B	Layered Atmos.	Height 10 Meters	Airplane Height	2-Pt.Ave of A&B	Layered Atmos.
ATMOSPHERIC PROFILE 5								
0°, 0%	112.6	115.9	114.1	114.0	112.6	115.5	113.9	113.9
+2°,+0%	112.3	115.4	113.8	113.6	112.4	115.1	113.6	113.6
-2°,+0%	112.8	116.4	114.5	114.4	112.7	116.0	114.2	114.1
+0°,+2%	112.4	115.1	113.7	113.5	112.4	114.8	113.5	113.5
+0°,-2%	112.8	116.8	114.7	114.5	112.7	116.5	114.4	114.3
+2°,+2%	112.2	114.6	113.3	113.2	112.3	114.5	113.3	113.3
+2°,-2%	112.5	116.2	114.3	114.1	112.6	116.0	114.0	114.0
-2°,+2%	112.6	115.6	114.0	113.9	112.6	115.2	113.8	113.7
-2°,-2%	113.1	117.4	115.1	114.9	112.9	117.1	114.7	114.6
RANGE	0.9	2.8	1.8	1.7	0.6	2.6	1.4	1.3
STANDARD DEVIATION	0.3	0.9	0.6	0.6	0.2	0.9	0.5	0.4
ATMOSPHERIC PROFILE 3								
0°, 0%	113.6	115.0	114.3	114.0	113.5	114.8	114.1	113.8
+2°,+2%	112.8	114.1	113.4	113.1	113.1	113.8	113.4	113.2
-2°,-2%	114.7	116.7	115.7	115.3	114.3	116.4	115.2	114.8
RANGE	1.9	2.6	2.3	2.2	1.2	2.6	1.8	1.6
ATMOSPHERIC PROFILE 8								
0°, 0%	108.7	122.4	114.4	114.0	108.8	122.3	113.4	112.7
+2°,+2%	108.5	117.9	112.5	112.0	108.6	116.3	111.5	111.2
-2°,-2%	109.2	127.8	117.3	116.6	109.0	127.6	116.1	115.1
RANGE	0.7	9.9	4.8	4.6	0.4	11.3	4.6	3.9

TABLE 3-24 CALCULATED NOISE LEVELS FOR VARIATION IN TEMPERATURE AND RELATIVE HUMIDITY

MODEL DC-10-40, Height 454 M., Takeoff Condition

VARIATION IN TEMPERATURE AND RELATIVE HUMIDITY	SAE ABSORPTION DATA				ANSI ABSORPTION DATA			
	LOCATION OF ATMOSPHERIC MEASUREMENTS							
	A	B	C	D	A	B	C	D
	Height 10 Meters	Airplane Height	2-Pt.Ave of A&B	Layered Atmos.	Height 10 Meters	Airplane Height	2-Pt.Ave of A&B	Layered Atmos.
ATMOSPHERIC PROFILE 5								
0°, 0%	101.2	104.4	102.7	102.6	101.3	104.5	102.7	102.6
+2°,+0%	101.0	103.9	102.4	102.2	101.1	104.0	102.4	102.4
-2°,+0%	101.5	104.9	103.1	102.9	101.5	105.1	103.0	102.9
+0°,+2%	101.0	103.7	102.3	102.1	101.1	103.7	102.3	102.3
+0°,-2%	101.4	105.4	103.2	103.1	101.4	105.6	103.2	103.1
+2°,+2%	100.8	103.2	102.0	101.8	101.0	103.3	102.0	102.1
+2°,-2%	101.2	104.8	102.9	102.7	101.3	105.0	102.8	102.8
-2°,+2%	101.3	104.1	102.6	102.5	101.3	104.1	102.6	102.5
-2°,-2%	101.7	105.9	103.7	103.5	101.6	106.5	103.6	103.5
RANGE	0.9	2.7	1.7	1.7	0.6	2.9	1.6	1.4
STANDARD DEVIATION	0.3	0.9	0.6	0.6	0.2	1.1	0.5	0.5
ATMOSPHERIC PROFILE 3								
0°, 0%	102.2	103.6	102.9	102.6	102.2	103.7	102.9	102.6
+2°,+2%	101.4	102.7	102.0	101.8	101.8	102.6	102.1	101.9
-2°,-2%	103.3	105.3	104.3	103.8	103.1	105.5	104.2	103.7
RANGE	1.9	2.6	2.3	2.0	1.3	2.9	2.1	1.8
ATMOSPHERIC PROFILE 8								
0°, 0%	98.8	111.4	103.0	102.6	99.0	114.3	102.2	101.7
+2°,+2%	98.7	106.5	101.1	100.7	99.0	106.8	100.4	100.3
-2°,-2%	99.0	115.8	105.6	105.1	99.1	119.5	104.8	104.0
RANGE	0.3	9.3	4.5	4.4	0.1	12.7	4.4	3.7

TABLE 3-25 CALCULATED NOISE LEVELS FOR VARIATION IN TEMPERATURE AND RELATIVE HUMIDITY

MODEL L-1011, Height 492 M., Takeoff Condition

VARIATION IN TEMPERATURE AND RELATIVE HUMIDITY	SAE ABSORPTION DATA				ANSI ABSORPTION DATA			
	LOCATION OF ATMOSPHERIC MEASUREMENTS							
	A	B	C	D	A	B	C	D
	Height 10 Meters	Airplane Height	2-Pt.Ave of A&B	Layered Atmos.	Height 10 Meters	Airplane Height	2-Pt.Ave of A&B	Layered Atmos.
ATMOSPHERIC PROFILE 5								
0°, 0%	100.3	105.0	102.3	102.1	100.5	105.1	102.1	101.9
+2°,+0%	100.1	104.3	101.7	101.6	100.4	104.2	101.6	101.5
-2°,+0%	100.8	105.8	102.9	102.7	100.7	106.1	102.7	102.5
+0°,+2%	100.2	103.8	101.6	101.4	100.4	103.7	101.4	101.4
+0°,-2%	100.7	106.5	103.1	102.9	100.6	107.7	102.9	102.7
+2°,+2%	100.0	103.2	101.2	101.1	100.2	103.0	101.2	101.2
+2°,-2%	100.3	105.7	102.5	102.3	100.5	106.0	102.3	102.1
-2°,+2%	100.3	104.5	102.1	102.0	100.5	104.5	101.9	101.7
-2°,-2%	100.9	107.4	103.7	103.6	100.8	109.3	103.6	103.4
RANGE	0.9	4.2	2.5	2.5	0.6	6.3	2.4	1.5
STANDARD DEVIATION	0.3	1.4	0.9	0.7	0.2	2.1	0.8	0.8
ATMOSPHERIC PROFILE 3								
0°, 0%	101.5	103.7	102.6	102.1	101.4	103.7	102.2	101.7
+2°,+2%	100.5	102.3	101.3	101.1	100.9	101.7	101.2	101.1
-2°,-2%	103.4	106.3	104.8	104.1	102.6	107.8	104.8	103.7
RANGE	2.9	4.0	3.5	3.0	1.7	6.1	3.6	2.6
ATMOSPHERIC PROFILE 8								
0°, 0%	98.4	115.6	102.6	102.1	98.5	118.2	101.7	101.4
+2°,+2%	98.3	108.1	100.2	100.1	98.4	109.5	100.2	100.2
-2°,-2%	98.5	119.8	105.1	105.5	98.6	122.5	104.7	104.5
RANGE	0.2	11.7	4.9	5.4	0.2	13.0	4.5	4.3

4.0 AVERAGING OF DATA SAMPLES

An aircraft jet engine is a source of random, fluctuating noise. To get a stable, meaningful reading of this noise level requires that the signal be integrated over an appropriate time period. The dynamic characteristics of a sound level meter in the "slow" response setting have been widely accepted for such measurements, and have been incorporated into FAR PART 36 expressly in Paragraph A36.3(d)(5) and by reference to the IEC 179 and IEC 225 standards. The implications of these standards, as set forth in IEC 561, Paragraphs 7 and 8 and in Appendix A, A.3, are that the effective averaging period for such an integrator is 1500 msec., so that the instant in time by which a 500 msec. sampling interval is characterized as 750 msec. before its termination.

To simulate a sound level meter which uses an RC averaging circuit, and so uses continuous exponential averaging, with a digital analyzer that produces results based on averaging over discrete time periods, various methods of "smoothing" the data have been used.

4.1 Linear Smoothing

If the analyzer produces results every 1/2 sec. (consecutively designated 1,2,3,4,5, etc.), these can be combined in groups of three to give an averaging period of 1500 msec., as specified in IEC 561.8. In the "linear smoothing" method, three sample levels (1,2,3) are combined (by power addition) and the result divided by 3 before reconversion to dBs according to the equation:

$$SPL_k = 10 \log_{10} \sum_{i=1}^{3} \frac{10^{\frac{SPL_i}{-10}}}{3}$$

where SPL_k is the averaged level characterized by the time instant 750 msec. before the end of sample 3.

The averaged level is characterized by the instant in time 750 msec. before the end of the last of the 3 samples (sample 3). Three more samples (2,3,4) are similarly averaged, and the instant characterizing this averaged result is therefore 750 msec. before the end of sample 4, and thus 500 msec. after the instant characterizing the previous averaged sample. This method gives successive data read-outs every 500 msec., which have an averaging time of 1500 msec.

4.2 Exponential Smoothing

In the "exponential smoothing" method all preceding samples are taken into account, as is true of an RC integrator. The effective averaging time of an RC integrator of time constant τ is 2τ , and the "smoothed" or averaged result after samples, A_r, is given by

$$S_r = A_{r-1} + \frac{T_r - A_{r-1}}{\tau}$$

where T_r is the value of the r^{th} sample

A_{r-1} is the average value for r-1 samples.

With a sound level meter, all previous input signals affect its reading at any instant, by however slight an amount. This is simulated digitally by using all available 1/2 sec. discrete readings and summing them on a power basis using the above formula with τ = 750 msec. This gives an effective averaging time of 1500 msec. and results are produced every 500 msec., as required.

4.3 Comparison of Noise Data Averaging Methods

Comparison of EPNLs calculated with exponentially smoothed, linearly smoothed and unsmoothed 1/2 second samples of 1/3 octave SPL data were made. In the exponential smoothing, all previous 1/3 octave data values were combined to simulate an equivalent RC integrator with a time constant (RC) of .75 sec. and an effective integration time of 1.5 seconds, samples being taken every 1/2 second. In the linear smoothing, three 1/2 second samples were averaged to give an integration time of 1.5 seconds, and again samples of the smoothed data were taken every .5 seconds.

Data were taken from 5 airplane models, using one recording of a takeoff condition and one of a landing for each type. The resulting EPNLs are shown in Table 4-1. In two out of the 10 cases, the range in values was 0.0 dB, in seven it was 0.1 dB and for the remaining one it was 0.2 dB.

The mode of averaging does not appear significant, nor does the difference between smoothed and unsmoothed data.

TABLE 4-1. EFFECT OF DATA AVERAGING METHODS ON EPNL

AIRPLANE	1/2 Sec. Average Unsmoothed	1.5 Sec. Effective Averaging Time		RANGE
		Exponential	Linear	
Take-off				
A300	89.6	89.6	89.6	0.0
DC-10	93.9	93.7	93.7	0.2
DC-9	101.0	100.9	100.9	0.1
DC-8	112.4	112.5	112.5	0.1
727	111.9	111.9	111.9	0.0
Landing				
A300	102.7	102.6	102.7	0.1
DC-10	103.2	103.3	103.3	0.1
DC-9	107.3	107.3	107.4	0.1
DC-8	111.1	111.1	111.2	0.1
727	101.5	101.4	101.5	0.1

5.0 PROPAGATION OF ERROR

Two principal kinds of errors of which we must be aware are those that are independent of or dependent on each other. The first is characterized by the fact that in the measurement of several quantities such as temperature, relative humidity, and airplane speed, the quantities are measured by different kinds of instruments and the reading of one does not affect the others. The effects of these errors are combined in a manner similar to vectors. Where S_V is the standard deviation of a single value of V due to combined errors in x and y.

$$S_V = \sqrt{\left(\frac{2V}{2X}\right)^2 S_x{}^2 + \left(\frac{2V}{2Y}\right)^2 S_y{}^2 + \ldots}$$

There is a probability partial cancellation of errors.

On the other hand, when a series of measurements depend on those made by a single instrument which is not properly calibrated, system errors add directly, according to the relation

$$dV = \frac{2V}{2X} dx + \frac{2V}{2y} dy, \ldots$$

where dV is the error in V (x,y) which is the quantity being measured. Temperature and relative humidity could fall in this category for example, if they were obtained from wet and dry bulb thermometers.

The combination of tracking errors and those from weather corrections could fall in either category, while those due to averaging methods are generally small enough to be insignificant.

6.0 RECOMMENDATIONS

Recommendations are made in the three areas of aircraft position monitoring, sound level atmospheric correction and data averaging (smoothing).

6.1 Aircraft Position

There are three main candidates for aircraft position monitoring: theodolite, camera, and radar, all of which are recommended.

6.1.1 *Theodolite*

The theodolite in principle has no fundamental flaws, but may be awkward to operate. With photographic or electronic recording of data, it is generally suitable for airplane certification when haze or lighting conditions do not render it unusable. Both of these conditions are candidates for further development work.

6.1.2 *Camera*

Ground or airplane-mounted cameras are accurate and, in principle, simple position monitoring installations. Results are positive and produce permanent records.

6.1.3 *Radar*

Tracking radar (33 GHz) and laser both produce excellent results. Auxiliary airplane installations such as corner reflector or retroreflector are required for unambiguous results.

6.1.4 *Costs*

Tracking and laser radar installations each would cost approximately $500,000. A theodolite installation supplemented by R.F. range equipment would cost approximately the same amount. Aircraft-mounted or ground-mounted camera installations would run up to $15,000.

6.2 Atmospheric Correction

Recommendations are made for atmospheric correction method and data measurement accuracy.

6.2.1 *Method*

The data in Tables 3.1 to 3.19 show that for atmospheric conditions within the FAR 36 requirements, weather corrections using the two-point average (airplane and ground) and the layered atmosphere model, the corrected EPNLs are not significantly different. Therefore, it is recommended that the two-point method be used in lieu of the layered atmosphere.

6.2.2 *Temperature and Relative Humidity Measurement Accuracy*

Tables 3-20 to 3-25 show that for reasonable weather profiles (approximating FAR 36 requirements), sound level corrections calculated with the two-point average method and with the layered atmosphere model having temperature variations of ±2°F (±1.1°C) and variations in relative humidity of ±2% yield results compatible with FAR 36 EPNL reliability requirements. It is, therefore, recommended that these limits be adopted as criteria.

6.3 Averaging

Table 4.1 shows that for 1/3 octave SPL data from a variety of airplanes using exponential or linear averaging the EPNL is not significantly different. With no smoothing, the results are similar. Therefore, it is recommended that smoothing not be required.

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