PAA-77-15

REPORT NO. FAA-RD-77-116

INVESTIGATION OF WIND CONDITIONS DURING EARLY MORNING HOURS AT LOS ANGELES INTERNATIONAL AIRPORT

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OCTOBER 1977
FINAL REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research and Development Service
Washington DC 20591

Technical Report Documentation Page

1. Report No. FAA-RD-77-116	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle INVESTIGATION OF WIND CONDITIONS DURING EARLY MORNING HOURS AT LOS ANGELES INTERNATIONAL AIRPORT		5. Report Date October 1977
		6. Performing Organization Code
7. Author(s) M.C. Krause, W.R. Eberle, G.M. Miller, and E.J. Gorzynski.		8. Performing Organization Report No. DOT-TSC-FAA-77-15 LMSC-HREC TR D497095
9. Performing Organization Name and Address Lockheed Missiles & Space Company, Inc.* Huntsville Research & Engineering Center 4800 Bradford Drive Huntsville AL 35807		10. Work Unit No. (TRAIS) FA742/R8105
		11. Contract or Grant No. DOT-TSC-1190
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Systems Research and Development Service Washington DC 20591		13. Type of Report and Period Covered Final Report April 1976-December 1976
		14. Sponsoring Agency Code

15. Supplementary Notes

*Under Contract to: U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge MA 02142

16. Abstract

Los Angeles International Airport (LAX) uses a unique runway utilization pattern to minimize noise pollution between midnight and 0600. During these hours, all approaches are conducted to the east, and all takeoffs are conducted to the west. The low-altitude portions of all takeoff and landing operations are thereby conducted over the Pacific Ocean. During these operations, pilots have occasionally reported encountering unusual wind conditions. It is the objective of this study to use the Lockheed-Huntsville mobile laser Doppler unit velocimeter unit to monitor winds and wake vortices in the approach zone of runway 6R to identify the sources of the wind anomalies reported by the pilots. No incidents of pilot-reported wind anomalies occurred during the five-week data collection period.

17. Key Words Wind Shear Wake Vortices Noise Abatement Los Angeles International Airport	18. Distribution Statement This document is available to the U.S. public through the National Technical Information Service, Springfield VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	84	

Form DOT F 1700.7 (8-72)

PREFACE

The work described in this report was initiated for the purpose of identifying the source of wind anomalies reported by pilots on final approach to Los Angeles International Airport during early morning hours. During these hours, all approaches are conducted to the east, and all takeoffs are conducted to the west. The low-altitude portions of all takeoff and landing operations are thereby conducted over the Pacific Ocean.

The Lockheed-Huntsville mobile laser Doppler velocimeter system was used to measure winds to an altitude of 150 m and to measure the trajectories of aircraft wake vortices – particularly for aircraft on takeoff. Data were recorded on magnetic tape. The intent of the work described in this report was to record data as continuously as possible and to perform off-line data processing for the time periods during which wind anomalies were reported by pilots. A formal report which identified the source of the pilot-reported wind anomalies would then be written.

During the data measurement period, no pilot-reported wind anomalies occurred. Therefore, off-line data reduction was performed for only a few sample cases. Since no pilot-reported wind anomalies were reported, an informal report was deemed as the most appropriate reporting procedure. Therefore, this report contains a very brief description of the mobile laser Doppler velocimeter system used. Refer to the reports listed in Section 6 for a more detailed description of the system and its capabilities.

The reader should be aware that much of the material in Section 4 is based upon observations made by the test crew at the test site. Normal processing of data for the laser Doppler velocimeter system in its configuration for the subject tests requires off-line computer processing. However, because no pilot-reported anomalies were reported, little off-line data processing was performed. Therefore, the results discussed in Section 4 should be construed as the result of a quick-look analysis and should not be construed as the result of a detailed analysis based on off-line processing of the data. The data tapes currently reside at Lockheed-Huntsville and may be processed.

Lockheed-Huntsville appreciates the assistance of Bert Lockwood of the Los Angeles International Airport for his help in the data-collection portion of this test.

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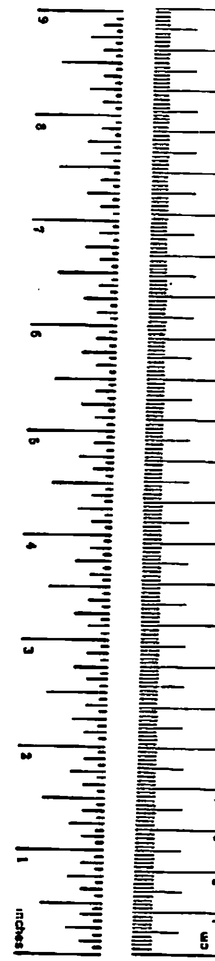
METRIC CONVERSION FACTORS

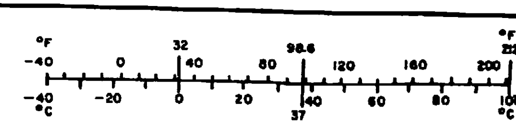
Approximate Conversions to Metric Measures

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



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



1. INTRODUCTION

Los Angeles International Airport (LAX) uses a unique runway utilization program to minimize noise pollution in the airport vicinity. Between midnight and 0600 local times, all takeoffs and approaches are conducted to and from the west over the Pacific Ocean on runways 6R-24L and 7L-25R. During these nightime approaches, aircraft have often been reported to overfly the glideslope. Pilots have attributed this to strange wind patterns and, possibly, to wind shear. With approaches and takeoffs from the same end of the runway, some incidents which may be attributable to wake vortices have been reported, although, at the present time, there is no evidence to support this assumption.

The Lockheed-Huntsville mobile Laser Doppler Velocimeter (LDV) unit has been used to monitor the winds and wake vortices in the approach zone to runway 6R. The results from the effort are presented in this document, which includes a detailed discussion of the problem, a brief description of the instrumentation, and a brief analysis and discussion of the data and conclusions.

2. DISCUSSION OF PROBLEM

2.1 STATEMENT OF PROBLEM

To minimize aircraft noise pollution in the vicinity of LAX, departure and approach operations are conducted to and from the west over the Pacific Ocean for runways 24L-6R and 25R-7L after midnight. Pilots have occasionally reported encountering wind anomalies during these operations.

Conversations between Lockheed-Huntsville personnel and pilots, flight controllers, and FAA officials at LAX have established the following general characteristics of the encounters of unusual wind conditions:

Wind-anomaly encounters produce uncomfortable and potentially hazardous variations in aircraft position and attitude.

Encounters occur intermittently.

Wind-anomaly encounters occur primarily for landing aircraft on final approach at low altitudes.

Lighter aircraft such as B-727s appear to be more susceptible to wind-anomaly encounters than the heavier B-747s and DC-10s.

Encounter of wind anomalies is of particular concern to pilots during low-visibility IFR approach conditions when the work load is large.

At present, the occurrence of wind-anomaly encounters has not been correlated with trailing vortex, wind shear, or atmospheric turbulence characteristics.

2.2 BACKGROUND

Noise abatement takeoff and landing operations at LAX involve take-offs and landings on the same or an adjacent parallel runway at two-minute intervals. Typical noise-abatement flight profiles for runway 24L-6R at LAX are shown in Fig. 1. Note that under no-wind conditions, the wake

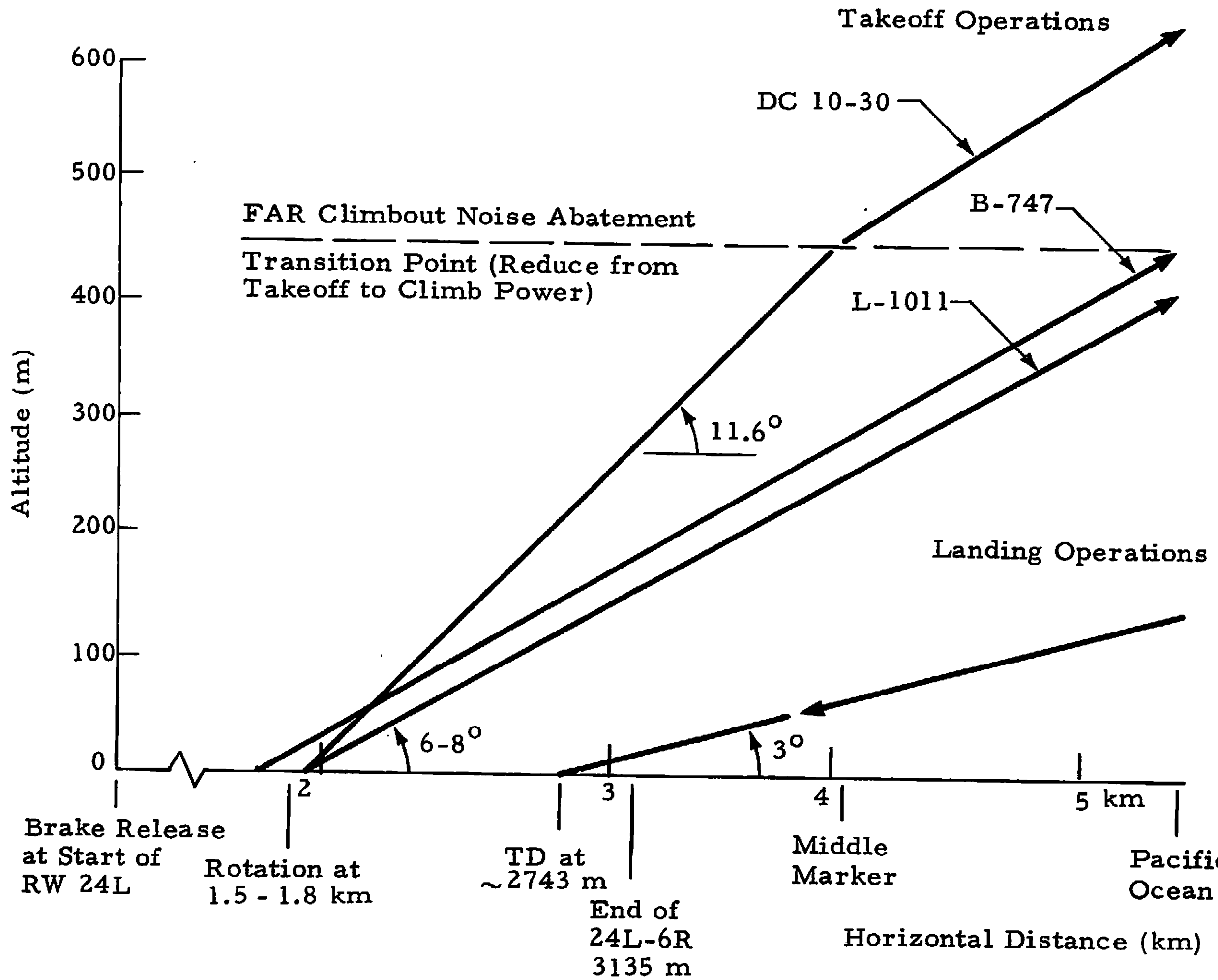


FIGURE 1. NOISE ABATEMENT TAKEOFF AND LANDING PROFILES ON RUNWAY 24L-6R AT LOS ANGELES INTERNATIONAL AIRPORT.

vortex from the takeoff aircraft can drift downward into the landing corridor. For example, at the middle marker location, the flight path of an L-1011 in takeoff is approximately 190 m above the landing glideslope. Assuming a typical vortex-descent rate of 1.9 m/sec for the L-1011 in takeoff configuration, the wake vortex could interfere with landing operations 98 sec later if the vortex has not decayed. A horizontal wind component aligned with the axis of the trailing vortex from the takeoff aircraft (such as a headwind or a tailwind) tends to delay the vortex drift from the takeoff corridor to the landing corridor, but the hazard may still exist.

Figure 1 also suggests that the wake vortex from landing operations could drift horizontally into the takeoff corridor. However, the distance between touchdown and takeoff point is approximately 900 m, so that even for a 10-knot tailwind landing case, the time period required for this to occur is too large (~3 min) to expect a vortex to maintain sufficient strength to affect an aircraft.

In addition to wake turbulence, a land breeze, wind shear, and uneven terrain may contribute to the wind-anomaly encounters at LAX. The landing corridors for runways 6R and 6L pass over rolling shoreline terrain which can introduce wind anomalies into the atmospheric boundary layer.

3. INSTRUMENTATION

3.1 MOBILE ATMOSPHERIC UNIT CAPABILITIES

The Lockheed Mobile Atmospheric Unit (MAU) (Figs. 2 and 3) used in this test program measures a velocity component of ambient atmospheric particulate matter within the sensing volume. The quantity measured is the magnitude of the velocity component in the line-of-sight direction between the MAU and the sensing volume. The magnitude of this velocity component is hereafter called line-of-sight velocity. The operating characteristics of the MAU are summarized as follows:

Scan Modes

1. Range or Line Scan
2. Elevation
3. Velocity Azimuth Display (VAD)
4. Arc Scan.

VAD Mode (used for measurement of atmospheric winds)

1. Measurement Altitude: 16 m to 865 m
2. Measurement Time per Altitude: 5 sec
3. Velocity Measurement Threshold: 0.5 m/sec
4. Measurement Accuracy: Velocity — ±0.5 m/sec
   Direction — ±3 deg.

System Output

1. Range
2. Elevation
3. Altitude
4. Azimuth
5. Horizontal Velocity Component
6. Vertical Velocity Component
7. Wind Direction
8. Line-of-Sight Velocity.

A complete description of the principles of operation of the LDV system, operating capabilities, and data-processing techiques is given in Refs. 1 and 2.

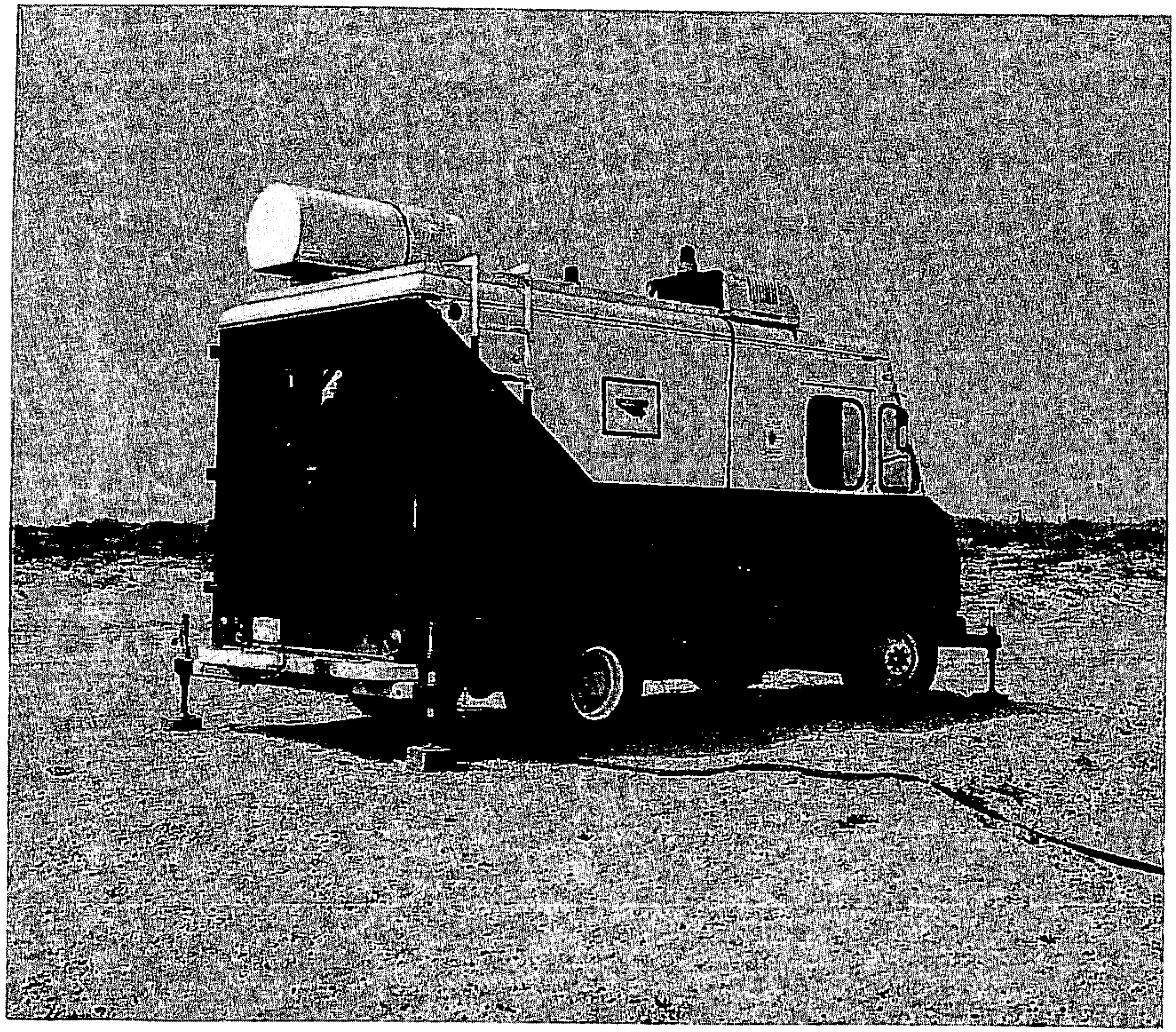


FIGURE 2. MOBILE ATMOSPHERIC UNIT.

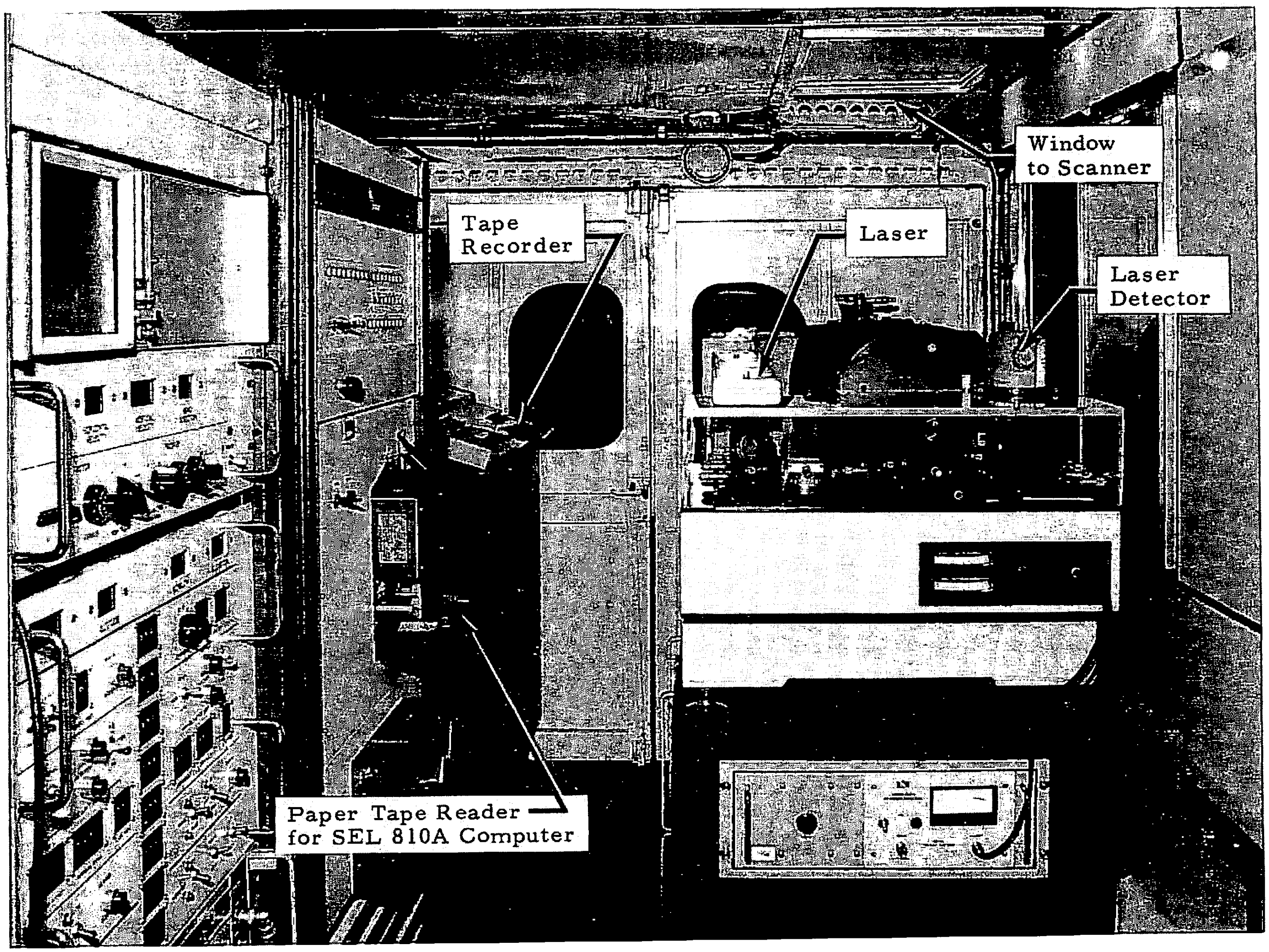


FIGURE 3. MOBILE ATMOSPHERIC UNIT INTERNAL VIEW OF LASER DOPPLER VELOCIMETER AND INSTRUMENTATION.

The velocity resolution of the MAU is determined by the signal/noise characteristics of the system as well as the atmospheric aerosol particle-size distribution. Significantly, the MAU can operate even under adverse snow and rain conditions since a strong signal can be obtained from the air-borne particles.

The spatial resolution of the MAU is determined by the size of the laser beam-sensing volume where the beam is focused. The sensing volume is approximately needle-shaped with a diameter of approximately 2 cm and a length as follows:

Range to Focus (m)	Sensing Volume Length (m)
30	0.3
100	3.2
200	12.8
400	51.2

Although a signal is returned from the entire sensing volume, the signal strength per unit length of sensing volume is greatest near the center of the volume. The limits of the sensing volume (in the length direction) are defined as the points at which the signal intensity per unit length is half that at the center of the sensing volume.

In addition to the focal volume spatial resolution, the sampling rate of the MAU plays an important role in determining the overall resolution of the system. Since the sampling rate is a function of the selected scan mode, it must be considered separately for each type of operation: the arc scan (i.e., elevation scan), finger scan, and VAD modes.

3.2 OPERATING MODES OF MOBILE ATMOSPHERIC UNIT HARDWARE

3.2.1 Multimode Scan System

The LDV system is equipped with a high-resolution pointing-and-scanning system which allows the system to be used in several operational modes, depending on the test parameters (Fig. 4).

3.2.2 Line of Sight

The basic operating mode is the line of sight where the output beam is directed out of the van side window. Micrometer adjustments allow elevation changes of -10 to +60 degrees, azimuth of 0 to 15 degrees, and range adjustments of 16 to 999 meters (measured from the telescope primary mirror).

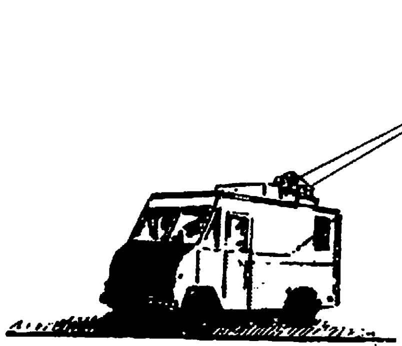
3.2.3 Range and Elevation Auto Scan

A high-resolution, high-speed scan system which automatically scans in range and/or elevation is installed:

Range	Adjustable Limits	16 to 999 m
	Adjustable Rate	0.1 to 6.9 Hz
Elevation	Adjustable Limits	0 to 90 deg
	Adjustable Rate	0.1 to 0.8 Hz
Combined	Operation of range and elevation simultaneously results in a finger-scan pattern.	

3.2.4 Velocity Azimuth Display Mode

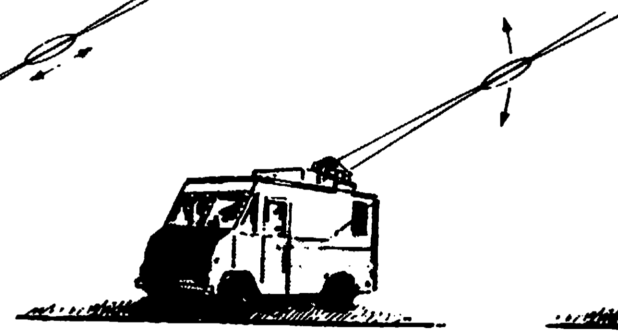
A set of mirrors mounted on a turntable is attached to the top of the van over the ceiling window. By rotating the mirrors, the output laser beam is directed around a circle whose diameter is set by the elevation angle of the output mirror and the range setting of the LDV.



RANGE SCAN

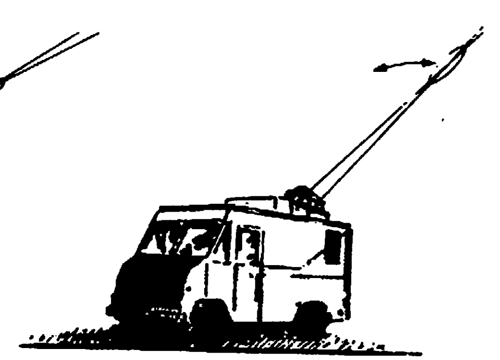
Limits		Rates
Upper	Lower	
100 to 999 m	16 to 989 m	0.1 to 6.9 Hz
One-meter increment		0.1-Hz increm.

Also can be stepped between 8 pre-selectable ranges.



ELEVATION SCAN

Limits		Rates
Upper	Lower	
10 to 90°	0 to 90°	0.1 to 0.5 Hz
1-deg. increment		0-1 Hz increm.

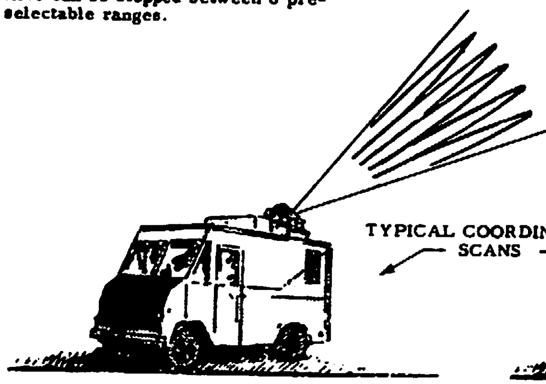


AZIMUTH SCAN

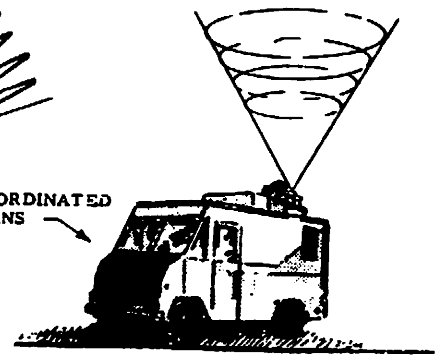
Currently 360° open loop operation. Can be modified for closed loop pointing and scanning.

Note:

- Maximum Sampling Rate: 70 Hz



TYPICAL COORDINATED SCANS



Range - Elevation

(for vortex tracks, plume tracks, etc.)

Range - Azimuth

(for wind measurement)

FIGURE 4. SCAN CAPABILITIES OF LASER DOPPLER VELOCIMETER.

The range controller has a sequencer mode whereby a set of ranges or altitudes can be preselected. When activated, the range sequences through the limits at a rate of one step per revolution of the VAD scanner. Thereby, a series of eight altitudes can be scanned in ~ 40 seconds to give a profile of the wind velocity at altitude. The maximum altitude is 865 meters (999-m range at 60-deg elevation angle), and the minimum is 16 meters.

3.3 SIGNAL PROCESSING AND DATA RECORDING

To yield a line-of-sight velocity, a voltage which has the same time behavior as the Doppler shift, f_d, is generated. By far, the most economical method of generating the voltage is a sampled spectrum analyzer incorporating a high-quality "front end" with accurately calibrated frequency/voltage analog. The only deficiency is that the entire domain of expected Doppler shift frequencies must be scanned for each time sample to find that region actually occupied by the signal, and this scanning must be done at a rate which is sufficiently slow to permit the narrowband filter of the spectrum analyzer to reach its full value. A typical spectrum analyzer signature is shown in Fig. 5. Since the conical scan cycle time is of the order of 5 sec, the limitation on scan speed (and hence, sampling rate) does not cause any difficulties in this application.

A Lockheed-developed signal tracker-processor converts the spectrum-analyzer output into a direct velocity readout. When operated in conjunction with the VAD scan system, the processor uses the scan position and range inputs to give an integrated output of horizontal velocity, vertical velocity, and wind direction. This is updated at each new altitude. Outputs are available in both digital and analog form.

The data acquired by the MAU are formatted by the computer software for the SEL 810A (the on-line minicomputer for the MAU) and stored on magnetic tape for subsequent processing. A SEL 7-track tape control unit and two magnetic tape units will allow digital recording of data at 200, 556, and 800 bytes per inch at 45, 75, 120, or 150 ips.

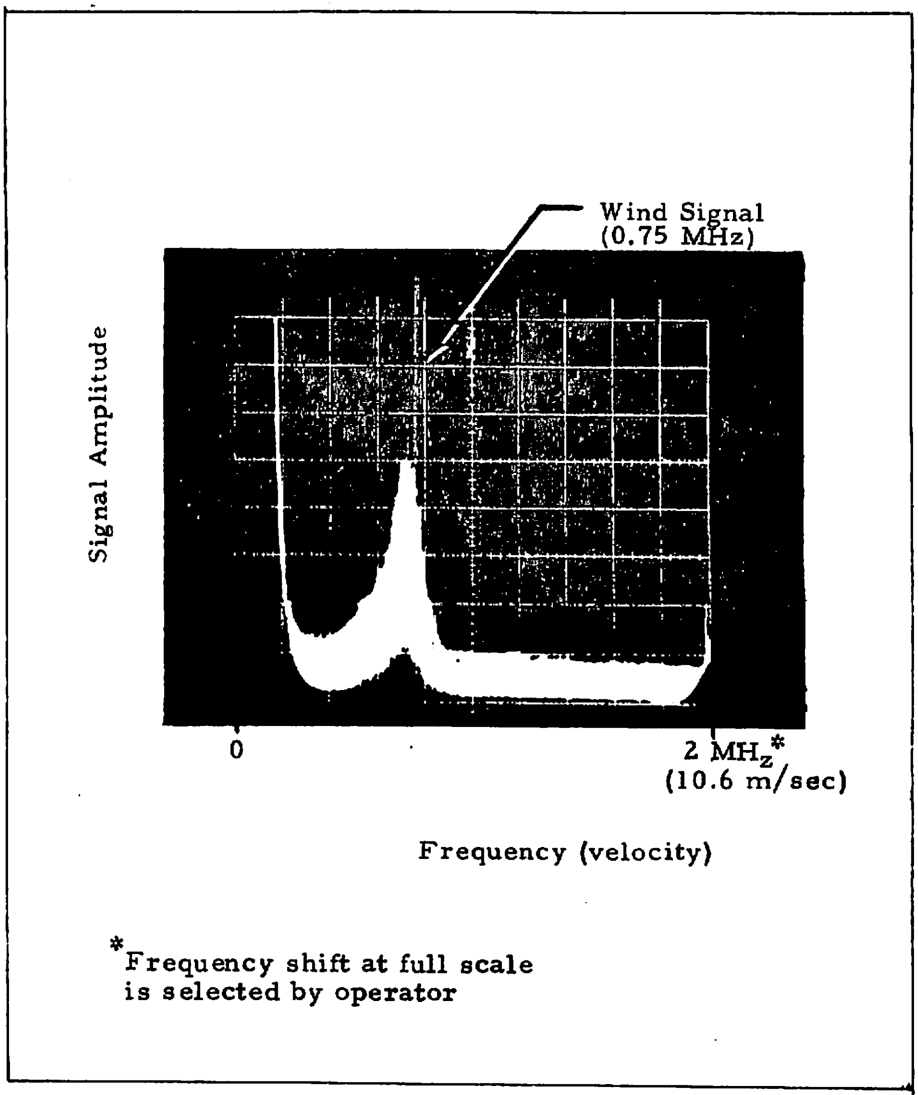


FIGURE 5. TYPICAL LASER DOPPLER VELOCIMETER WIND SIGNATURE AS DISPLAYED BY SPECTRUM ANALYZER.

4. TEST RESULTS

A field measurement program was designed to measure remotely wake vortices, wind speed, and wind direction, and to detect shear or turbulence in the approach corridor to runway 6R at LAX. Test operations began on 17 April 1976 and were completed on 20 May 1976. Operations were conducted between the hours of midnight and 0600 PST to coincide with noise procedures in effect at LAX which required all aircraft to takeoff and land over the ocean (i.e., in opposite directions) using inboard runways 6R and 7L. This procedure was used until a tailwind exceeded 10 knots or the runway was closed because of fog.

The test site was located on a sand dune, near the ILS instrumentation building, on the approach to runway 6R. The site was approximately 490 m from the runway threshold and 88 m north of the runway centerline (Fig. 6). At this position, the aircraft passed over the van at an altitude of 23 to 30 m during approach and from 30 to 610 m on takeoff. Runway 6R was used by all wide-body aircraft (B-747, DC-10, and L-1011) because 7L has a bridge near the middle of the runway which is not stressed for the heavier aircraft.

The LDV system arrived at the LAX maintenance facility on 14 April 1976, with the test crew arriving 15 April 1976. The system was moved to the site on 16 April and was operational by 17 April. The setup and system calibration took six hours; however, an additional five hours were required to get the power installed. A short circuit developed in the slip-ring assembly, which required five hours of troubleshooting and repair.

Test operations began at 2215 when the crew arrived at the site. This allowed ample time to warm up the system and check calibrations in order to become operational by 2330. Aircraft began landing on 6R between 2330 and

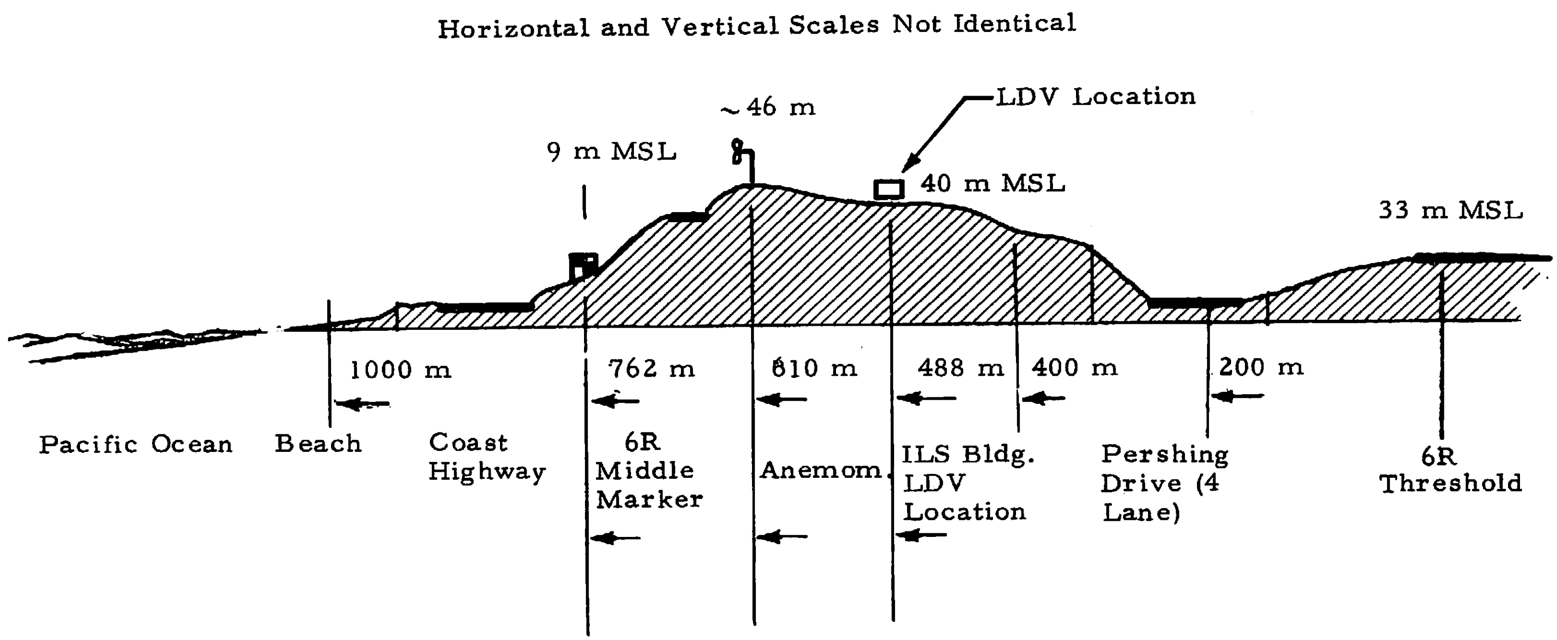


FIGURE 6. ELEVATION PROFILE OF APPROACH TO RUNWAY 6R AT LOS ANGELES INTERNATIONAL AIRPORT.

and 2345. The last aircraft landed at approximately 0600, and the system was recalibrated and then shut down by 0630.

Data were recorded on 23 nights for a total time of approximately 172 hours. Appendix A is a sample set of logs for the test period. Actual VAD data recording was 85.25 hours; the remainder of the time was in the vortex tracking mode. The laser was operated for approximately 200 hours. Down time caused by system problems was 11 hours, of which only 3 hours occurred during a peak operating period (laser water pump changed). During the entire test period, the system operation was very stable and required realignment once (following a weekend when the temperature change was greater than normal). Range calibration was checked twice each day but required adjustment only once during the entire test period.

During the test period, a total of 650 aircraft flybys were recorded; of these 338 were landings and 312 were takeoffs. Figure 7 shows a B-747 takeoff over the test site.

The wind and weather conditions encountered during the test period are given in Table 1. Note that on two occasions (20 April and 11 May), the runway was closed due to heavy fog and on 23 April was closed due to tailwinds in excess of 12 knots.

4.1 WINDS ALOFT MEASUREMENT

The first week of the test period was dedicated primarily to measuring winds and noting any wind shear conditions or other atmospheric peculiarities. During the remainder of the test, primary concern was devoted to tracking wake vortices except when conditions dictated the VAD mode. Criteria for recording VAD data were winds 240 deg (tailwind) at greater than 6 knots or 060 deg (headwind) at greater than 10 knots. When the wind velocity was below these levels, vortex data were recorded.

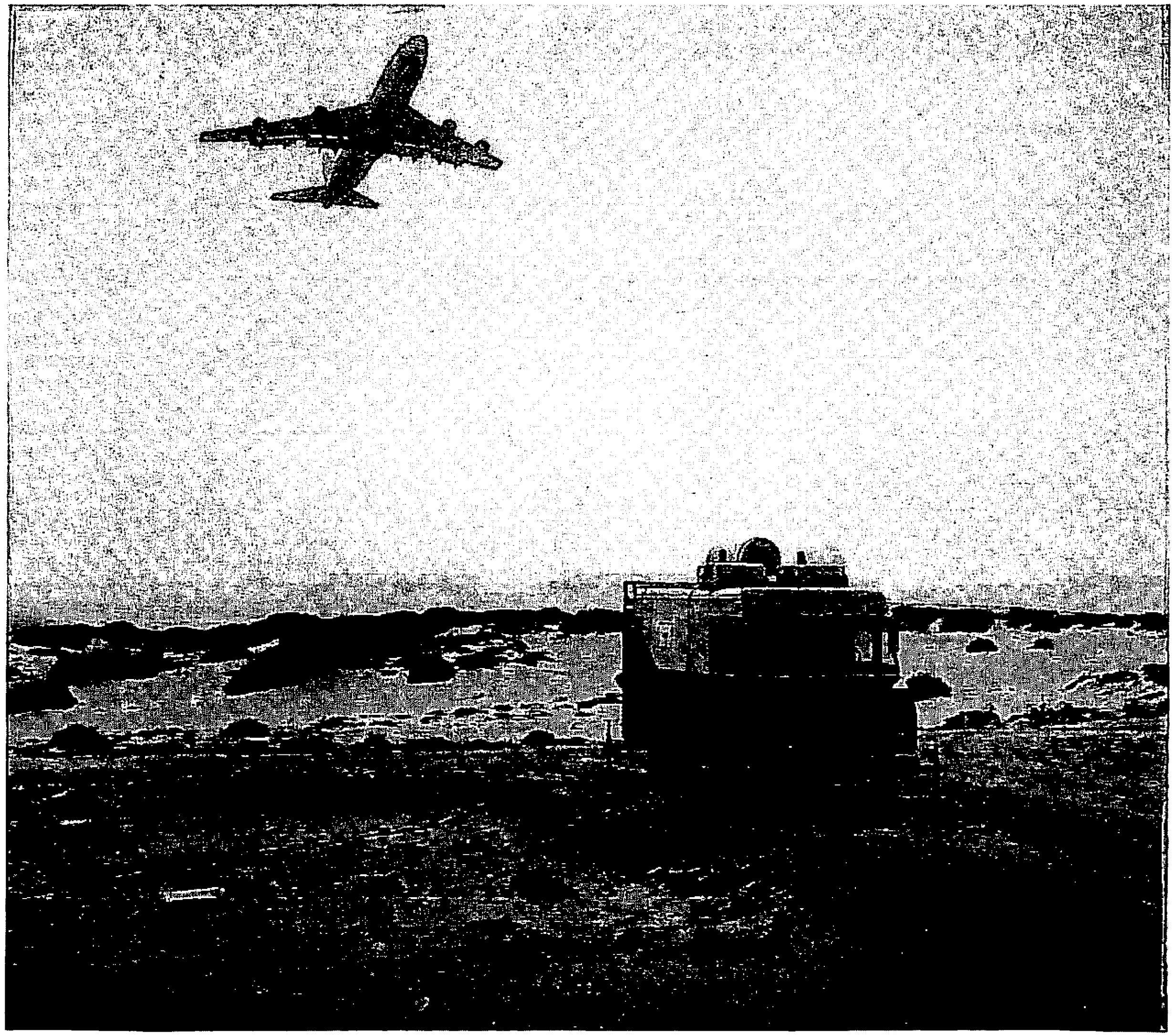


FIGURE 7. MOBILE ATMOSPHERIC UNIT DURING B-747 TAKEOFF ON LOS ANGELES INTERNATIONAL AIRPORT RUNWAY 6R.

TABLE 1. METEOROLOGICAL DATA TAKEN DURING LOS ANGELES INTERNATIONAL AIRPORT TESTS

Date (1976)	Wind Dir./ Speed (deg/knots)	Temp. (F)	Dew Point (F)	Visibility (mi.)	Ceiling (ft)
4-19	090/4	55	—	10-20	Clear
4-20	160/3-240/5	56	—	8-10	2500, Fog at 400 ft (6R Closed 0400)
4-21	080/9	59	—	12	1500
4-22	250/5-7	55	33	10-15	2300 Broken
4-23	240/7	56	53	7	High Clouds (Closed 6R High Tailwinds)
4-26	090/8	56	—	—	—
4-27	060/7	56	46	15	3200 Broken
4-28	050/5	56	52	10	Clear
4-29	040/4	56	54	10	Clear
4-30	110/5	63	—	15	Clear
5-3	180/5	60	53	12	4000 Overcast 2800 Scat.
5-4	220/6	58	54	8	2800 Broken
5-5	070/8	59	53	14	2700 Overcast 1700 Scat.
5-6	020-090/5	58	—	15	4400 Overcast 2500 Scat. (Rain)
5-7	160/7	59	—	12	2500 Overcast
5-10	250/5	60	57	10	1100 Broken
5-11	Calm	60	58	10	Fog (Closed 6R at 0200)
5-12	060/5	62	58	5	800 Broken, Haze
5-13	080-240/4	61	58	4	900 Overcast
5-14	160-080/3	59	56	3	800 Overcast, Haze
5-17	170-360/4	59	—	10	1300 Broken
5-18	180/5	60	—	10	Clear
5-19	320-180/5	58	54	7	2500 Broken, 1500 Scat.

Winds at LAX during the test period were normally light (i.e., less than 7 knots) with little or no crosswind. After 0300, winds dropped and either low overcast or fog occurred rather frequently. Some turbulence and shear occurred at various times but was usually associated with low-velocity winds.

Wind measured by an anemometer located 152 m from the van (Fig. 6) was recorded on a stripchart in the LDV van but was not recorded by LAX or the FAA. The tower readout is a meter which is calibrated to +2 knots of actual anemometer output to account for starting torque. Thus, the tower report of wind speed was consistently 2 knots higher than that recorded in the LDV van. This anemometer was a cup-and-vane type and provided the horizontal component of the wind approximately 6 m above the ground.

Frequently, a definite gradient or shear situation was indicated by increasing wind velocity with altitude. This condition was most notable when the wind was from over the ocean (240 deg) and to a lesser extent with winds from 060 deg. Typical conditions are noted in Table 2 below and are shown in Fig. 8.

TABLE 2. VELOCITIES FROM STRIPCHART ON-LINE

Measurement	Wind Speed for Wind from 060 deg (knots)	Wind Speed for Wind from 240 deg (knots)
LAX Anemometer	6.0	5
LDV 26 m	5.5	8
LDV 38 m	7.0	10
LDV 76 m	7.5	14
LDV 152 m	8.0	16
LDV Vertical Component	1.5	3

Note: Anemometer output is taken from recorded data, not tower-reported data, and LDV wind data presented are from one profile (four altitudes in sequence). However, profile-to-profile variation was very small during this period.

Winds from approximately 60 deg tended to produce a more uniform flow over the site with velocities approximately the same at all altitudes, within

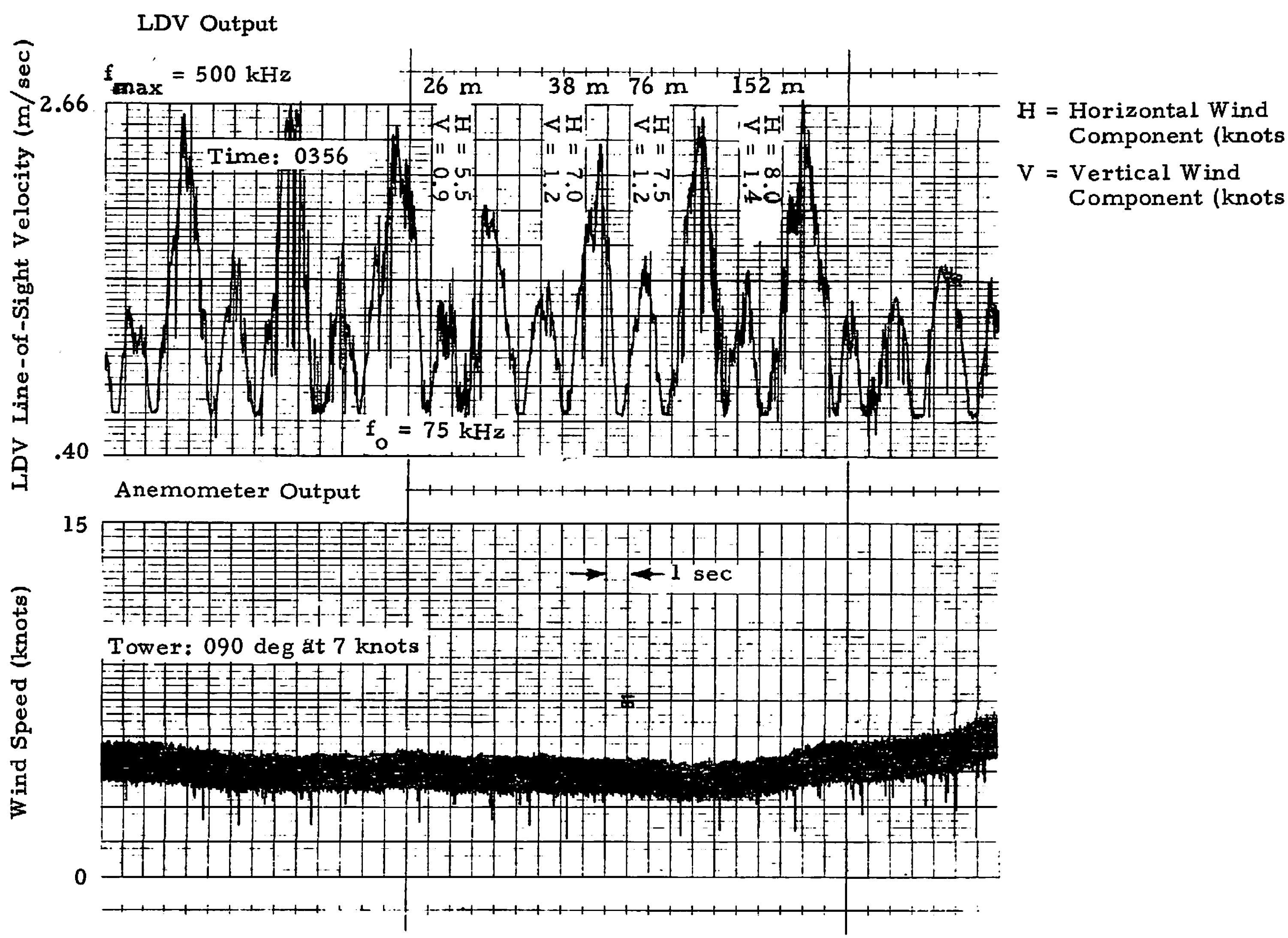


FIGURE 8. DATA SHOWING INCREASE IN WIND VELOCITY WITH ALTITUDE (05/13-14/76).

2.5 knots. Also, the vertical component is less from 60 deg as would be expected from the terrain (see Figs. 6 and 7).

Turbulence was indicated when multiple velocity peaks were encountered in the focal volume. This occurred most frequently at 152 m, but occasionally at 76 m. This situation was noted on the night of 19-20 May at the 152-m and 76-m altitudes. The two signals in the focal volume were within 2 to 3 knots in velocity but separated in direction by 45 to 90 deg. There were no reports of turbulence from pilots.

On the night of 29-30 April, at 2354, the tower gave the wind as 40 deg at 4 knots for an approaching DC-10. The anemometer being monitored by the tower was located in the approach corridor to 6R and was being recorded on a stripchart recorder in the LDV van (see Fig. 9). For a second approaching DC-10, the tower indicated winds variable at greater than 10 knots; at this time, high-velocity peaks were being recorded due to vortices generated by the first DC-10. This high-velocity wind information was also given to the third landing aircraft, a B-747. Following this sequence, a B-747 took off and was given the wind as 80 deg at 3 knots. From the stripchart, it is obvious that the vortices from the landing aircraft had affected the anemometer, and the tower was then giving the vortex velocity as the wind velocity. Although we have no data on the wind direction, it would undoubtedly have also been affected. In this case, the wind never changed appreciably, but the tower did not indicate the actual wind to the aircraft. At the end of the figure, note that the tower again indicated winds gusting to 14 knots. Unfortunately, this anemometer will generally be affected, at least to a small degree, by the vortices due to its location.

Another case is indicated in Fig. 10 where the winds were approximately 100 deg at 5 knots. Again, the tower gave an indication of 120 deg at 10 knots following an L-1011 landing.

One instance in which the tower gave the wrong wind direction was recorded. Note in Appendix A, on the night of 30-31 April, the tower indicated

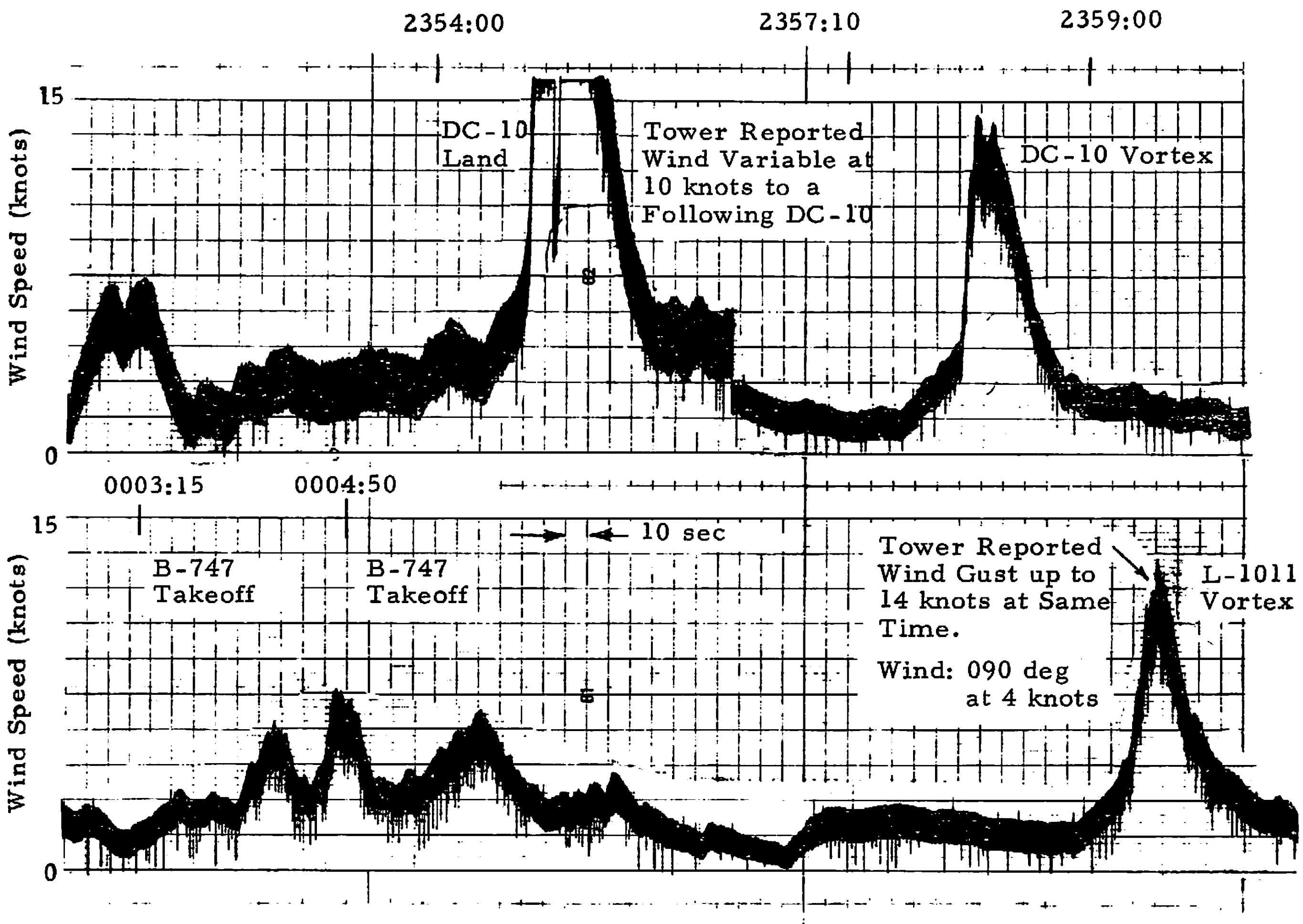


FIGURE 9. SEQUENCE OF CUP ANEMOMETER DATA SHOWING VORTEX EFFECT WITH TOWER REPORTS NOTED (4/29-30/76).

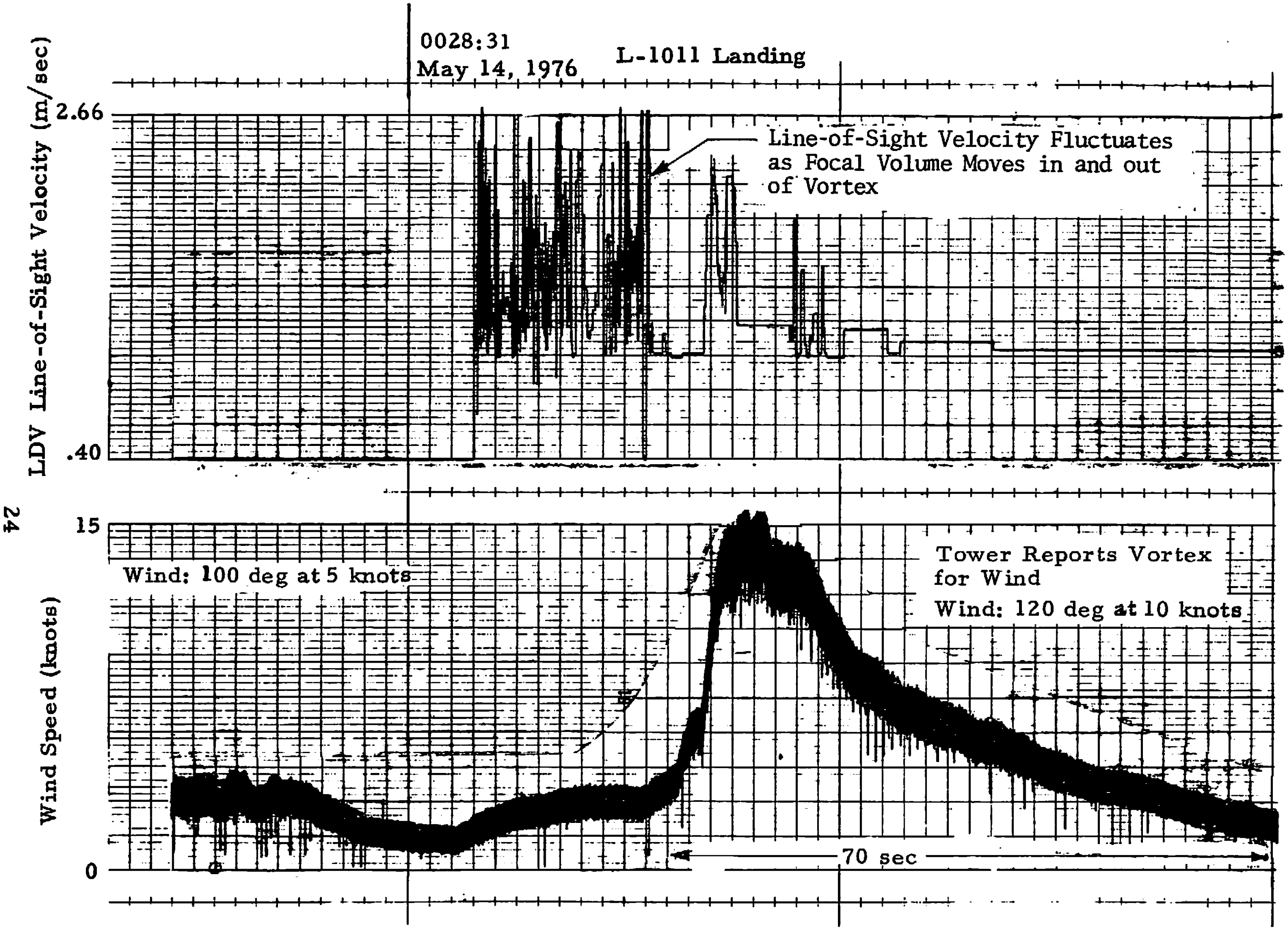


FIGURE 10. DATA SHOWING EFFECT OF VORTICES ON CUP ANEMOMETER AND LASER DOPPLER VELOCIMETER OUTPUT.

the winds were from 290 to 360 deg from 2345 until approximately 0030 when the wind was given at 150 deg. During the entire period, the wind vane was monitored visually, and the winds at the site were from 150 to 180 deg. This could have affected an aircraft if the winds had not been light. There were no problems reported by the pilots.

On two occasions, runway 6R was closed because of heavy fog. During these times, the system operated exceptionally well. When RVR read "0" (runway and/or airport closed), the signal-to-noise ratio varied from > 45 dB at 26 m to > 25 dB at 500 m. On the night of 20-21 April, no turbulence was noted or reported during the fog; however, at 0020, turbulence was noted and recorded at 150-m altitude. At 0300, light fog was reported at 400 ft above the runway and by 0400 had dropped down to the runway and forced the closure. The fog covered the runway and ocean, but was relatively light at the site.

On the night of 11-12 May, clear skies were reported at 2300, but by 0200, fog had moved in from the ocean and again forced the closing of runway 6R. In this case, the fog layer was 90-m thick with the RVR reading zero. Again, no turbulence was reported by pilots, nor was turbulence observed by the LDV crew. During these fog conditions, the wind velocity varied from calm to no more than 5 knots; i.e., very light winds not likely to produce a hazardous situation.

The purpose of the test was to identify the wind anomalies reported by pilots. Since no wind anomalies were reported by pilots during the time that the LDV system was operated at the test site, only representative test data were evaluated. Figures 11-14 show sample wind profiles. Figure 11 shows the wind-speed profile fitted to a power-law form. Figure 12 shows the wind direction in degrees from magnetic north fitted to a quadratic form. Figures 13 and 14 show cross-runway wind (positive from port to starboard for a landing aircraft) and down-runway wind (positive as a headwind for a landing aircraft). The solid lines in Figs. 13 and 14 are derived from the curve fits of

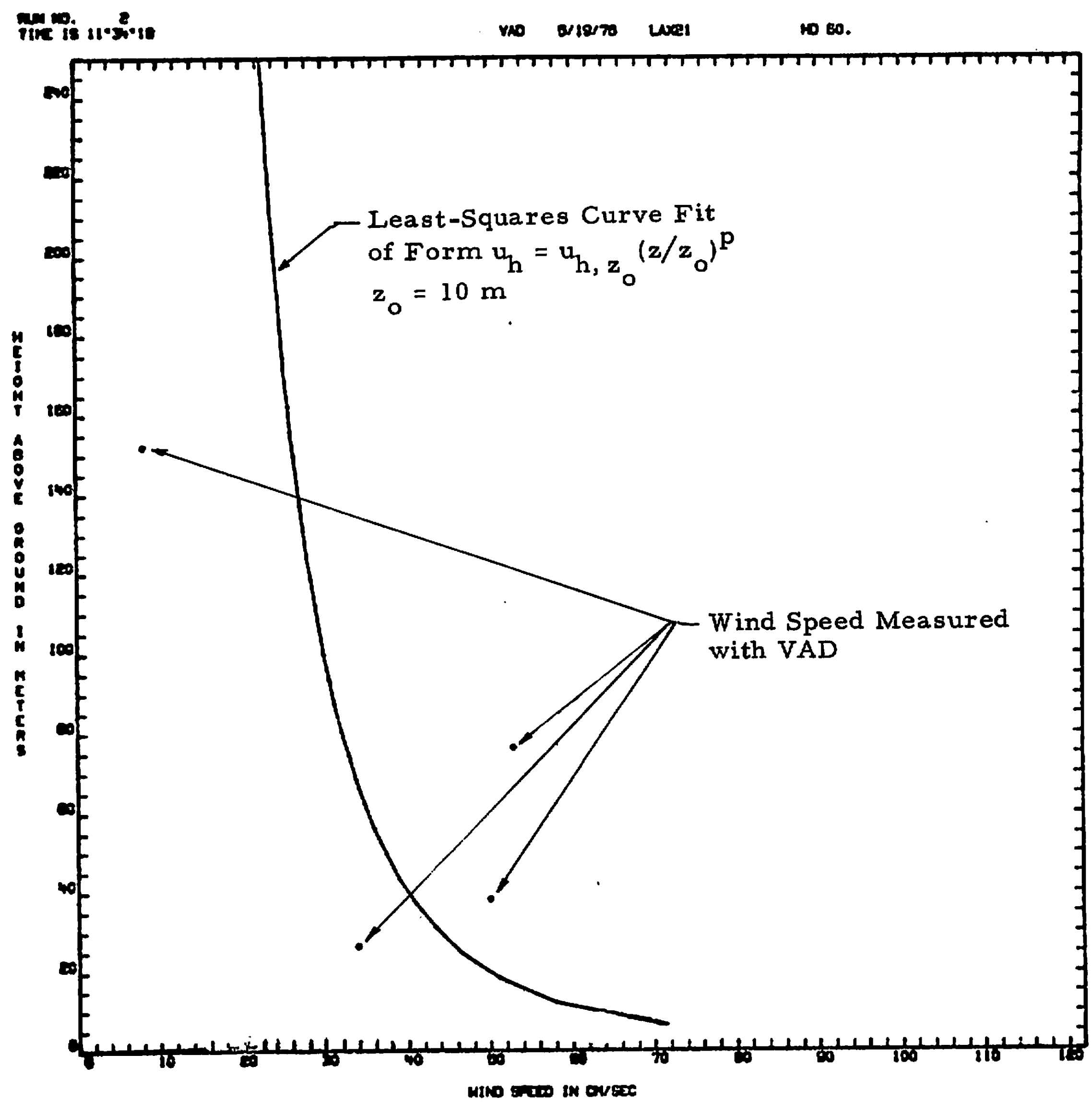


FIGURE 11. MEASURED WIND SPEED PROFILE.

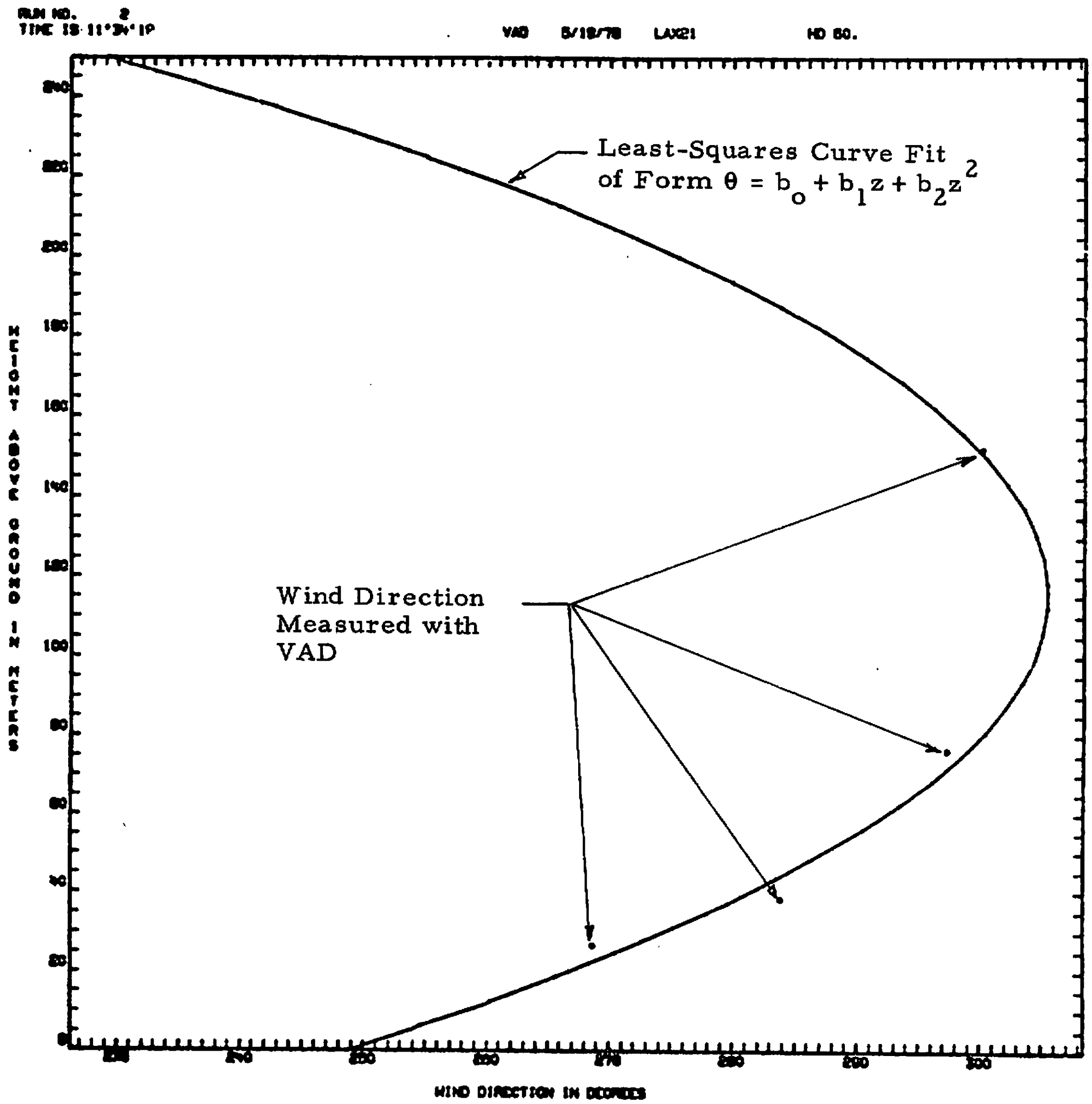


FIGURE 12. MEASURED WIND DIRECTION PROFILE.

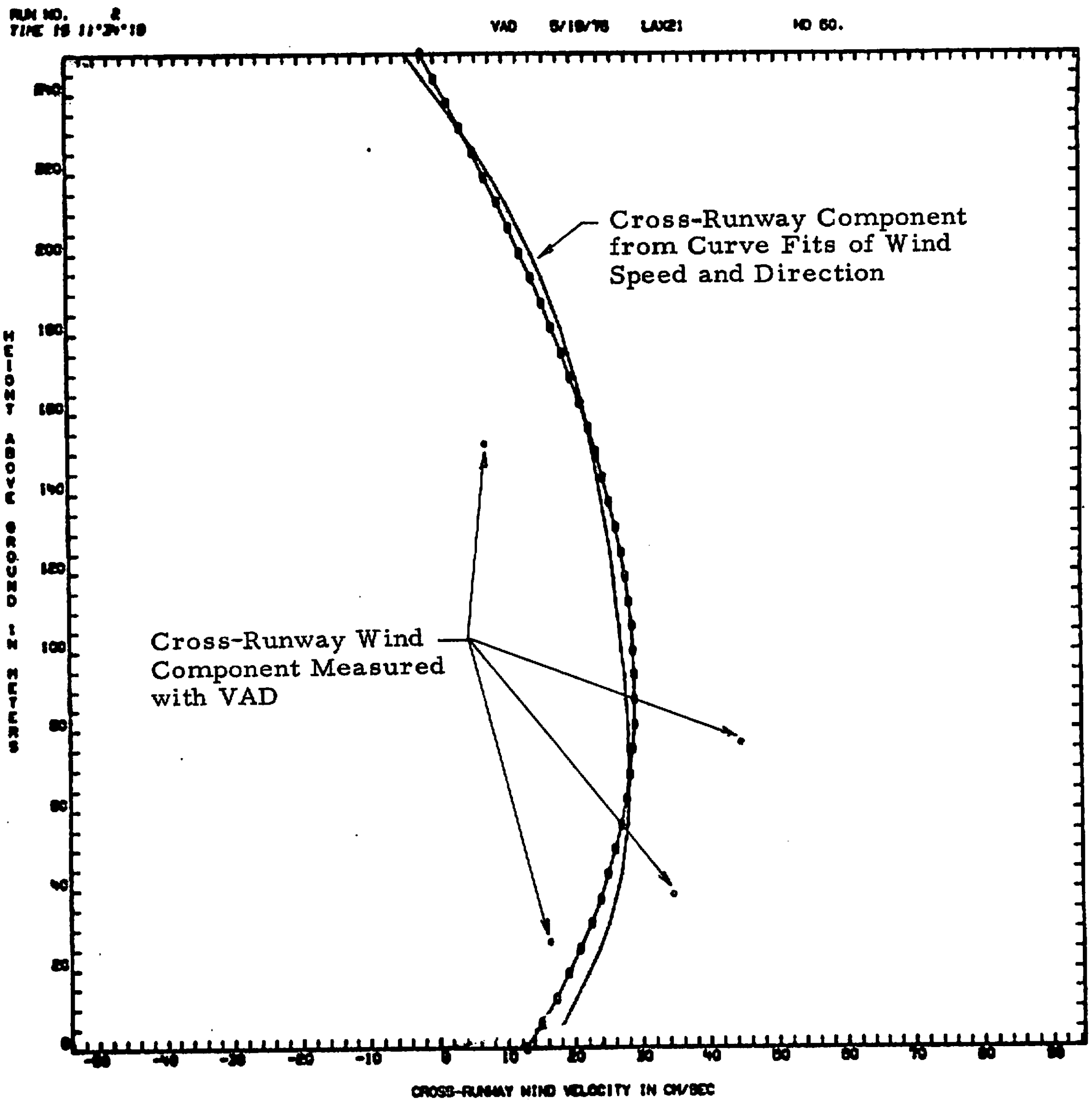


FIGURE 13. CROSS-RUNWAY COMPONENT OF WIND.

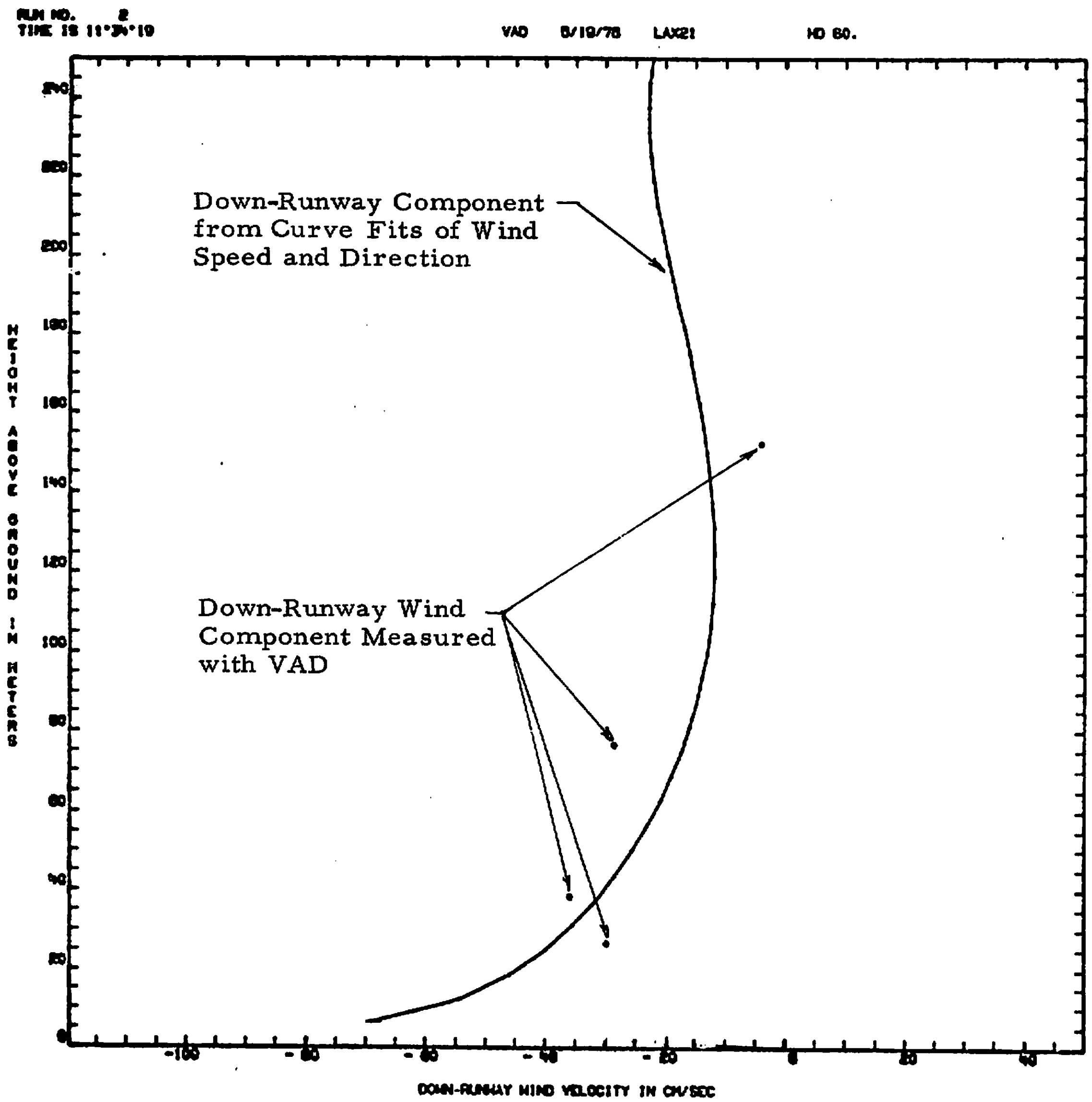


FIGURE 14. DOWN-RUNWAY COMPONENT OF WIND.

Figs. 11 and 12. If HD is the heading of a landing aircraft (i.e., 60° for Runway 6)

$$u = u_h \cos(HD - \theta),$$
$$v = u_h \sin(HD - \theta).$$

The line identified with zeroes in Fig. 13 is a cubic-curve fit of the data from the solid line. Additional data similar to that shown in Figs. 11 through 14 are presented in Appendix B.

4.2 VORTEX TRACKING

One of the concerns at LAX while using the noise-abatement procedure was whether or not trailing vortices from one aircraft were affecting the following aircraft. A total of 650 flybys were recorded. The data tapes for these flybys currently reside at Lockheed-Huntsville. The data tapes have not been processed because no pilot-reported wind anomalies occurred during the test period. A few sample vortex trajectories were generated from the data tapes and are shown in Appendix D.

5. CONCLUSIONS

The Lockheed-Huntsville laser Doppler velocimeter system was operated at the approach end of runway 6R at Los Angeles International Airport for 23 nights. The purpose of the test was the identification of unusual wind conditions previously reported by pilots landing at LAX. No pilot reports of wind anomalies were received during the test. Therefore, only representative data were reduced and are presented. No conclusions on the source of pilot-reported wind anomalies could be made because no such reports occurred during the test.

6. REFERENCES

1. Brashears, M.R., T.R. Lawrence, and A.D. Zalay, "Mobile Laser Doppler System Checkout and Calibration," FAA-RD-77-48, Vols. I and II, Final Report, Lockheed Missiles & Space Company, Huntsville AL, June 1977, 492 p.

2. Brashears, M.R., and W.R. Eberle, "Verification of Wind Measurement with Mobile Laser Doppler System," FAA-RD-77-117, Lockheed Missiles & Space Company, Huntsville AL, September 1977, 170 p.

Appendix A

SAMPLES OF MOBILE ATMOSPHERIC UNIT EXTERNAL LOG

Appendix A

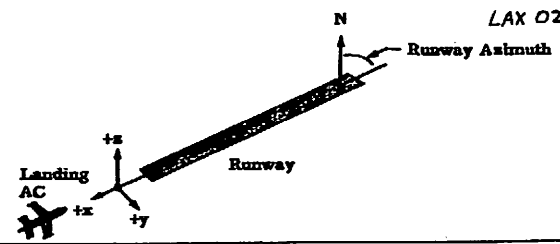
MVU External Log

LAX 02

Location: LAX
Date: 4-20-76
Sheet 1 of 1

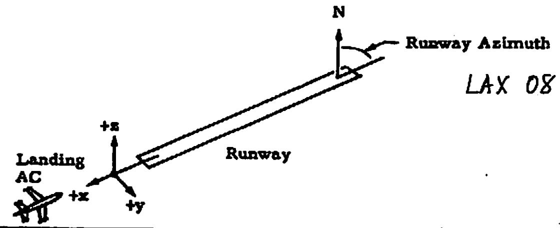
Van X Position: 1800'
Ref. Pt. Threshold
Van Y Position: Center of RW
Ref. Pt. 288FT.

Runway Azimuth: 60°
Mirror Azimuth for Switch: 37°



Run ID		Spectrum Analyser						Scanner						Computer		Time		Estimated	
				Freq. Span (MHz)				Range			Elevation							Wind Azimuth	
No.	AC Type or VAD	B. W. (kHz)	Log Lin	Min.	f_c	Max.	Rate (msec)	Max.	Min.	Rate	Max.	Min.	Rate	Tape No.	No. Records	Start	Stop	(from)	Comments
001	VAD-707	10	LIN	0	100kHz	500kHz	1	-	-	-	60	-	-	2		2343		160@3	26,50,75,150, 26,50,75,150
"	DC-10	"	"	"	"	"	"				"	"	"	"		2346		160@3	Seen VorTex
"	707	"	"				"	"	"	"	"	"	"	"		2359		160@3	Seen VorTex AT 26m
"	DC-10	"	"	"	"	"	"	"	"	"	"	"	"	"		00 04	12:08	160@3	Seen VorTex AT 26m, 50m Spectrum with -FF 50kHz
002	VAD	"	"	"	75	"	"	"	"	"	"	"	"	"		00:09		170@3	"
"	727	"	"	"	"	"	"	"	"	"	"	"	"	"		00:14		170@3	"
"	DC-10	"	"	"	"	"	"	"	"	"	"	"	"	"		00 24		200@3	"
"	DC-10	"	"	"	"	"	"	"	"	"		"	"	"		00 32		210@5	"
"	DC-10	"	"		"	"	"	"	"	"	"	"	"	"		00 36		220@4	"
"	DC-8	"	"	"	"	"	"	"	"	"	"	"	"	"		00:43		230@6	"
"	747	"	"	"	"	"	"	"	"	"	"	"	"	"		00:47		230@6	takeoff
"	707	"	"	"	"	"	"	"	"	"	"	"	"	"		00:51		230@6	takeoff ≃ 500 ft.
"	707	"	"	"		"	"	"			"	"	"	"		01:01		200@6	
"	747	"	"	"	"			"			"	"	"	"		01:04		200@6	TAKEOFF
	DC-10	"	"	"	"			"			"	"	"	"		01 06		200@6	TAKEOFF
"	707	"	"	"		"		"				"	"	"		01:10		210@5	TAKEOFF
"	DC-10	"	"	"			"					"	"	"		01:17		210@5	takeoff
"	707	"	"									"	"	"		01:19	01:23	210@5	TAKEOFF
003	DC-10	30	LIN	0	300kHz	1meg	1	150	41	31	45	03	1	2		1 36	1:38	210@5	TAKEOFF
004	DC-10	"	"				"	250	51	"	55	15	"	"		1 43	1:46	210@5	TAKEOFF
005	VAD	10	LIN	0	100kHz	500kHz	1	—	—	—	60	—	—	—		1:52		—	As ABOVE {TURBULENCE AT 150.}
"	L-1011	"												"		2:09		240@5	
"	707	"	"	"	"	"	"	"	"	"		"	"	"		2:17	2.19	230@5	
006	VAD	"	"	"	"	"	"	"			"	"	"	"		2 20		—	26,50,75,150, 26,50,75,150
"	727	"	"	"	"	"	"	"	"		"	"	"	"		2:25		260@5	
"	707	"	"	"	"			"	"	"	"	"				2 58		260@5	Light Fog Report @400'
	DC-10															3:0			TAKEOFF
N/C	—													"	—	03 36	4:10		Switch TO R25 for LANDING
007	VAD	"	"		"	"		"	"	"	"			"		3:17	6.00		400' ALT FOG

MVU External Log



LAX 08

Location: LAX
Date: 1-28-76
Sheet 1 of 2

Van X Position: 1800
Ref. Pt.: ———

Van Y Position: 288'
Ref. Pt.: Center of RW

Runway Azimuth: 60°

Mirror Azimuth for Switch: 37°

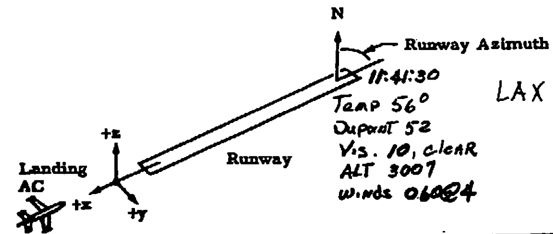
Run ID		Spectrum Analyzer						Scanner						Computer		Time		Estimated Wind Azimuth (from)	Comments
				Freq. Span (MHz)				Range			Elevation								
No.	AC Type or VAD	B.W. (kHz)	Log / Lin	Min.	f_c	Max.	Rate (msec)	Max.	Min.	Rate	Max.	Min.	Rate	Tape No.	Aircraft flyby Records time	Start	Stop		
0100	VAD			0	75KC	0.5	1	—	—	—	60	—	—	8		12:16:10			V 26,38,76,152 - Runout
0101	DC10	10	LIN	0	"	0.5		"	"	"	"	"	"	"	12:16:24			050@5	L
0102	707	10	LIN		"			"	"	"	"	"	"	"	12:18:48			050@5	L
0103	DC10	10	LIN	0	"	0.5		"	"	"	"	"	"	"	12:24:35			050@5	T
0104	L1011	"	"	"	"	"		"	"	"	"	"	"	"	12:25:10		12:27:35	050@5	L
0205	L1011	30	LIN	0	600KC	2.0		170	035	3.1	35	01	.1	"	12:31:00	12:31:10	12:35	050@5	L
0306	707	"	"	"	"	"		"	"	"	"	"	"	"	12:39:19	12:39:00	12:41:22	"	L
0407	747	"	"	0	600KC	2.0M		170	035	3.1	70	35	.1		12:42:00	12:41:50		"	T
—	—	—	—	—	—	—		—	—	—	35	05	"		12:44:00		12:45:00	"	— CHANGE Ell. ANGLES
0508	DC10	"	"								35	01	"		12:46:35	12:46:1?		"	L
0509	707	"	"	"	"	"		"	"	"	35	01	"		12:48:42		12:57:5?	050@5	L
0610	DC10	"	"	"	"	"		170	035	3.1	65	31	.1		12:56:00	12:56:00	12:58:2?	050@5	T
0711	727	"	"	"	"	"		"	"	"	35	01	"		01:00:55	01:00:48	01:0?:??	050@7	L
0812	DC10	"	"	"	"	"		"	"	"	65	31	"		01:09:00	01:03:58	01:06:5?	050@5	T high VTX @~150m ALT
0913	DC10	"	"	"	"	"		"	"	"	65	31	"		01:19:51	01:1?:30		050@5	T "
0914	707	"	"	"	"	"		"	"	"	65	31	"		01:17:0		01:19:48	050@5	T "
1015	DC10	"	"	"	"	"		"	"	"	65	31	"			01:27:08		050@5	T
—	—	"	"	"	"	"		170	035	3.1	35	01	"		01:28:40	—	01:29:27	050@5	— no HITS.
1160	VAD	10	LIN	0	100KHz	0.5M		—	—	—	60	—	—			01:32:10	↓	"	V
1116	DC10	"	"	"	"	"		"	"	"	"	"	"		01:37:00			"	T
1117	DC10	"	"	"	"	"		"	"	"	"	"	"		01:44:??		01:48	"	T
1218	727	"	"	0	400KC	1.0M		170	045	3.1	35	01	.1		01:54:42	01:54:00	01:57:??	"	L
1319	L1011	"	"	"	"	"		"	"	"	"	"	"		02:17:10	02:16:11	↓	"	L
1320	DC10							170	045	3.1	"	"	"		02:19:29			"	L L1011 VTX
1321	707	"	"	"		"		170	035	3.1	"	"	"		02:21:27		02:24:5?	"	L
1400	VAD	10	LIN	0	75KC	0.5M		—	—	—	60	—	—			02:28:3?		"	V
1422	L1011	"	"	"	"	"		"	"	"	"	"	"		03:03:06			"	T
1423	DC10	"	"		"	"		"	"	"	"	"	"		03:13:25		03:20:5?	050@5	T
1524	707	30	LIN	0	400KC	1.0M		170	035	3.1	65	31	.1		03:22:20	03:22:??	03:24:??		T

MVU External Log

Location: LAX
Date: 4-29-76
Sheet 1 of 2

Van X Position: 1800'
Ref. Pt. THRESHOLD
Van Y Position: 288'
Ref. Pt. Center of RW

Runway Azimuth: 60°
Mirror Azimuth for Switch 37°



11:41:30
Temp 56°
Dupoint 52
Vis. 10, clear
ALT 3007
winds 060@4

LAX 09

Run ID		Spectrum Analyser						Scanner						Computer		Time		Estimated Wind Azimuth (from)	Comments
				Freq. Span (MHz)				Range			Elevation								
No.	AC Type or VAD	B.W. (kHz)	Log Lin	Min.	f_c	Max.	Rate (msec)	Max.	Min.	Rate	Max.	Min.	Rate	Tape No.	Aircraft Flyby ~~No.~~ ~~Records~~ Time	Start	Stop		
0100	VAD	10	Lin	0	80 KC	500KC	1	—	—	—	60	—	—	9		11:33:46	11:45:19	060@4	26, 38, 76, 152, 26, 38, 76, 152
0201	707	30	Lin	0	300KHz	1meg	1	170	35	3.1	35	01	1	"	11:45 16	11:47:12		040@4 L	Left Brake on Elev At Beginning of Run
0202	DC-10	"	"	"	400KHz	"	"	"	"	"	65	31	"	"		11:50:15	11:52:15	040@4	T- SAW VORTEX
0303	DC-10	90	[illegible]	0	[illegible]	2meg	1	"	"	"	35	01	"	"	11:59:18	11:53:56		040@4	L-
0304	DC-10	"	"	"	600KHz	"	"	"	"	"	"	"	"	"		11:57:28		VAR@10	L- Tower Told Pilot VAR. Winds due To VORTEX
0305	727	"	"	"	"	"	"	"	"	"	"	"	"	"		00:00:55		VAR@10	L " " " " " " "
0306	747	"	"	"	"	"	"	"	"	"	65	-31	"	"		00:03:12		080@7	T
0307	747	"	"	"	"	"	"	"	"	"	75/65	31/61	"	"		00:04:07	00:05:30	040@3	T- 00:06:50 changed scale
0408	L-1011	"	"	"	"	"	"	"	"	"	35	01	"	"	00:10:47	00:08:47		090@4	L
0409	707	"	"	"	600/800	"	"	"	"	"	"	"	"	"		00:11:35		010@4	L
0410	707	"	"	"	800/600	"	"	"	"	"	35/65	31	"	"		00:16:57		100@2	T-
0411	747	"	"	"	600	"	"	"	"	"	75	31	"	"		00:18:07		100@2	T
0412	DC-10	"	"	"	"	"	"	"	"	"	35	01	"	"		00:21:00	00:26:86	100@2	L
0513	L-1011	"	"	"	"	"	"	"	"	"	45	"	"	"	00:32 39	00:32:18	00:34:57	100@4	L
0614	L-1011	"	"	"	"	"	"	"	"	4.1	"	"	.2	"		00:37:07		050@4	L
0615	DC-10	"	"	"	"	"	"	"	"	"	"	"	"	"		00:39:51	00:41 26	050@5	L
0716	707	"	"	"	"	"	"	"	"	3.1	"	"	.1	"	00:44 24	00:43:46	00:45:57	020@3	L
0817	707	"	"	"	"	"	"	"	"	"	65	31	"	"	00:46 48	00:46:35		020@3	T
0818	747	"	"	"	"	"	"	"	"	"	"	"	"	"		00:48:21		020@4	T
0819	707	"	"	"	"	"	"	"	"	"	65/35	31/01	"	"		00:52:04		020@4	L 00:49.48 changed scale
0820	DC-10	"	"	"	"	"	"	"	"	"	35	01	"	"		00:54:21	00:55:31	030@4	L
0900	VAD	10	Lin	0	100KHz	1meg	1	—	—	—	60	—	—	"		00:56:36	01:11:58	CALM	26, 38, 76, 152, 26, 38, 76, 152
1021	727	30	Lin	0	600KHz	2meg	"	170	35	3.1	35	01	1	"	01:15 10	01:15:00	01:16:47	020@5	L
1122	707	"	"	"	"	"	"	"	"	"	65	31	"	"	01:17 31	01:17 00		020@5	T
1123	DC-10	"	"	"	"	"	"	"	"	"	"	"	"	"		01:18:32		110@5	T 01:19 51 changed scale
1124	DC-10	"	"	"	"	"	"	"	"	"	75	"	"	"		01:20:02		130@5	T
1125	DC-10	"	"	"	"	"	"	"	"	"	"	"	"	"		01:21:22		150@5	T
1126	DC-10	"	"	"	"	"	"	"	"	"	85	41	"	"		01:24:25	01:26:53	070@3	T 01 25:14 changed scale
1227	L-1011	"	"	"	"	"	"	"	"	"	85-75 65-55 35	41-38 21-11 01	"	"	01 29 24	01:28:30	01:32:49	020@3	T RAN ELEV FROM 85-35 RAN LOWER ELEV 41-01

A-3

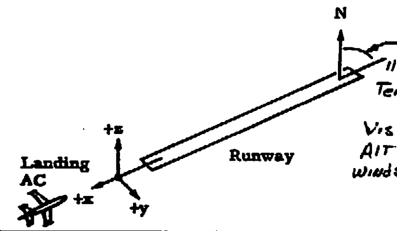
12

MVU External Log

Location: LAX
Date: 4-29-76
Sheet 1 of 2

Van X Position: 1800'
Ref. Pt. Threshold
Van Y Position: 284'
Ref. Pt. Center of RW

Runway Azimuth: 60°
Mirror Azimuth for Switch 37°



11 09 15
Temp-63
Vis-clear, 15
AIT-2998
winds-180@2

LAX 10

Run ID: No.	Run ID: AC Type or VAD	Spectrum Analyzer: B.W. (kHz)	Log / Lin	Freq. Span (MHz): Min.	f_c	Max.	Rate (msec)	Scanner: Range Max.	Range Min.	Range Rate	Elevation Max.	Elevation Min.	Elevation Rate	Computer: Tape No.	Aircraft Flyby No. / Time	Time: Start	Stop	Estimated Wind Azimuth (from)	Comments
0100	VAD	30	LIN	0	200KHz	1meg	1	—	—	—	60	—	—	10		11:20:00	11:21:30		26 38 76 152 26 38 76 152
0200	"	"	"	"	"	"	"	"	"	"	"	"	"	"		11:2:59		350@4	" " "
0201	DC-10	"	"	"	"	"	"	"	"	"	"	"	"	"		11:44:40	11:47:30	360@5	T Vortex @ 7½ m.
0302	DC-10	30	LIN	1meg	1meg	2meg	1	170	35	3.5	65/35	31/01	1	"	00:04:28	00:04:10	00:06:15	310@7	T 00:04:58 change ele.
0403	707	30	Lin	1m	1m	2m	"	170	35	3.5	65/35	31/01	1	"	00:06:44	00:06:44	00:08:15	310@7	T 00:07:24 change elev.
0504	DC-10		"		"	"	"	"	"	"	35	01	"	"	00:15:32	00:15:10	00:17:00	300@4	L
0605	DC-10	"	"	"		"		"	"		65 /	31 /	"		00:19:16	00:17:45		310@3	T Winds AT Site are 180°
0606	707	"		"	"	"	"	"	"	"	65	31	"	"	00:21:08		00:22:34	310@3	T
0709	DC-8	"	"	"	"	"	"	"	"	"	35	01	"	"	00:23:28	00:23:18	00:24:26	310@3	L
0808	L-1011	"	"	"	"	"	"	"	"	"	65	01	"	"	00:27:44	00:27:35	00:29:17	290@3	L Vane direction between 160-180°
0909	747	"	"	"	"			"	"	"	85	41/61	"	"	00:30:30	[illegible]	00:35:05	300@3	T 00:31:33 changed elev
1010	L-1011	"	"	"	"	"	"	110	31	3.1	45	01	"	"	00:35:08	00:34:50	00:37:18	290@3	L The read dir. wrong ↑
1100	VAD	30	Lin	0	200KHz	1meg	1	—	—	—	60	—	—	"	00:38:00	00:38		150@5	26, 38, 76, 152, 26, 38, 76, 152
1111	DC-10	"	"	"	"	"	"	"	"	"	"	"	"	"	00:43:07			150@5	L Vortex 26m
1112	DC-10	"	"	"	"	"	"	"	"	"	"	"	"	"	00:45:41			150@5	T Vortex 152m, 76m
1113	747	"	"	"	"	"	"	"	"	"	"	"	"	"	00:47:25			190@5	T Vortex 152m, 76m
1114	DC-9	"	"	"	"	"	"	"	"	"	"	"	"	"	00:51:39			150@5	L Vortex 26m
1115	727	"	"	"	"	"	"	"	"	"	"	"	"	"	00:54:52			110@5	L Vortex 26m 38m
1116	Two Eng Prop	"	"	"	"	"	"	"	"	"	"	"	"	"	00:56:45		00:57:30	110@5	L
1217	707	10	"	0	100KHz	500KHz	"	"	"	"	"	"	"	"	00:59:57	00:58:03		110@5	T
1218	DC-10	"	"	"	"	"	"	"	"	"	"	"	"	"	01:01:01			100@5	T Vortex 152m
1219	DC-10	"	"	"	"	"	"	"	"	"	"		"	"	01:02:53			100@5	T Vortex 76 152m
1220	707	"	"	"	"	"	"	"	"	"					01:07:19			100@5	L Vortex 26m 38, 76, 152m
1221	DC-10	"	"	"	"			"		"	"	"	"	"	01:16:11			150@5	T
1222	707	"	"			"		"		"	"	"	"	"	01:17:29			150@5	T
1223	DC-10	"	"					"		"		"	"	"	01:30:55			150@5	T Vortex 152m 76m
1224	DC-10	"				"	"	"	"	"	"			"	01:45:26			150@5	T
1225	L-1011	"	"		"			"	"	"	"	"	"		01:58:42			140@4	T
1226	727							"	"	"	"				02:05:00			140@3	L

CONTINUATION OF TAPE 16
4-11/12-76 57 dB @ 62.5

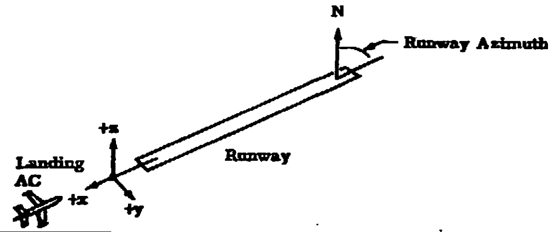
MVU External Log

LAX 16

Location: LAX
Date: 5-11/12-76
Sheet 2 of 3

Van X Position: 1600'
Ref. Pt. Threshold
Van Y Position: 288'
Ref. Pt. Center of RW

Runway Azimuth: 60°
Mirror Azimuth for Switch 37°



Run ID No.	AC Type or VAD	Spectrum Analyzer B.W. (kHz)	Log Lin	Freq. Span (MHz) Min.	f_c	Max.	Rate (msec)	Scanner Range Max.	Range Min.	Range Rate	Elevation Max.	Elevation Min.	Elevation Rate	Computer Tape No.	Aircraft Flyby Time	Time Start	Time Stop	Estimated Wind Azimuth (from)	Comments
2027	DC-10	10	LIN	0	100KHz	500KHz	1	164	—	—	60	—	.1	16	06:29:57	06:29:56	06:37:30		VAD L CONT
4-11/12-76																			26 · 30dB, 38-30dB 76-46dB, 152 30dB (4-11/12-76)
2200	VAD	10	LIN	0	75KHz	500KHz	1	—	—	—	60	—	—	16		11:22:30		CALM	26 38 76 152, 26 38 76 152
2201	DC-10	"	"	"	"	"	"	"	"	"	"	.	.	"	11:41:29		11:45:02	CALM	T-CONT 906
2302	727	30	LIN	0	400KHz	2meg	"	170	35	3.1	45	01	"	"	11:51:48	11:51:34	11:59:08	150@3	L-United 267 500-900' Clouds ~300' above runway approach
2403	747	"	"	"	"	"	"	"	"	"	85/45	31/01	"	"	11:55:10	11:54:42	11:58:10	CALM	T- changed Elev
2504	727	"	"	"	500KHz	"	"	"	"	"	45	01	"	"	00:06:08	00:06:00	00:08:36	CALM	L-TWA 385
2605	727	"	"	"	"	"	"	"	"	"	"	"	"	"	00:09:23	00:09:00	00:10:53	150@5	L-American 435 Gave vortex Reading
2706	707	"	"	"	"	"	"	"	"	"	75/35	31/01	"	"	00:11:57	00:11:26		CALM	T-TWA 20 Changed Elev
2707	707	"	"	"	"	"	"	"	"	"	75	31	"	"	00:13:35		00:15:38	CALM	T-TWA 76
2808	747	"	"	"	"	"	"	"	"	"	35	01	"	"	00:19:18	00:17:56	00:21:10	CALM	L-Korean 803
2909	L-1011	"	"	"	"	"	"	250	"	"	"	"	"	"	00:23:54	00:23:35	00:25:45	090@4	L-DELTA 1080 Gave vortex reading, fog bank at shoreline
3010	DC-10	"	"	"	600	"	"	200	"	"	"	"	"	"	00:27:22	00:27:05	00:29:15	CALM	L-Western 500
3111	707	"	"	"	"	"	"	"	"	"	"	"	"	"	00:32:31	00:32:01	00:34:10	CALM	L-American 37
3212	DC-10	"	"	"	"	"	"	"	"	"	"	"	"	"	00:39:28	00:39:00	00:41:06	CALM	L-National 53
3313	747	"	"	"	"	"	"	"	"	"	75/35	31/01	"	"	00:43:13	00:43:13	00:46:30	CALM	T United 118 changed Elev
3414	707	"	"	"	"	"	"	"	"	"	75/35	31/01	"	"	00:46:14	00:46:55	00:48:17	CALM	T- TWA 92 " "
3515	707	"	"	"	"	"	"	"	"	"	35	01	"	"	00:49:33	00:49:00	00:51:12	CALM	L- TWA 17
3616	L-1011	"	"	"	"	"	"	"	"	"	"	"	"	"	00:56:50	00:56:20	00:59:50	CALM	L- DELTA 1085 (Could be one more End of Files)
3717	727	"	"	"	"	"	"	"	"	"	"	"	"	"	01:02:11	01:01:45	01:04:00	CALM	L- TWA 137
3818	DC-10	"	"	"	"	"	"	"	"	"	75	31	"	"	01:06:00	01:05:31		CALM	T- CONT 606
3819	DC-10	"	"	"	"	"	"	"	"	"	75/35	31/01	"	"	01:07:57		01:10:05	CALM	T-Northwest 172 changed Elev
3920	727	"	"	"	"	"	"	"	"	"	75/35	31/01	"	"	01:12:00	01:11:51	01:13:56	CALM	T-TWA 72 " "
4021	DC-10	"	"	"	"	"	"	"	"	"	75	31	"	"	01:15:50	01:15:24	01:17:10	CALM	T- CONT 954
4122	DC-10	"	"	"	"	"	"	"	"	"	75/31	31/01	"	"	01:27:47	01:27:20	01:30:13	CALM	T- Western 500 Changed Elev
4223	DC-10	"	"	"	"	"	"	"	"	"	75	31	"	"	01:44:57	01:44:30	01:46:10	CALM	T National 54
4324	727	"	"	"	"	"	"	"	"	"	35	0	"	"	01:50:43	01:50:43		CALM	L. Eastern 87 Fog
4325	L-1011	"	"	"	"	"	"	"	"	"	"	"	"	"	01:53:24		01:56:28	CALM	L. DELTA 1195
4426	DC-10	"	"	"	"	"	"	"	"	"	"	"	"	"	01:58:27	01:58:09	02:00:00	CALM	L-American 317 Fog 300' down to RVR 4/4 RVR 0 Did not land due to heavy fog. Fog is so thick, cannot see runway light

Closed Runway 2:08:00

A-5

Continuation of Tape 17
68 dB @ 625

MVU External Log

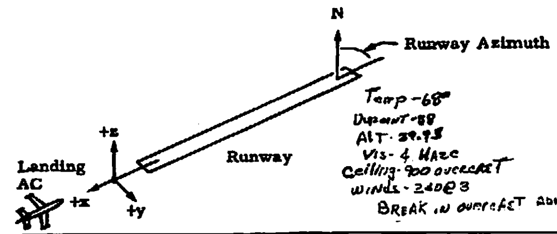
Location: LAX
Date: 5-13/14-76
Sheet 2 of 3

Van X Position: 1600'
Ref. Pt. Threshold

Van Y Position: 288'
Ref. Pt. Center of RW

Runway Azimuth: 60°

Mirror Azimuth for Switch 37°



LAX 17

Temp - 68°
Dewpoint - 58
ALT - 29.93
Vis - 4 Haze
Ceiling - 900 overcast
winds - 240@3
Break in overcast above 900'

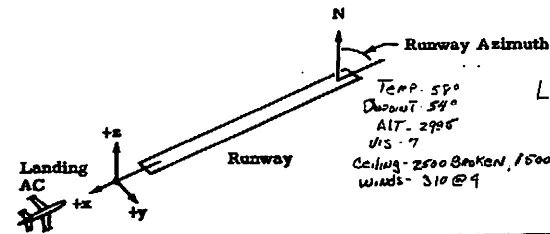
Run ID		Spectrum Analyzer						Scanner						Computer		Time		Estimated Wind Azimuth (from)	Comments
				Freq. Span (MHz)				Range			Elevation								
No.	AC Type or VAD	B.W. (kHz)	Log Lin	Min.	f_c	Max.	Rate (msec)	Max.	Min.	Rate	Max.	Min.	Rate	Tape No.	Aircraft FlyBy Time	Start	Stop		
1400	VAD	10	Lin	0	75KHz	500KHz	1	—	—	—	60	—	-	17		00:10:00		—	24,38 7, 162, 26, 88, 76 15.
1401	707	"	"	"	"	"	"	"	"	"	"	"	"	"	00:12:55		00:21:00	—	T-TWA 76
1502	DC-8	30	Lin	0	600KHz	2Meg	1	170	35	3.1	35	01	.1	"	00:22:54	00:22:59	00:23:23	030@4	L United 229
1603	L-1011	"	"	"	"	"	"	"	"	"	"	"	"	"	00:28:26	00:28:10	00:29:45	100@5	L Delta 1080
1704	DC-10	"	"	"	"	"	"	"	"	"	"	"	"	"	00:30:59	00:30:54	00:32:02	120@10	L Western 500
1805	L-1011	"	"	"	"	"	"	"	"	"	"	"	"	"	00:33:05	00:32:50	00:34:19	160@4	L Delta 1085
1906	707	"	"	"	"	"	"	"	"	"	"	"	"	"	00:35:20	00:35:40	00:36:44	140@3	L American 37
2007	DC-10	"	"	"	"	"	"	"	"	"	"	"	"	"	00:38:17	00:37:59	00:40:15	130@4	L National 53
2108	747	"	"	"	"	"	"	"	"	"	75/35	31/01	"	"	00:41:56	00:41:45	00:44:26	—	T United 102 Changed Elev
2209	747	"	"	"	"	"	"	"	"	"	75/35	31/01	"	"	00:45:47	00:46:46		240@3	T United 118 "
2210	707	"	"	"	"	"	"	"	"	"	55/35	01	"	"	00:47:05		00:49:31	240@3	T-TWA 92 " " "
2311	707	"	"	"	"	"	"	"	"	"	35	01	"	"	00:52:45	00:52:30	00:54:47	240@2	L TWA 17
2412	727	"	"	"	"	"	"	"	"	"	"	"	"	"	00:55:31	00:55:20	00:56:39	230@3	L-TWA 137
2513	DC-10	"	"	"	"	"	"	"	"	"	75/35	31/01	"	"	01:02:51	01:02:20	01:05:25	230@3	T-Northwest 194
2614	DC-8	"	"	"	"	"	"	"	"	"	35	01	"	"	01:07:36	01:07:13	01:09:34	230@3	L-United 66
2715	727	"	"	"	"	"	"	"	"	"	75/35	31/01	"	"	01:19:42	01:19:20	01:21:15	310@4	T TWA 72 Changed Elev
X 2816	DC-10	"	"	"	"	"	"	"	"	"	75	31	"	"	01:22:03	01:21:30		310@3	T Cont 606
2817	DC-10	"	"	"	"	"	"	"	"	"	75	21	"	"	01:23:46		01:26:34	300@3	T Cont 954 Both Vortex on screen
2918	727	"	"	"	"	"	"	"	"	"	35	01	"	"	01:31:23	01:31:10	01:32:45	300@3	L Eastern 87
3019	L-1011	"	"	"	"	"	"	"	"	"	75/35	31/01	"	"	01:35:04	01:35:23		280@3	T Delta 1080 Changed Elev
3020	DC-10	"	"	"	"	"	"	"	"	"	75/45	31/01	"	"	01:37:44		01:40:08	280@3	T Western 500 " "
3121	707	"	"	"	"	"	"	"	"	"	45	01	"	"	01:43:02	01:42:49		270@4	L Western 617
3122	DC-10	"	"	"	"	"	"	170/200	"	"	75/35	31/01	"	"	01:45:43		01:48:45	270@4	T National 64 Changed Range + Elev
3223	L1011	"	"	"	"	"	"	200	"	"	45	01	"	"	02:03:29	02:03:11	02:05:00	230@4	L Delta 1195
3324	DC-8	"	"	"	"	"	"	"	"	"	"	"	"	"	02:10:21	02:09:56	02:12:05	080@4	L Delta 9930
3425	707	"	"	"	"	"	"	"	"	"	"	"	"	"	02:12:51	02:12:27		080@4	L TWA 133
3426	DC-10	"	"	"	"	"	"	"	"	"	"	"	"	"	02:14:21		02:16:41	080@5	L American 317
3527	707	"	"	"	"	"	"	"	"	"			"	"	-	02:23:51	02:24:39		T Argentine 371

MVU External Log

Location: LAX
Date: 5-[illegible]-76
Sheet 1 of V

Van X Position: 1600'
Ref. Pt. Threshold
Van Y Position: 288'
Ref. Pt. Center of RW

Runway Azimuth: 060°
Mirror Azimuth for Switch 037°



Temp. 58°
Dewpoint 54°
Alt. 2996
Vis. 7
Ceiling - 2500 Broken, 1500 Scatter
Winds - 310@9

LAX 21

66dB@62.5

Run ID		Spectrum Analyzer						Scanner						Computer		Time		Estimated Wind Azimuth (from)	Comments
				Freq. Span (MHz)				Range			Elevation								
No.	AC Type or VAD	B.W. (kHz)	Log / Lin	Min.	f_c	Max.	Rate (msec)	Max.	Min.	Rate	Max.	Min.	Rate	Tape No.	Aircraft Fly-By ~~No. Records~~ Time	Start	Stop		
0100	VAD	10	LIN	0	100KHz	500KHz	1	–	–	–	60	–	–	21		11:25 00	11:29 00	320@4	26,38,76,152, 26,38,76,152
0200	VAD	"	"	"	"	"	"	"	"	"	"	"	"	"		11:31 25		320@5	" " " Wind shear@ 152m
0201	DC-10	"	"	"	"	"	"	"	"	"	"	"	"	"	11:42:26			320@4	T Cont 906
0202	DC-10	"	"	"	"	"	"	"	"	"	"	"	"	"	11 53.24			360@2	T National 68
0203	707	"	"	"	"		"	"	"	"	"	"	"	"	00:01 02		00 03 00	340@2	T TWA 20
0304	727	30	LIN	0	600KHz	2meg	1	200	35	3.1	45	01	"	"	00 08 54	00 08 35	00 10 00	020@4	L TWA 355
0405	DC-10	"	"	"	"	"	"	"	"	"	75	31	"	"	00 11 54	00 11 36		030@4	T Korean 510 No Track
0406	707	"	"	"	"	"	"	"	"	"	"	"	"	"	00 13 38		00 16 00	030@4	T TWA 76 "
0507	L-1011	"	"	"	"	"	"	"	"	"	45	01	"	"	00 22 34	00 22 15	00 25 05	020@3	L Delta 1080 Good Run
0608	L-1011	"	"	"	"	"	"	"	"	"	"	"	"	"	00 25.27	00 25.15	00 28 00	360@2	L Delta 1085 "
0709	707	"	"	"	"	"	"	"	"	"	"	"	"	"	00 40 10	00 39 30	00 42 00	140@5	L American 37 "
0810	747	"	"	"	"	"	"	"	"	"	75/45	31/01	"	"	00 43 13	00 42 45	00 46 38	140@5	T United 118 " Changed Elev
0911	DC-10	"	"	"	"	"	"	"	"	"	45	01	"	"	00 47 54	00 47 30	00 49 26	180@5	L Western 500
1012	707	"	"	"	"	"	"	"	"	"	"	"	"	"	00 50 53	00 50 00	00 52 05	190@4	L TWA 17
1113	727	"	"	"	"	"	"	"	"	"	"	"	"	"	00 52 43	00 52 31	00 54 00	180@6	L TWA 139
1214	707	"	"	"	"	"	"	"	"	"	"	"	"	"	00 54:28	00 54 06	00 56 00	180@5	L Avianca 80
1315	707	"	"	"	"	"	"	250	"	"	75	31	"	"	00 57 24	00 57 05	00 59 00	120@5	T TWA 92 No Track
1416	DC-10	"	"	"	"	"	"	"	"	"	85	41	"	"	01.01 40	01 01 00	01 02 40	120@5	T Northwest 172 No Track
1517	DC-10	"	"	"	"	"	"	"	"	"	"	"	"	"	01 03:02	01 02 46	01 04 30	130@6	T Cont 606 No Track
1600	VAD	30	LIN	0	200KHz	1Meg	1	–	–	–	60	–	–	"		01 08 00	01 10 00	100@4	26,38,76,152 26,38,76,152
1700	VAD	10	LIN	0	100KHz	500KHz	"	"	"	"	"	"	"	"		01 10 38		100@4	" " "
1718	DC-10	"	"	"	"	"	"	"	"	"	"	"	"	"	01 10 57			120@6	T Cont 954
1719	727	"	"	"		"	"	"	"	"	"	"	"	"	01 13 44			090@5	T TWA 72
1720	727	"	"	"	"	"	"	"	"	"	"	"	"	"	01.21 37			090@8	L PSA 902
1721	DC-10	"	"	"	"	"	"	"	"	"	"	"	"	"	01:29:41			090@8	T National 64
1722	L-1011	"	"	"	"	"	"	"	"	"	"	"	"	"	01 31:02		01 38 30	090@8	T Delta 1080
1823	727	30	LIN	0	800KHz	2meg	1	200	35	3.1	45	01	1	"	01 48 01	01 47 45	01 49 30	110@10	L Eastern 87
1924	L-1011	"	"	600KHz	800KHz	2.6meg	"	"	"	"	"	"	"	"	01 55 37	01 55 19	01 57 39	100@10	L Delta 1195

A-7/A-8

Appendix B

WIND PROFILE PLOTS

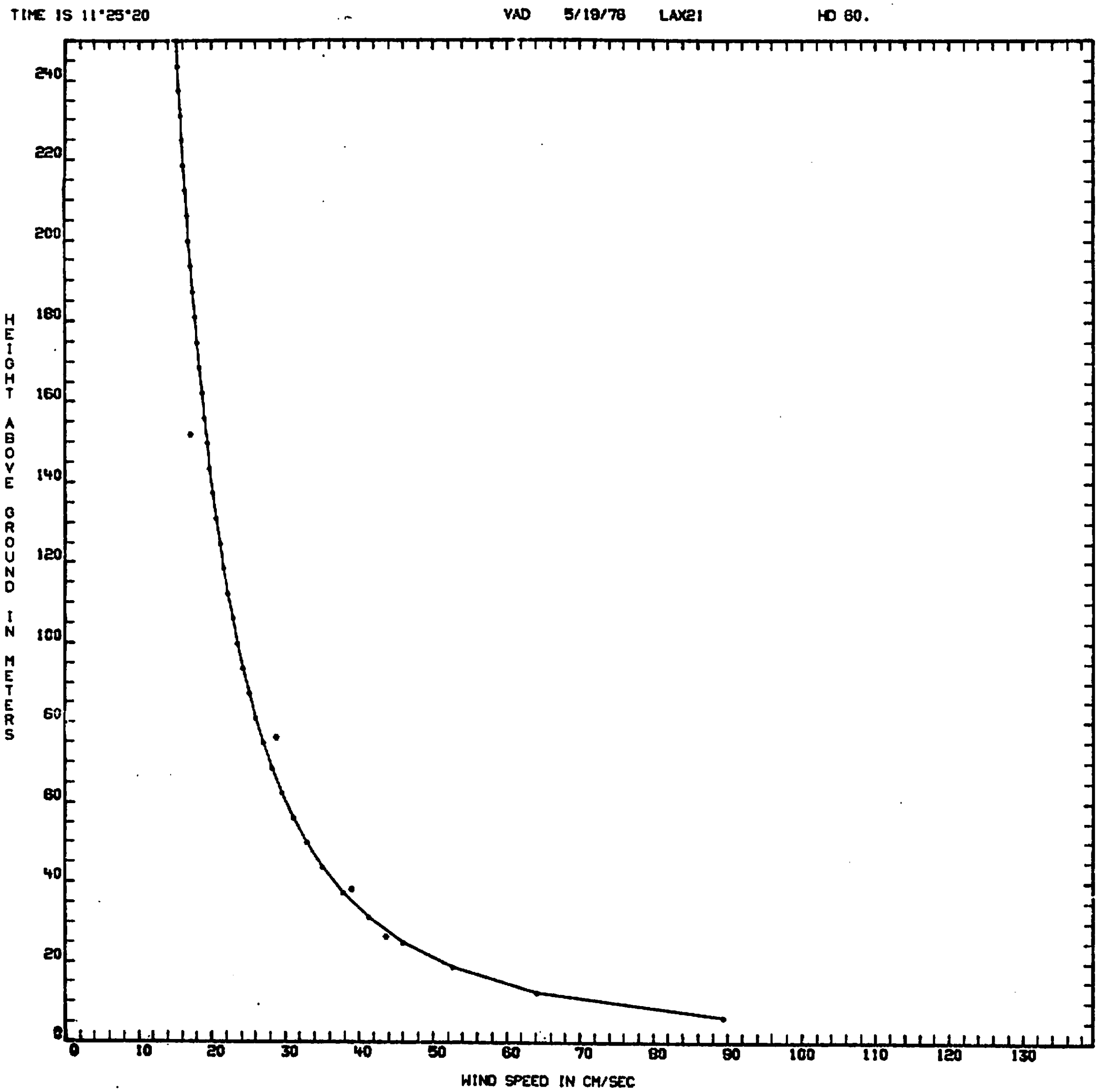


FIGURE B-1. SAMPLE WIND PROFILE PLOTS.

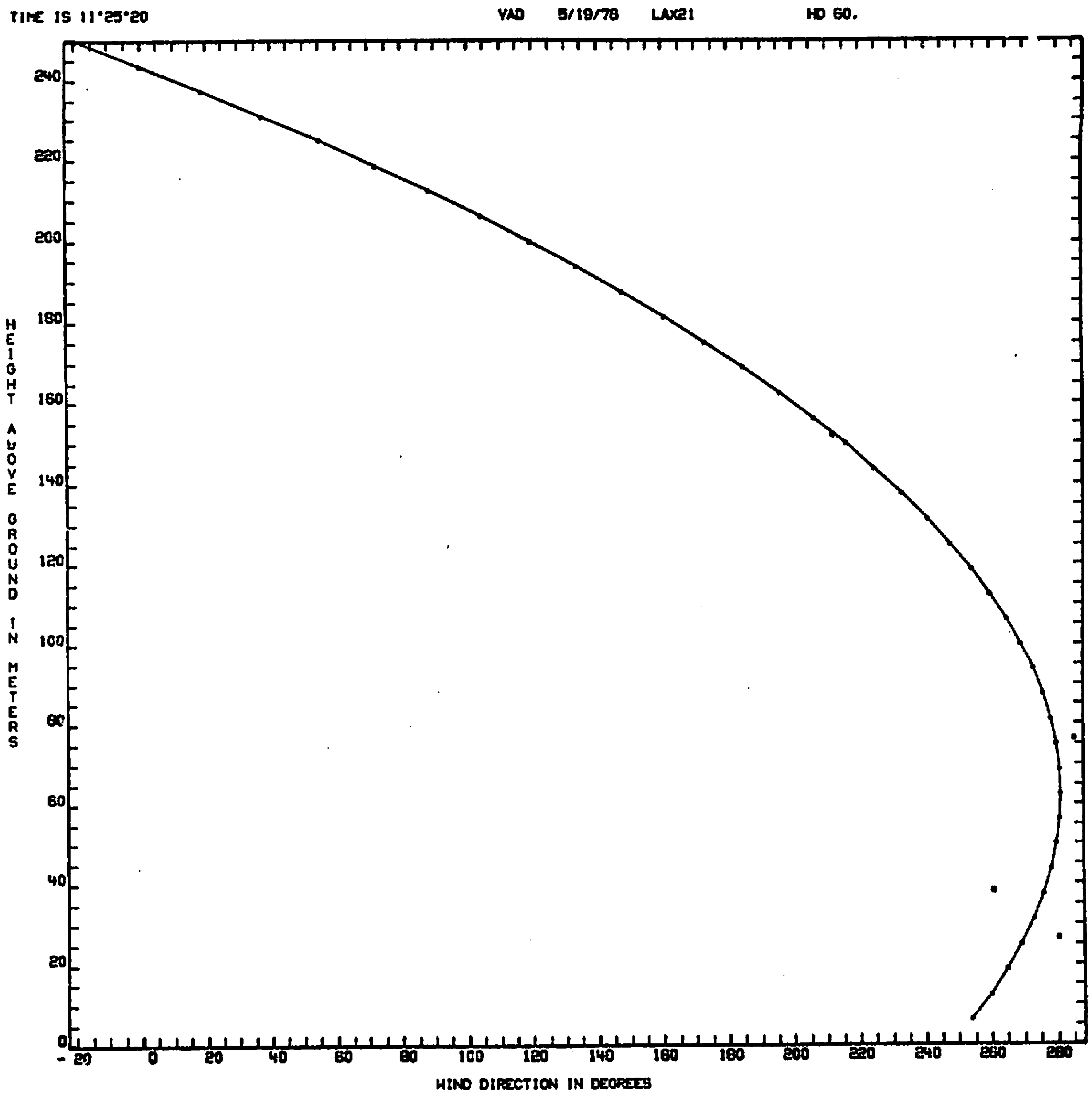


FIGURE B-1. (Continued)

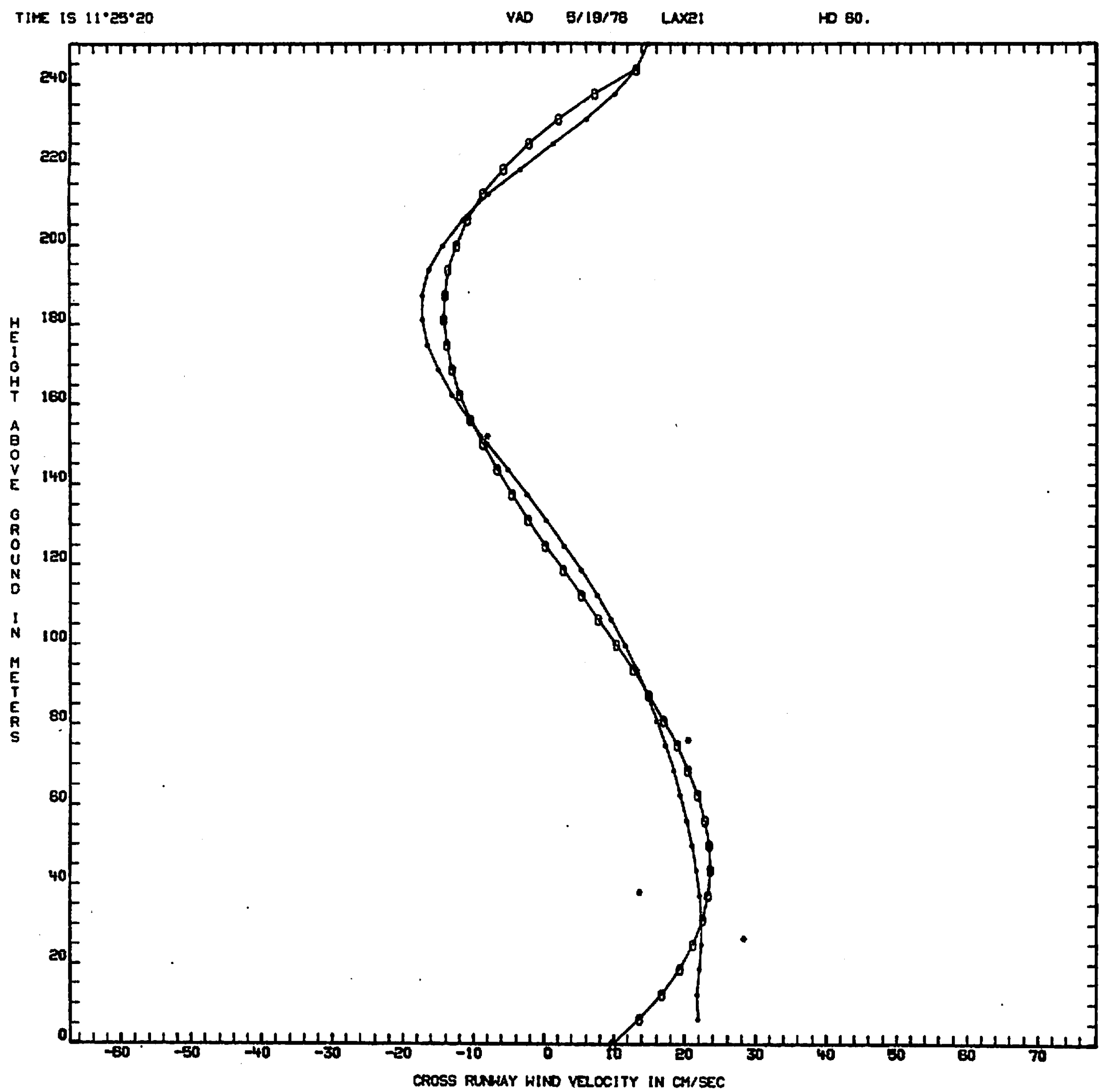


FIGURE B-1. (Continued)

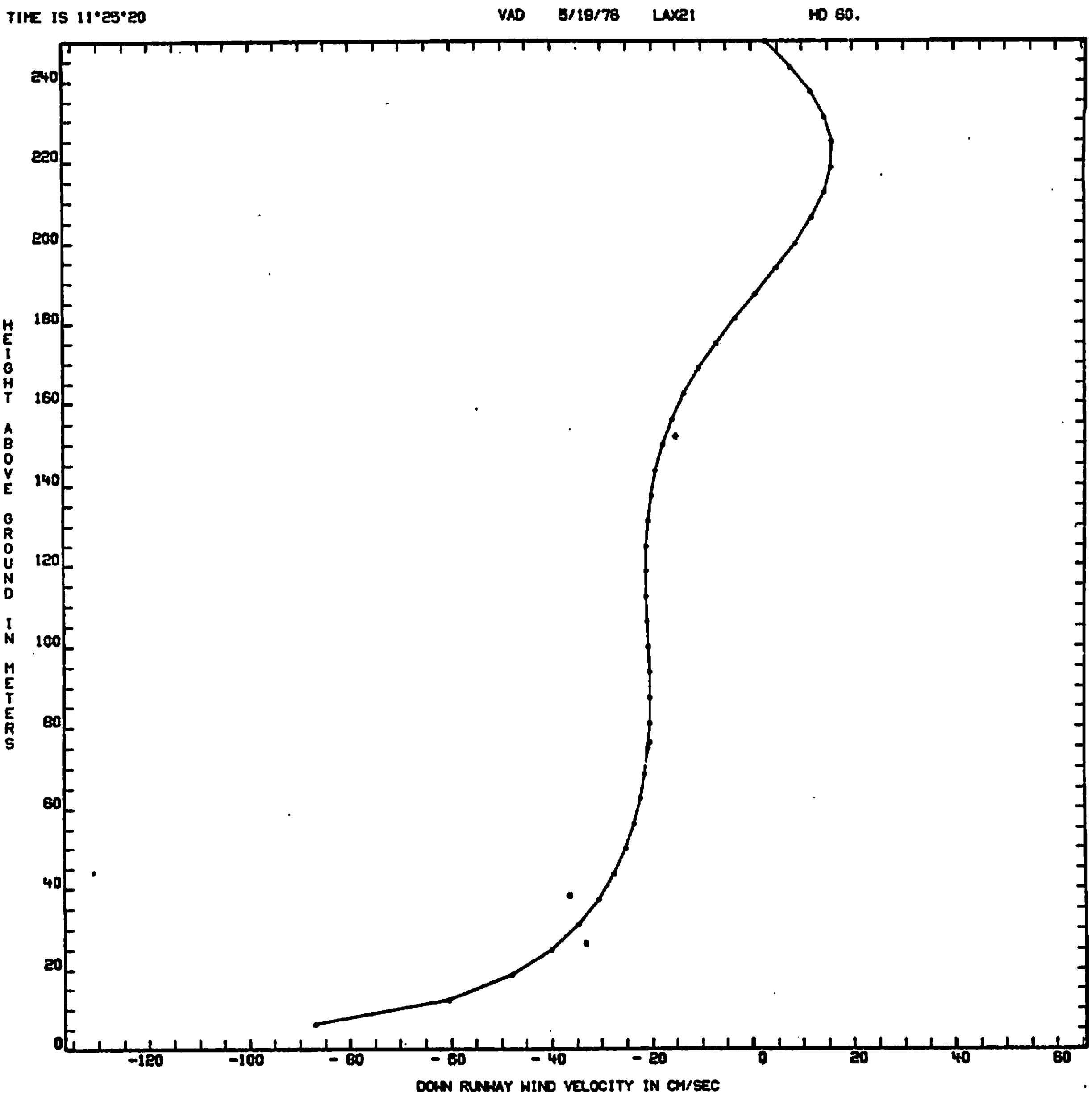


FIGURE B-1. (Continued)

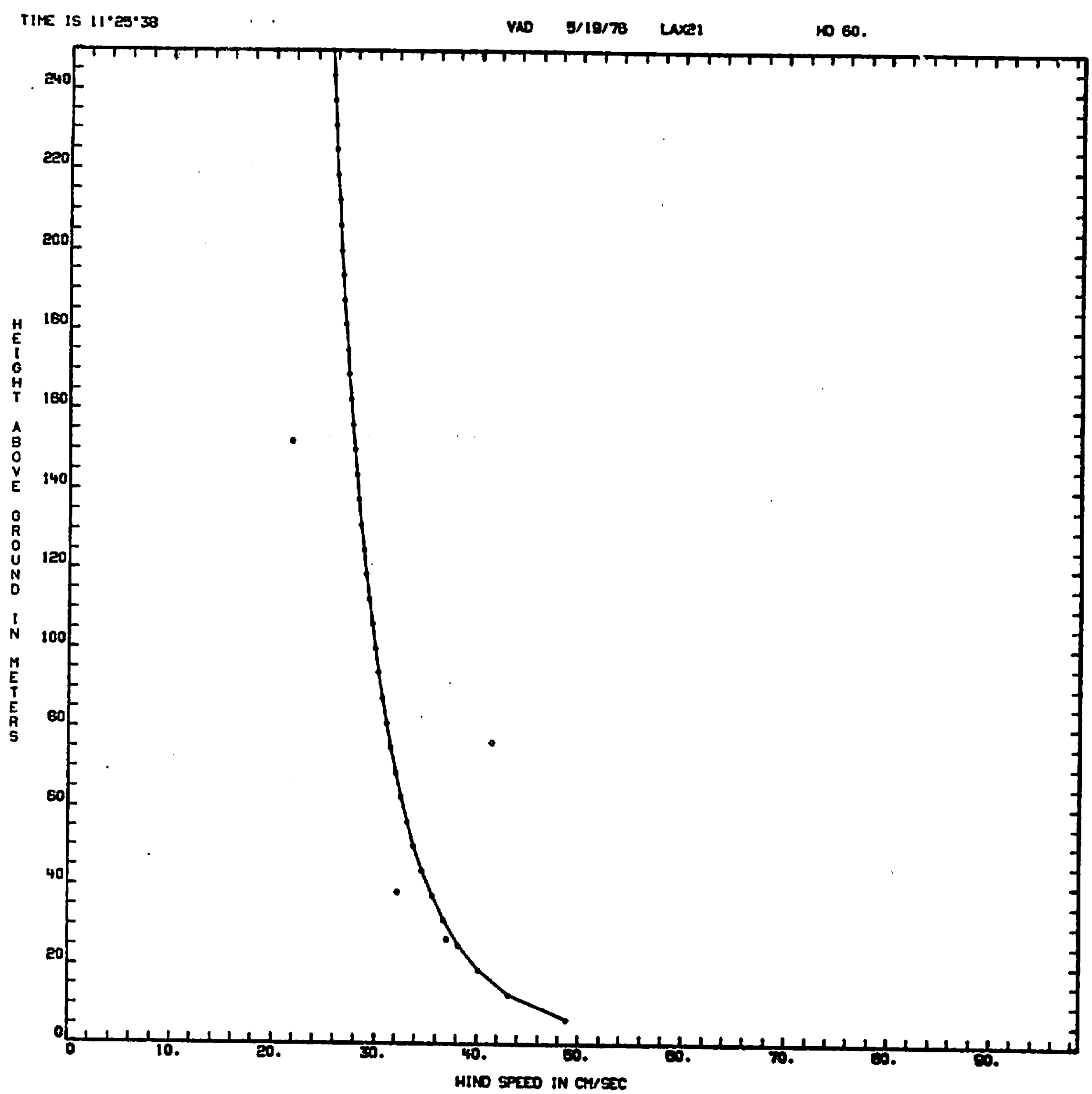
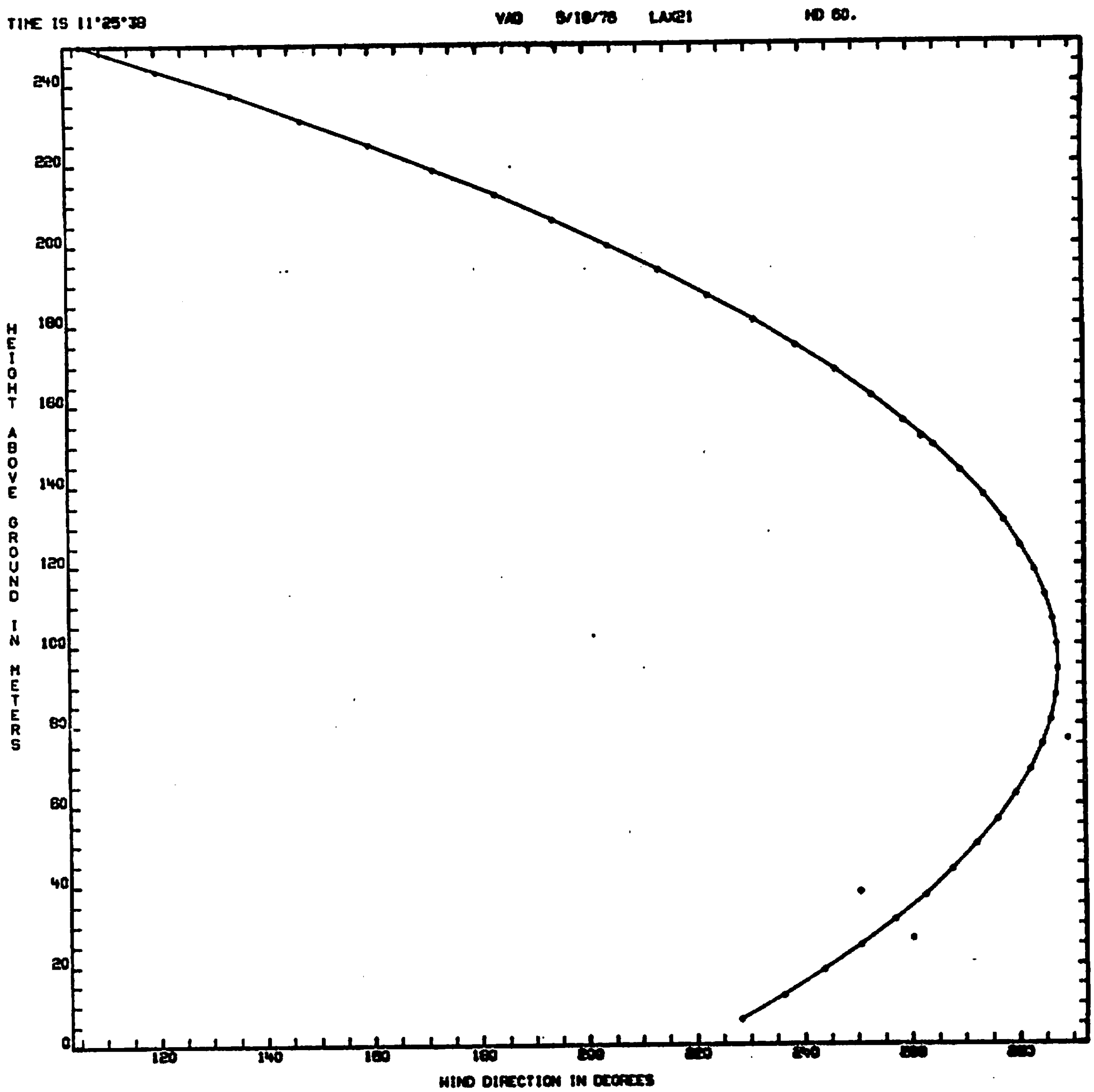


FIGURE B-1. (Continued)



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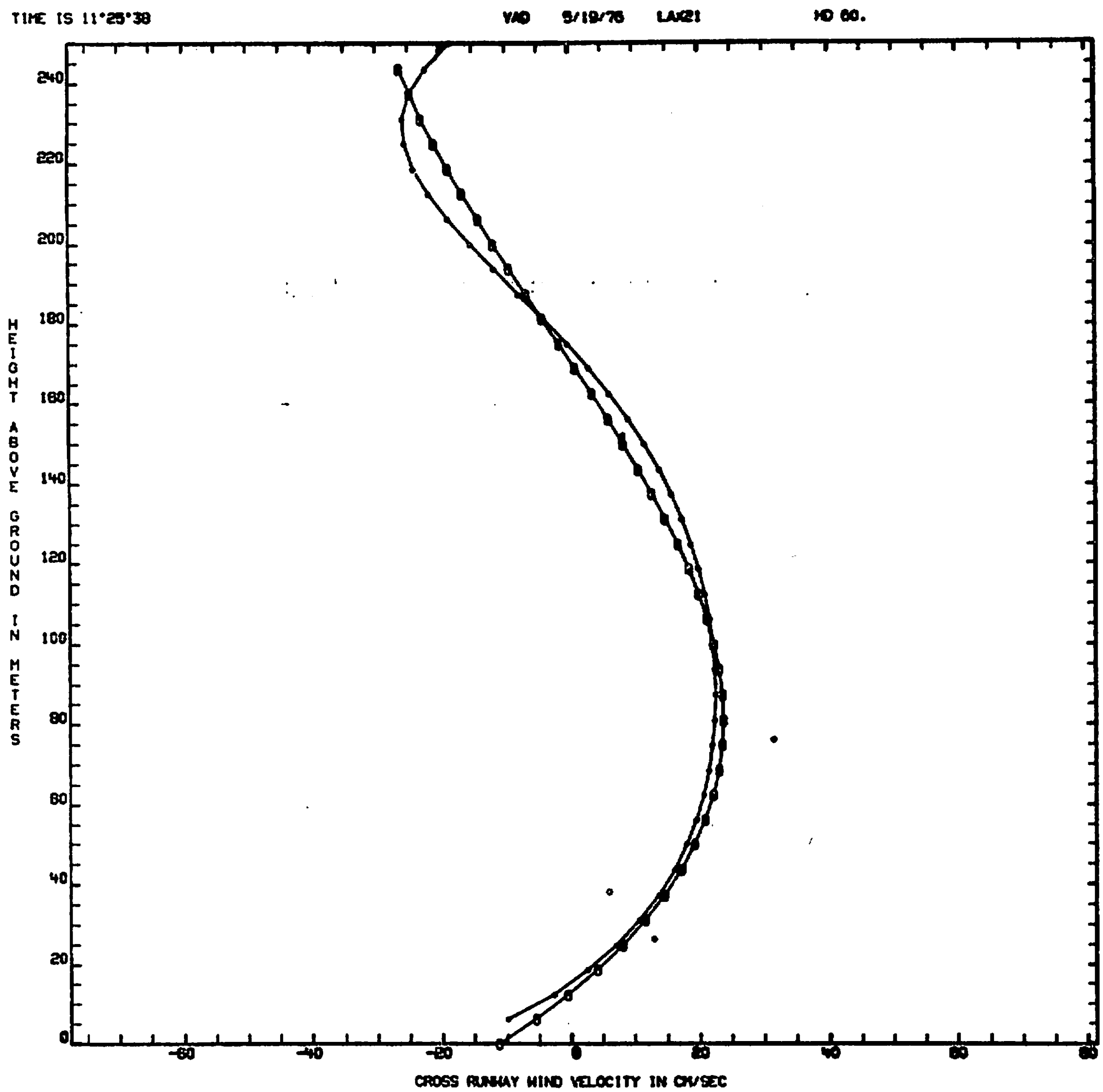

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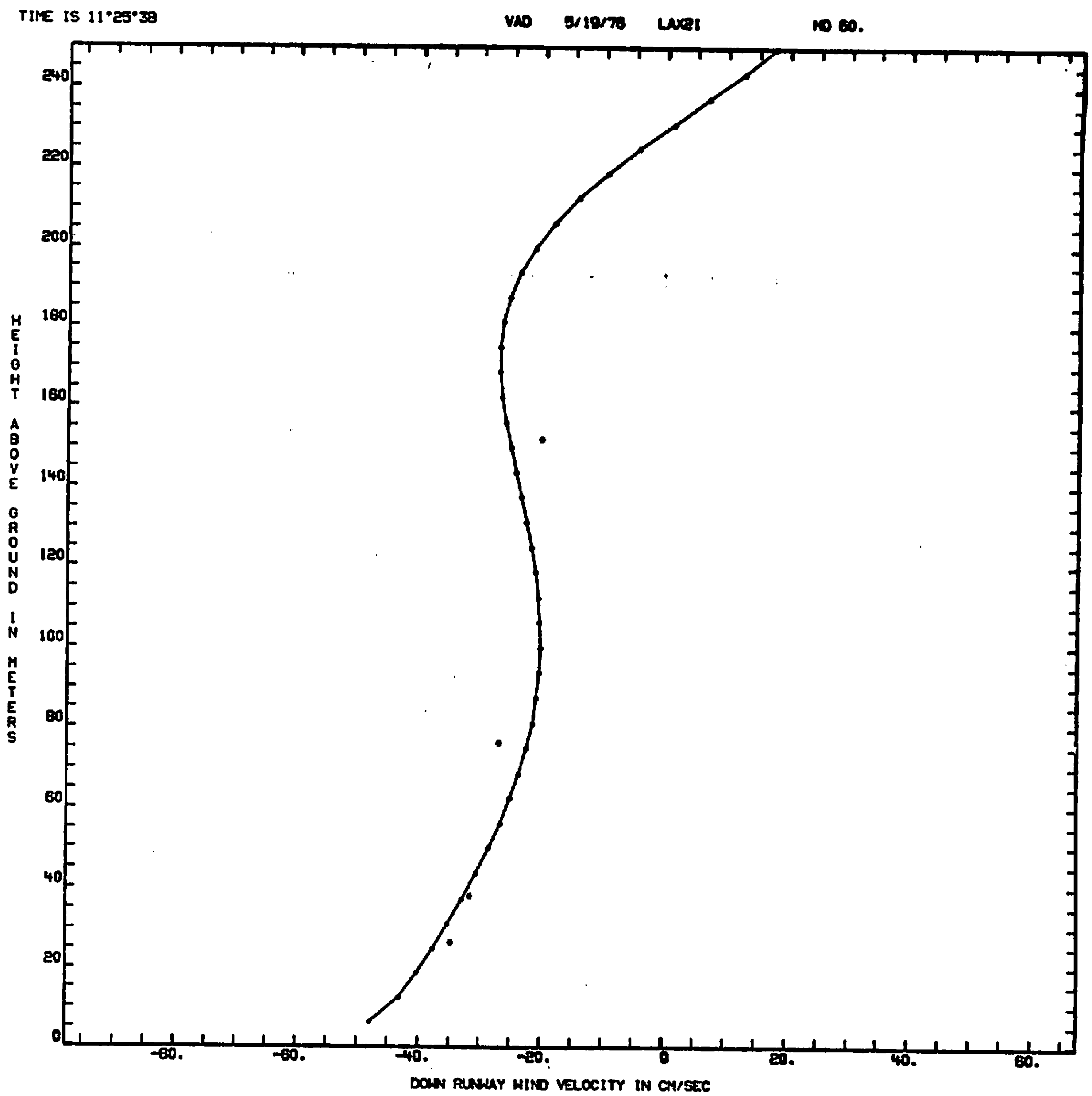


FIGURE B-1. (Continued)

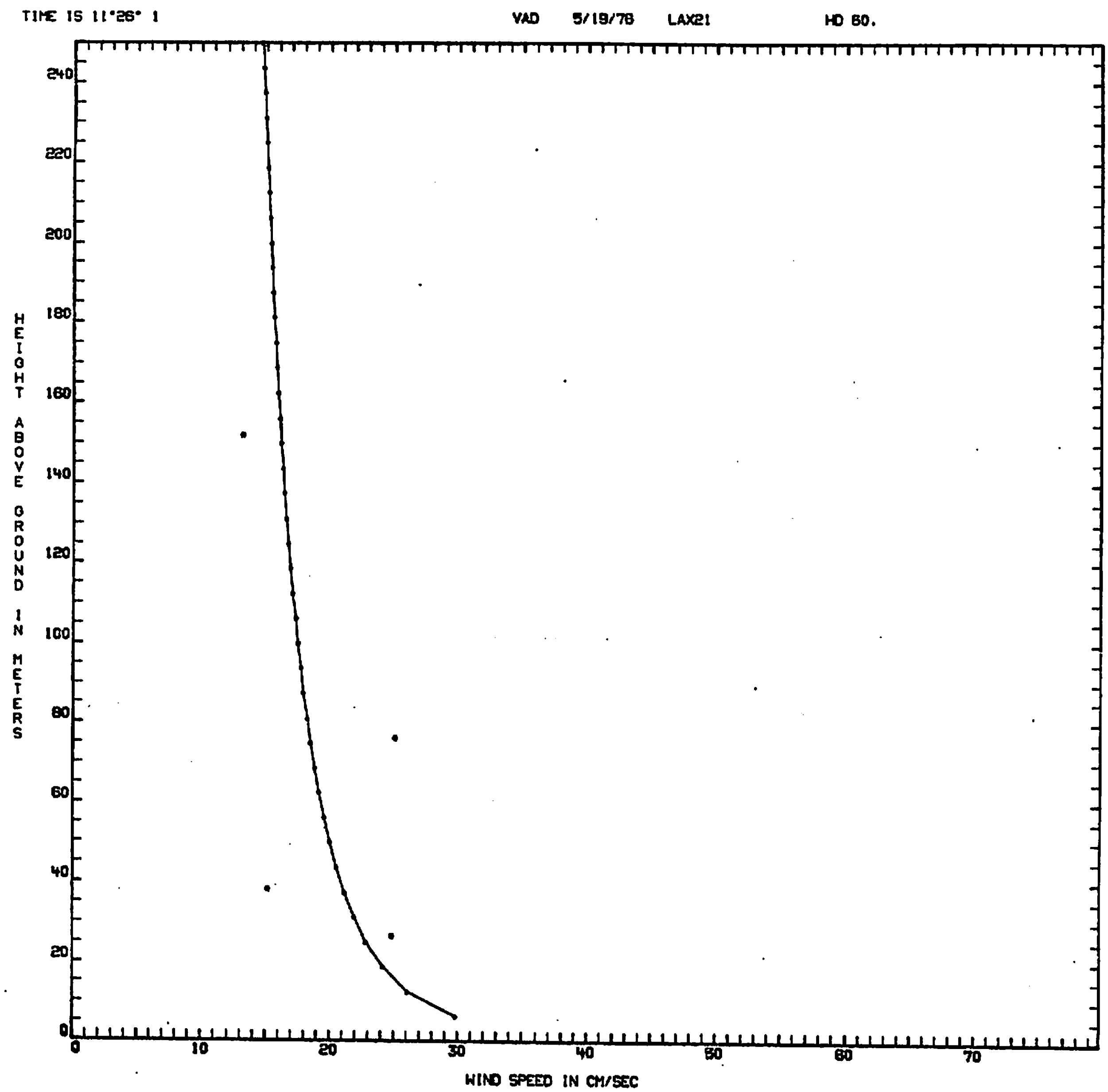


FIGURE B-1. (Continued)

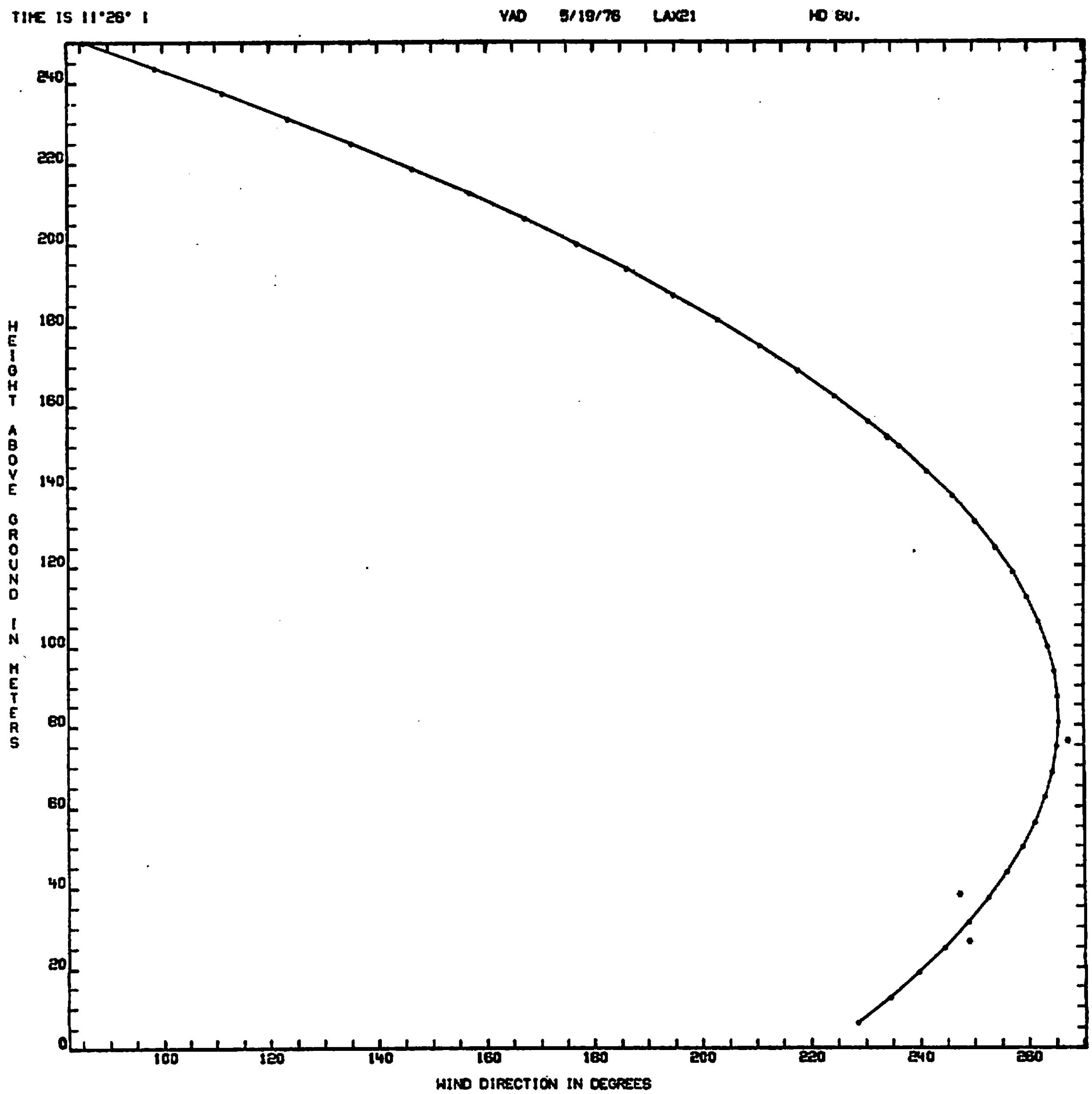


FIGURE B-1. (Continued)

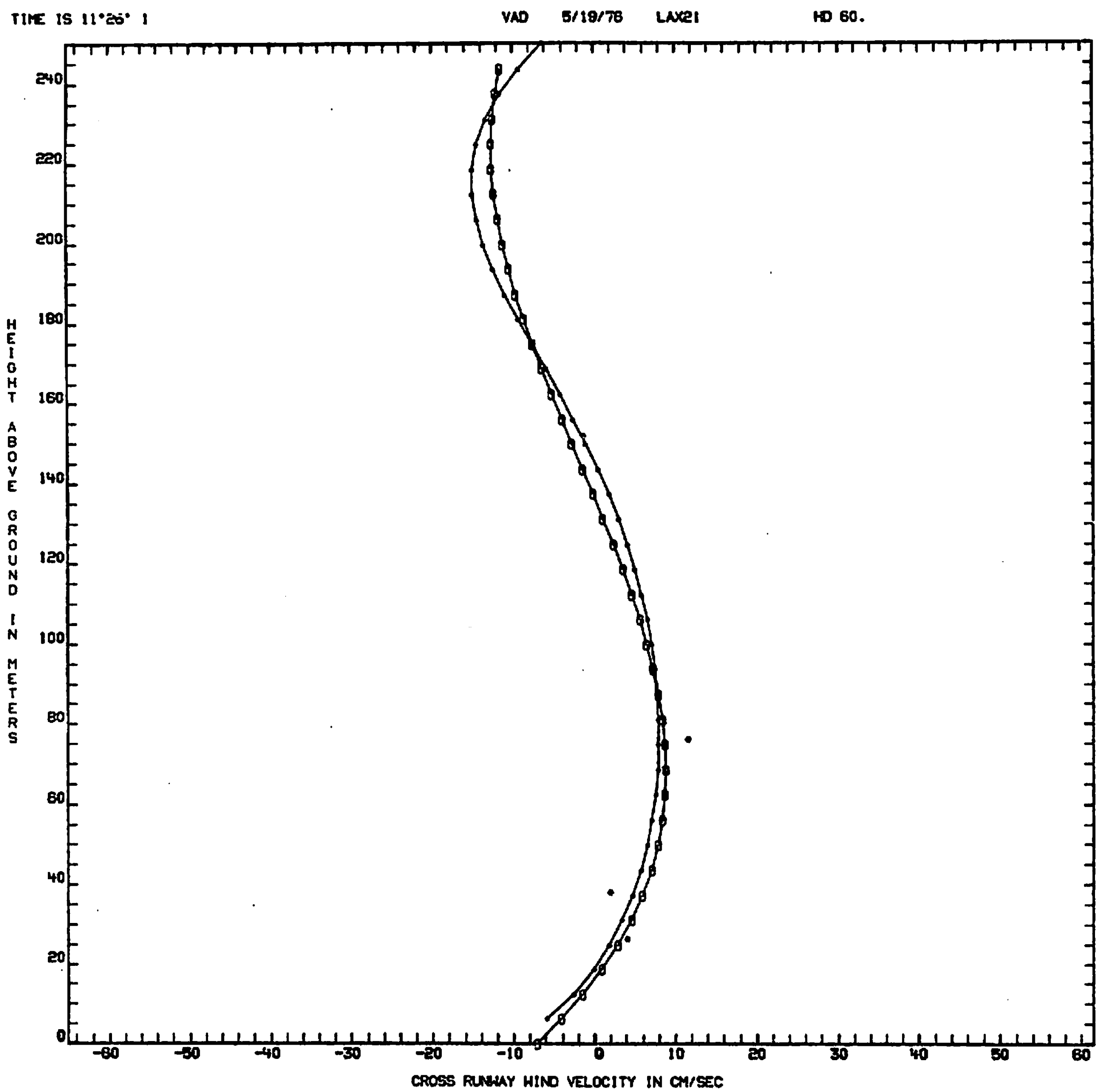


FIGURE B-1. (Continued)

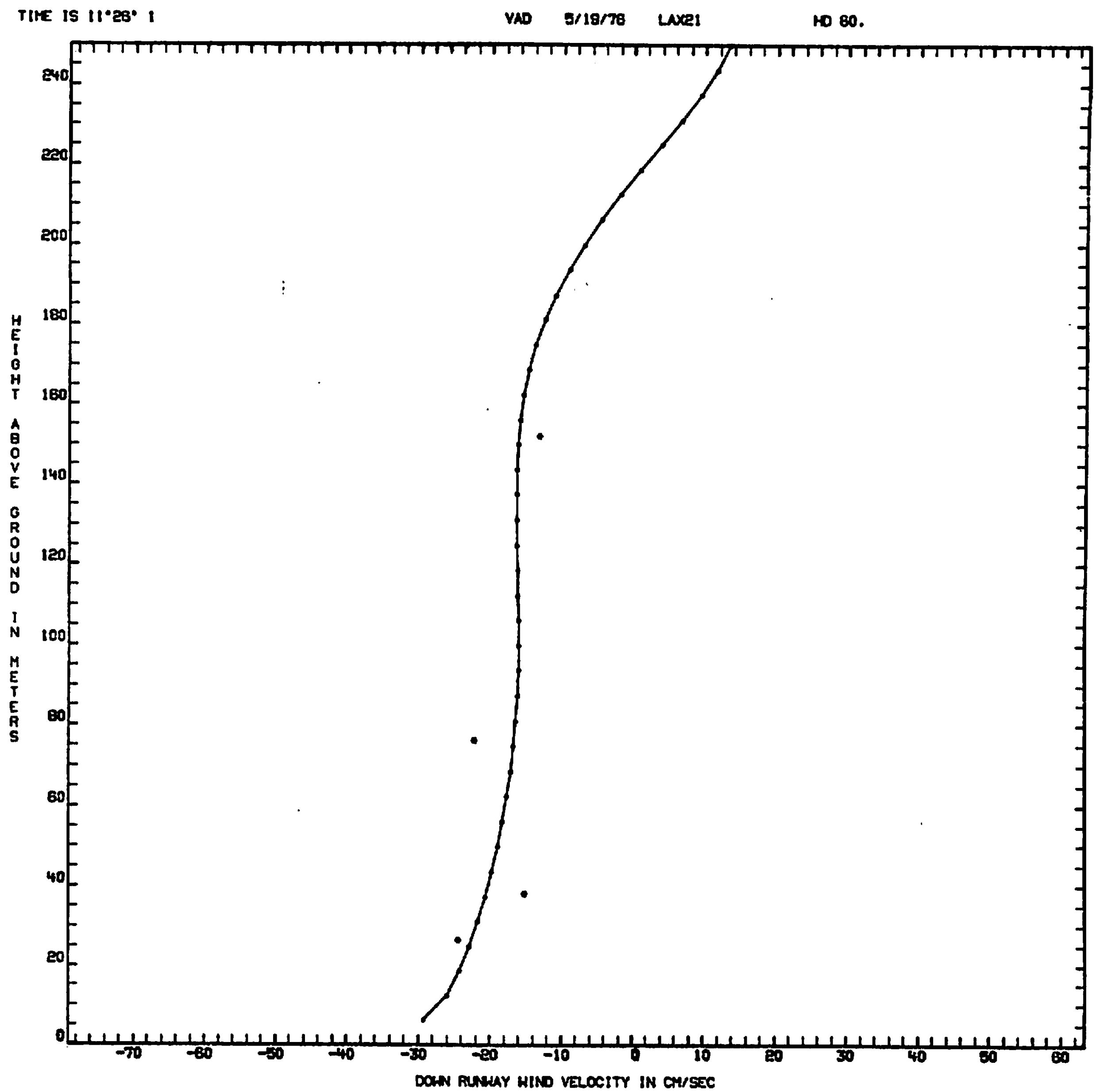


FIGURE B-1. (Continued)

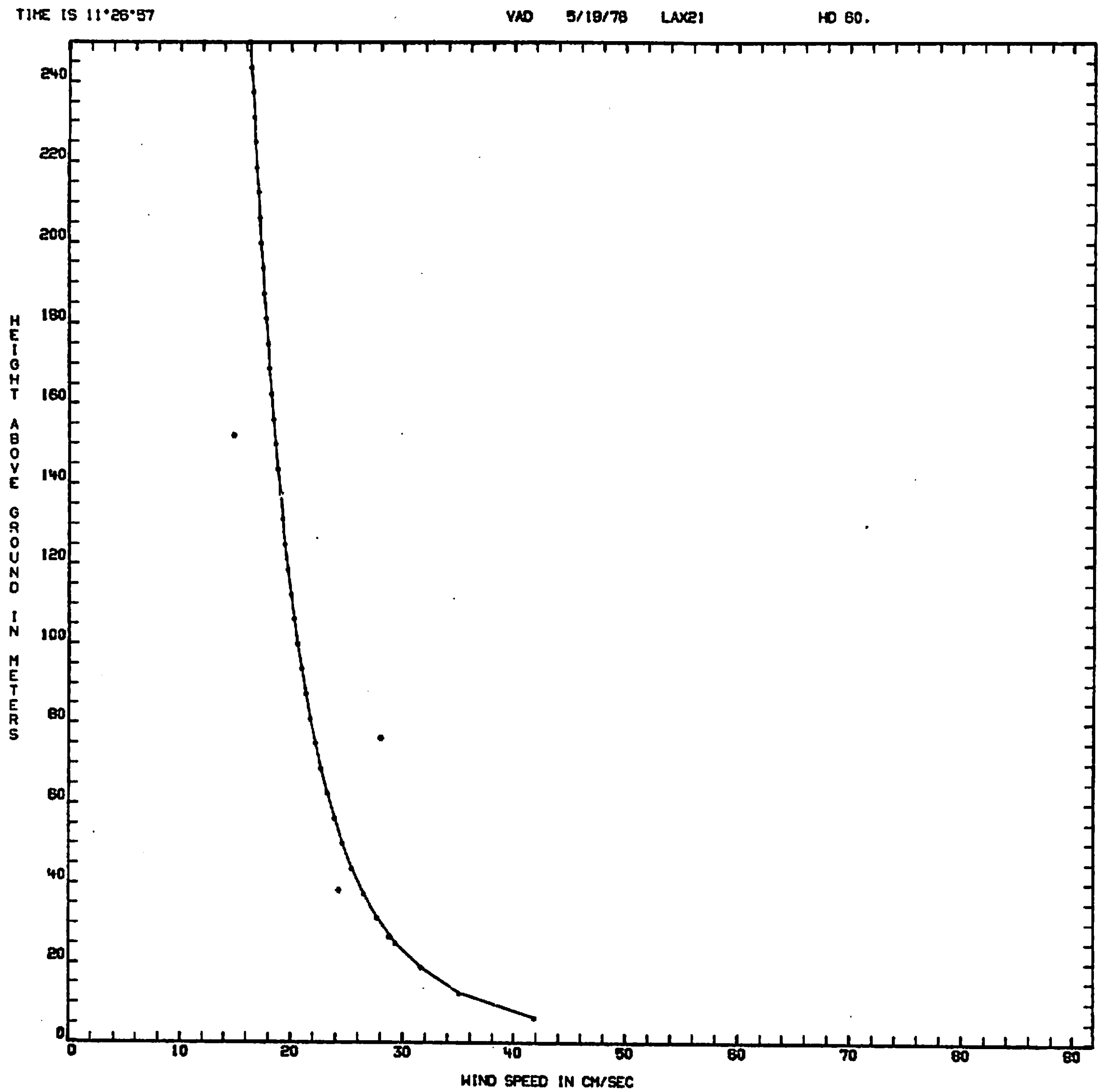


FIGURE B-1. (Continued)

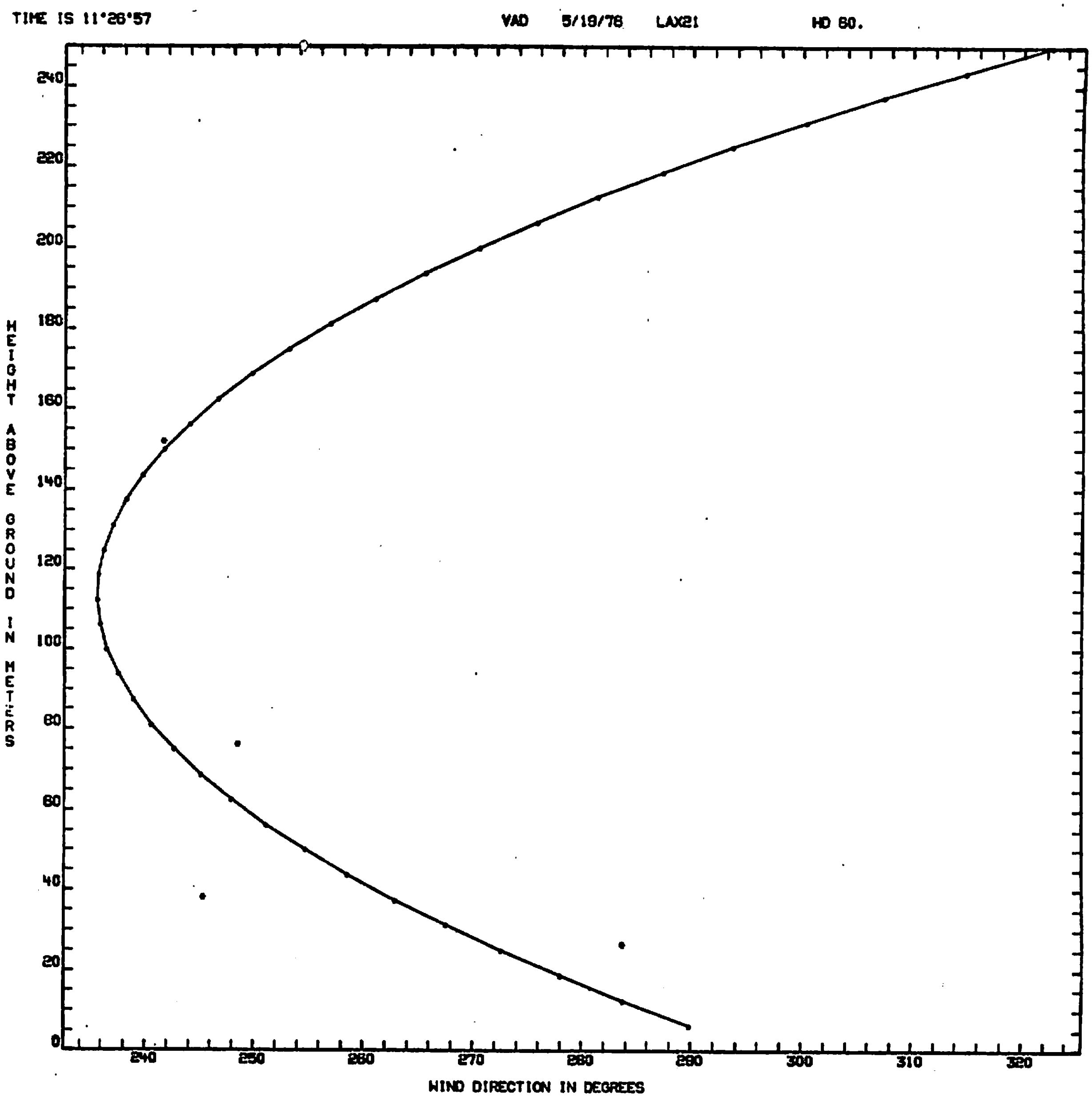
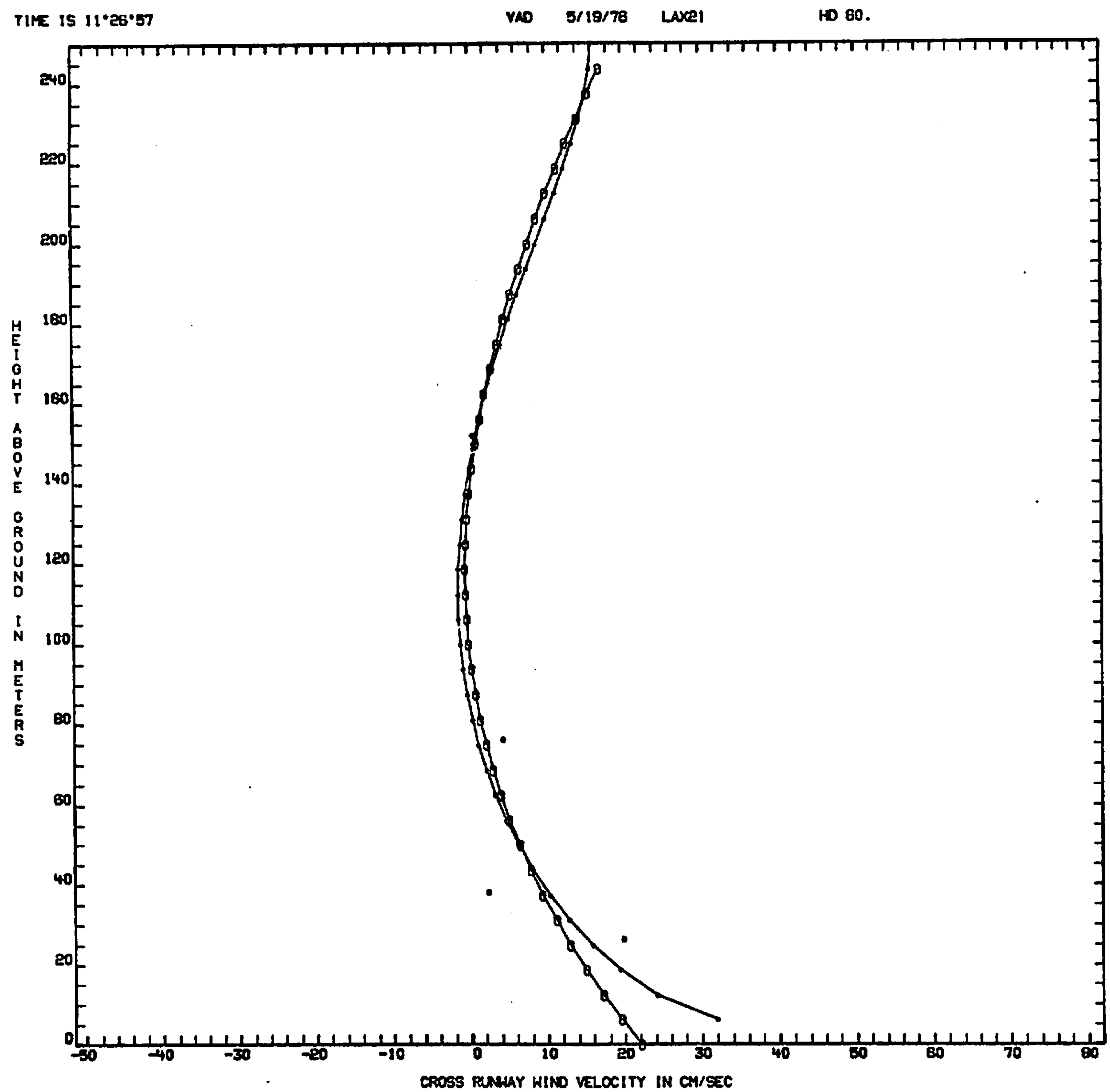


FIGURE B-1. (Continued)



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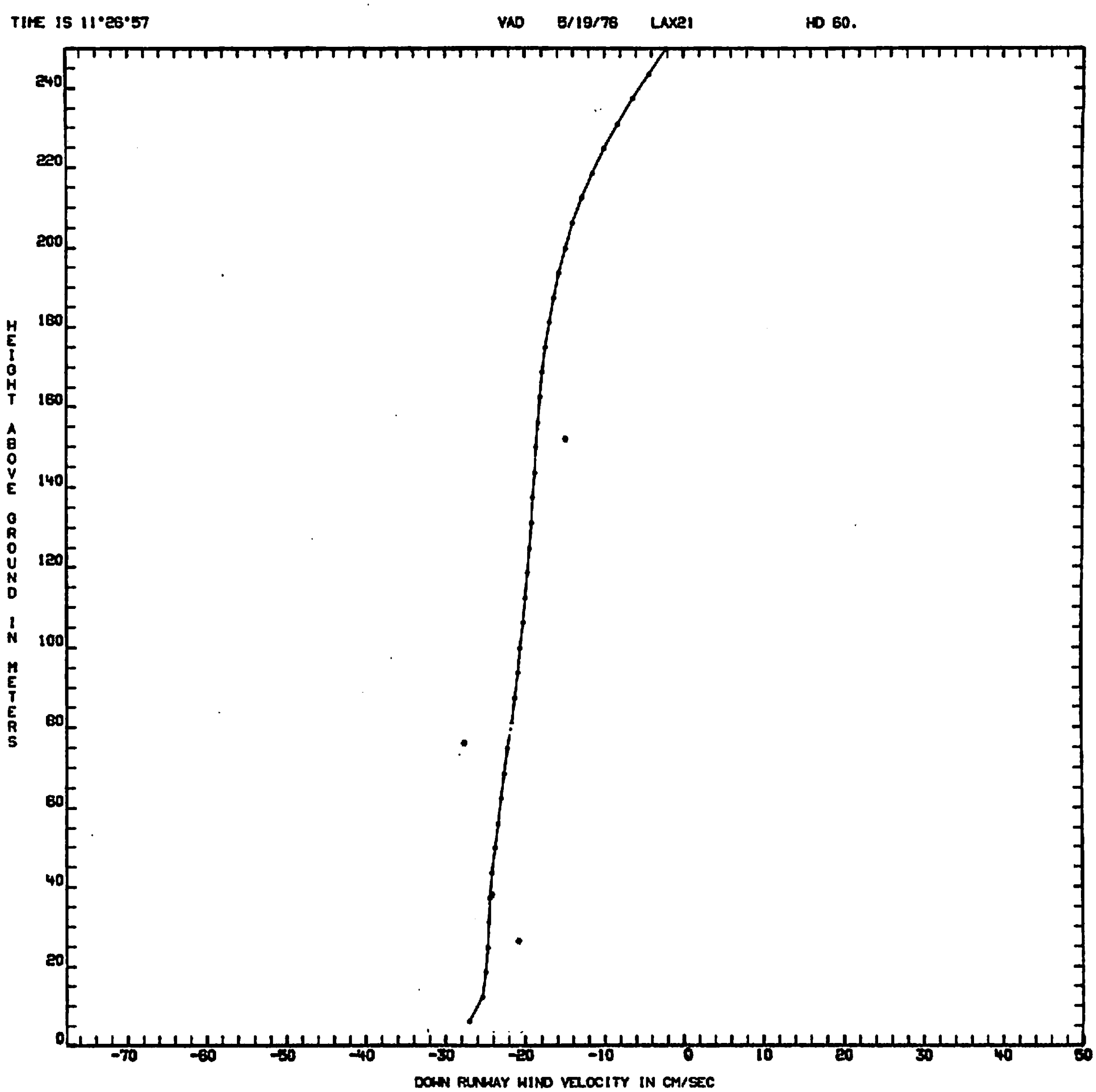

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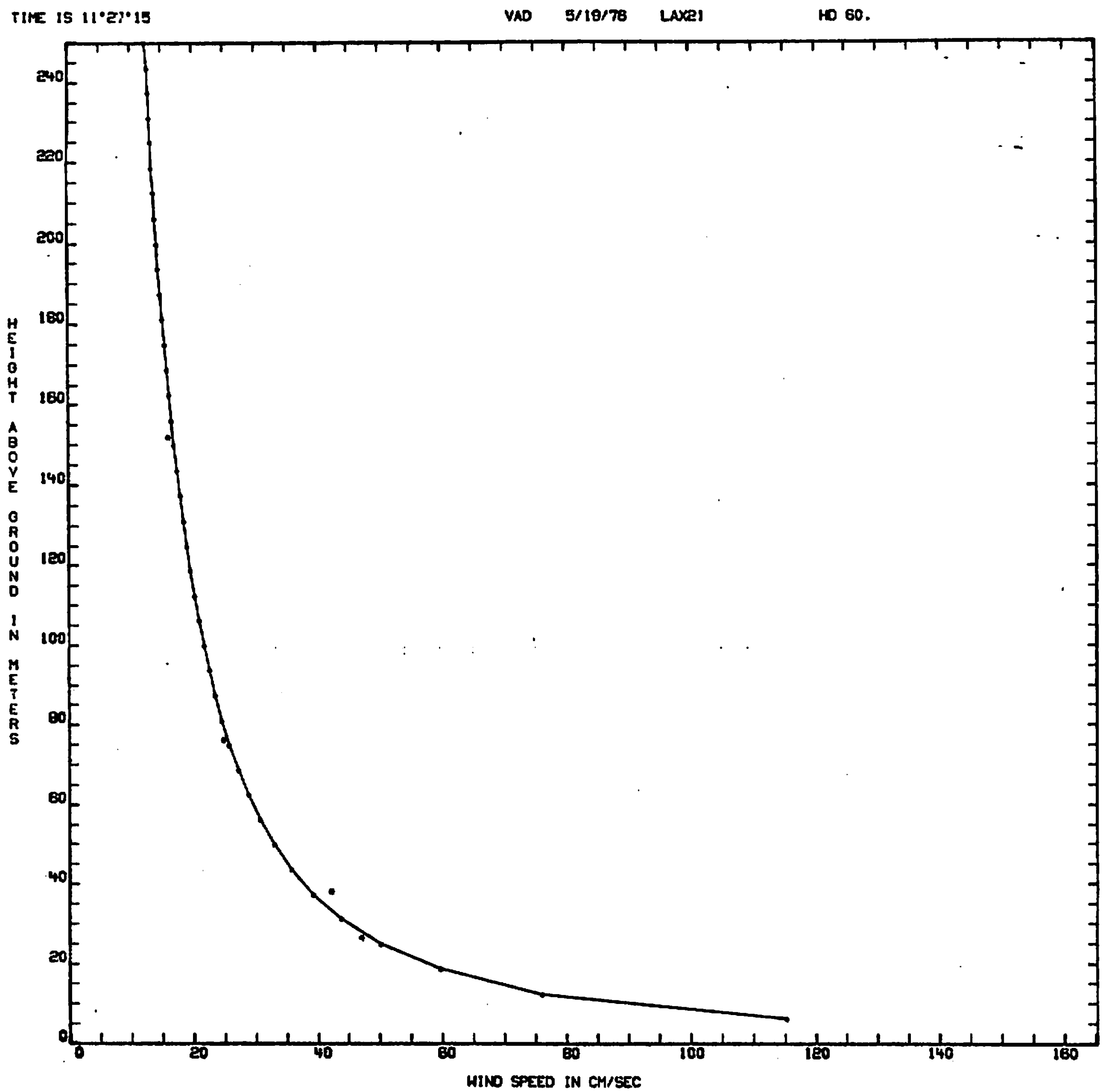

FIGURE B-1. (Continued)

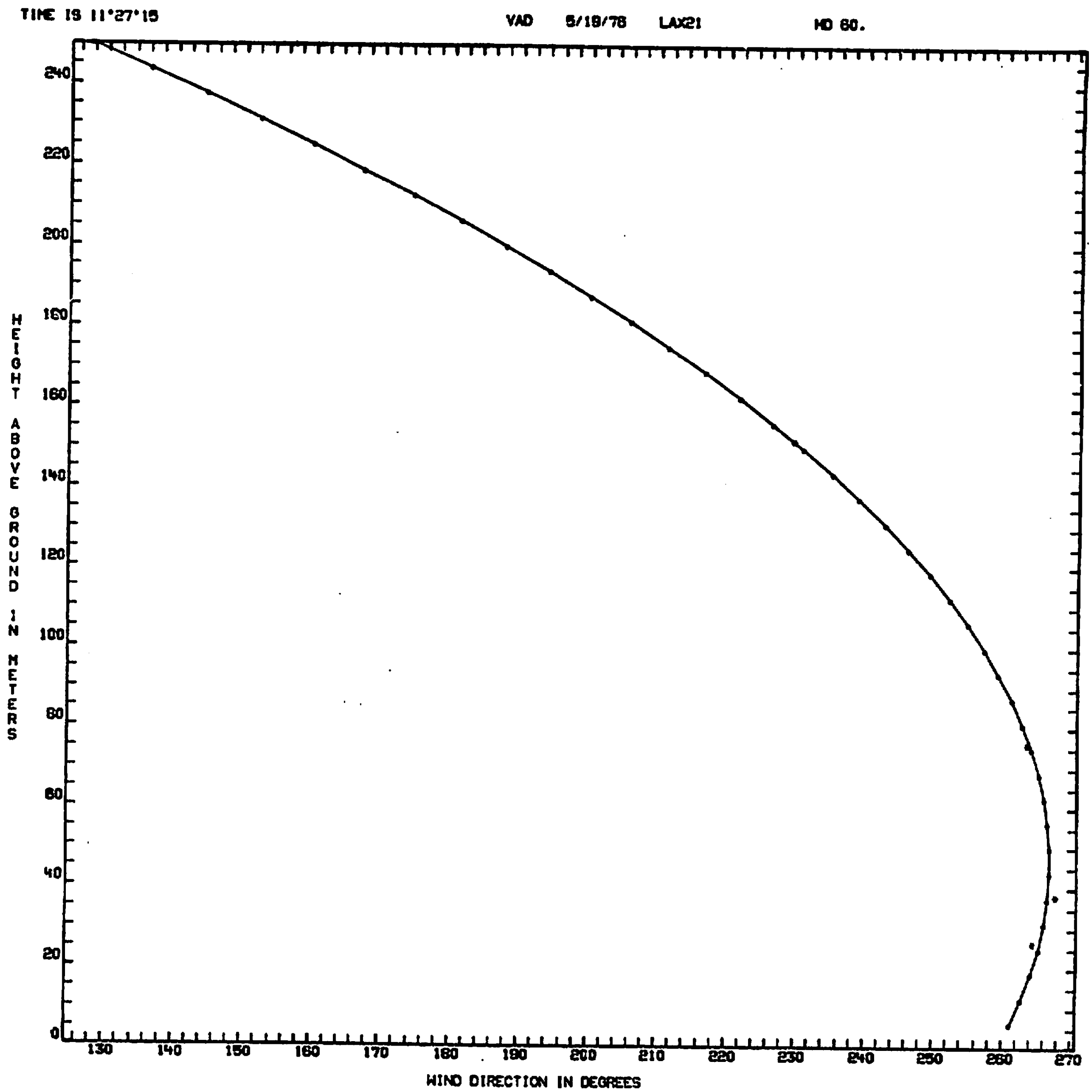

FIGURE B-1. (Continued)

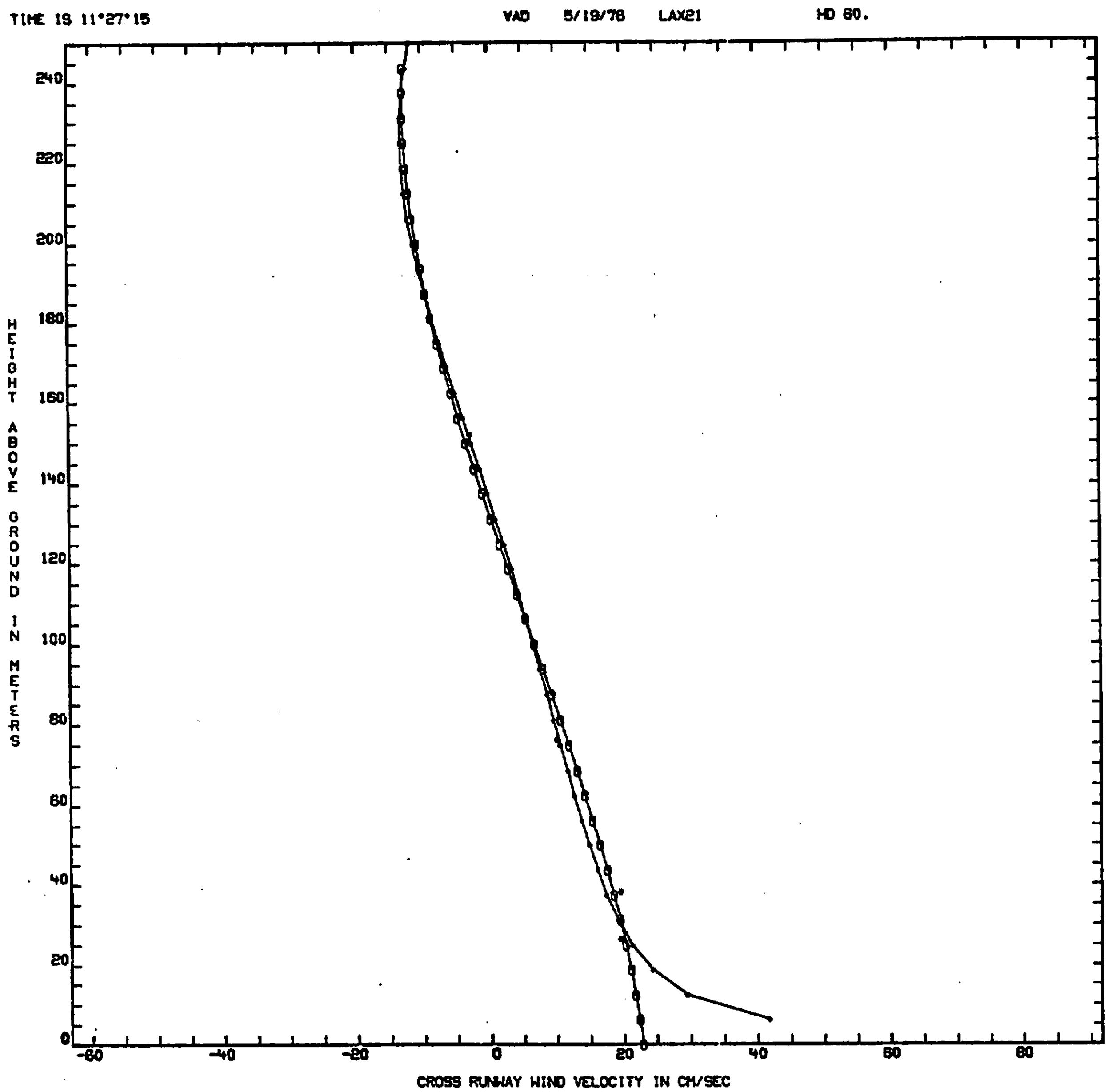

FIGURE B-1. (Continued)

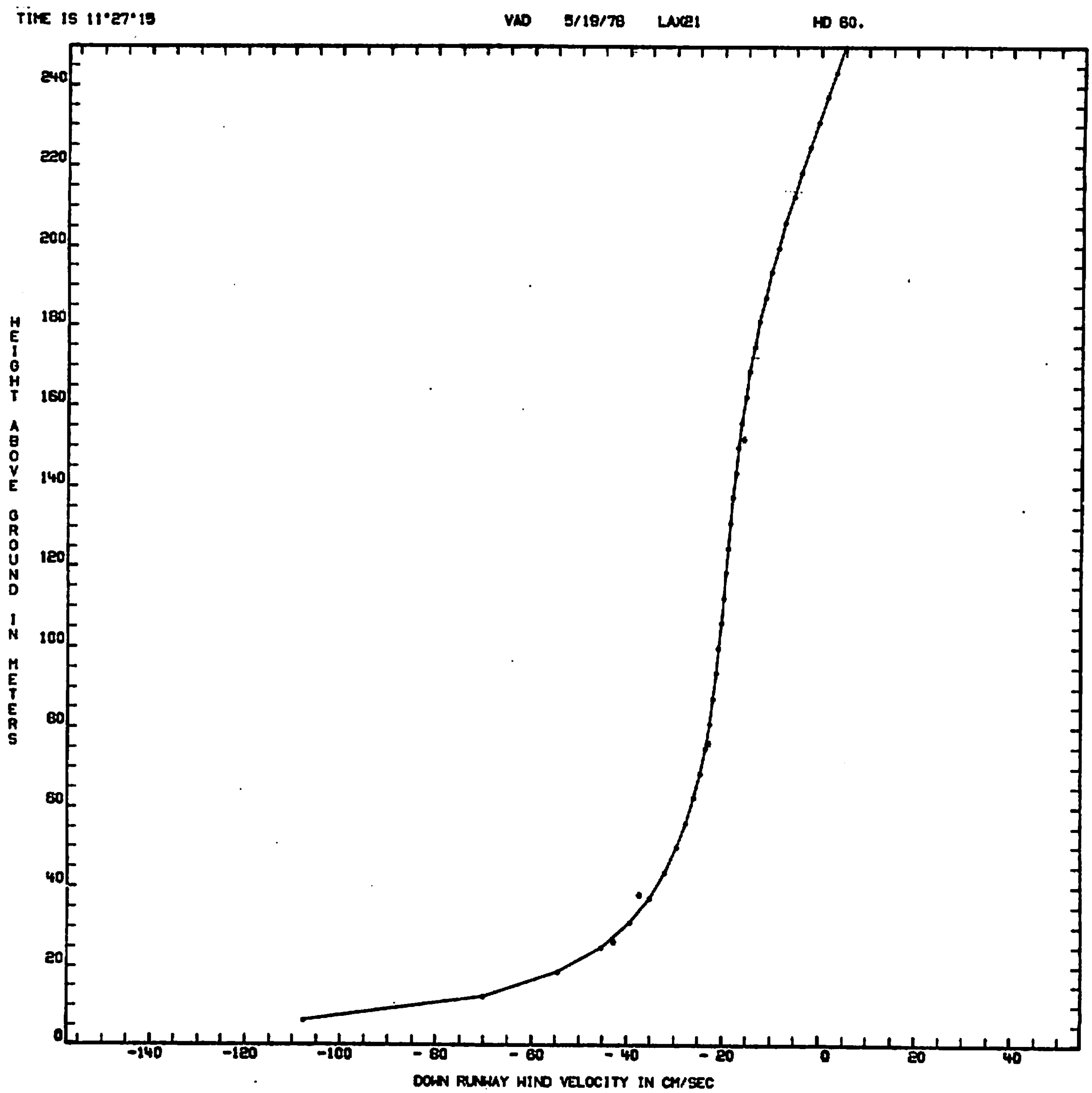

FIGURE B-1. (Continued)

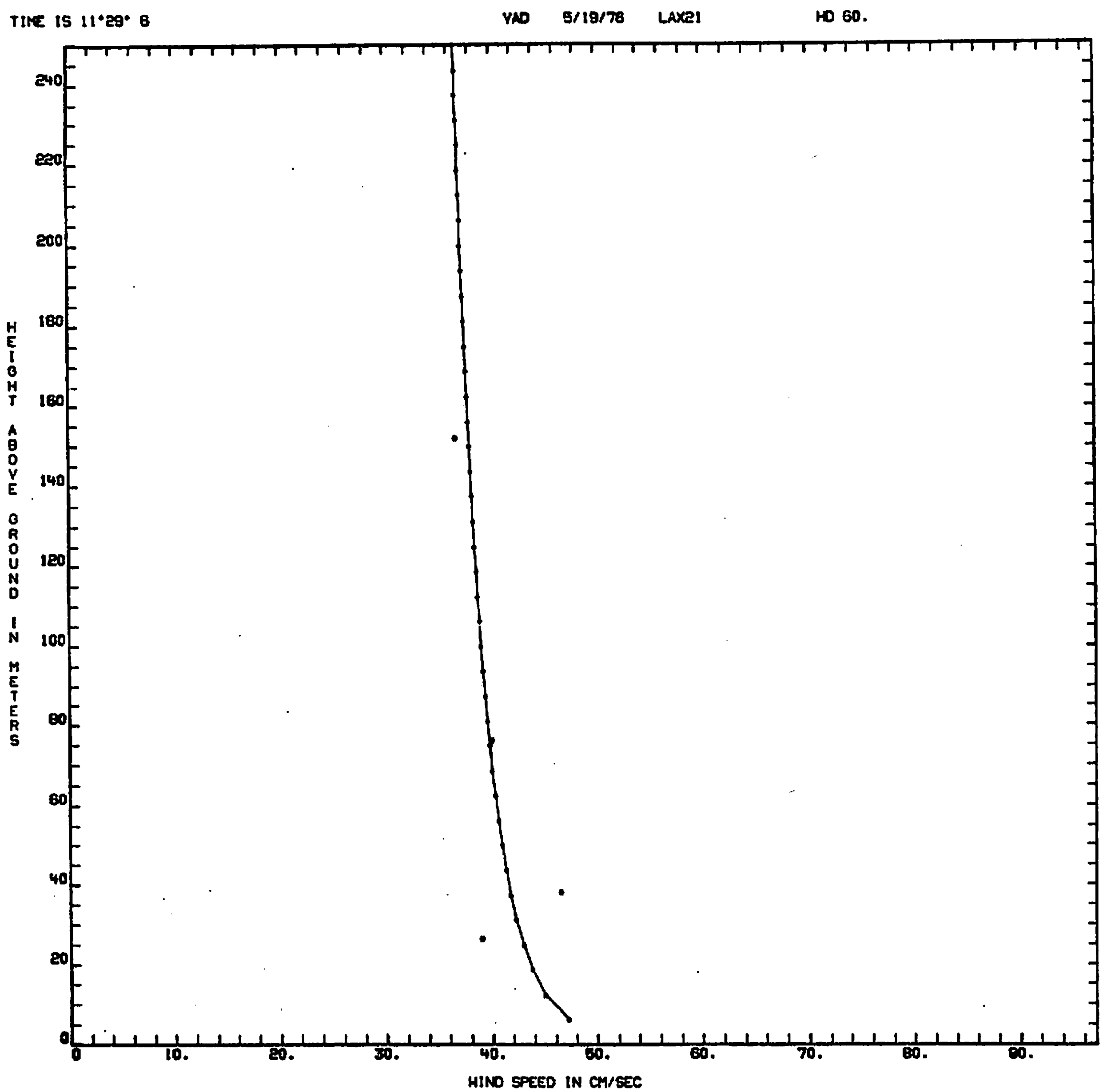

FIGURE B-1. (Continued)

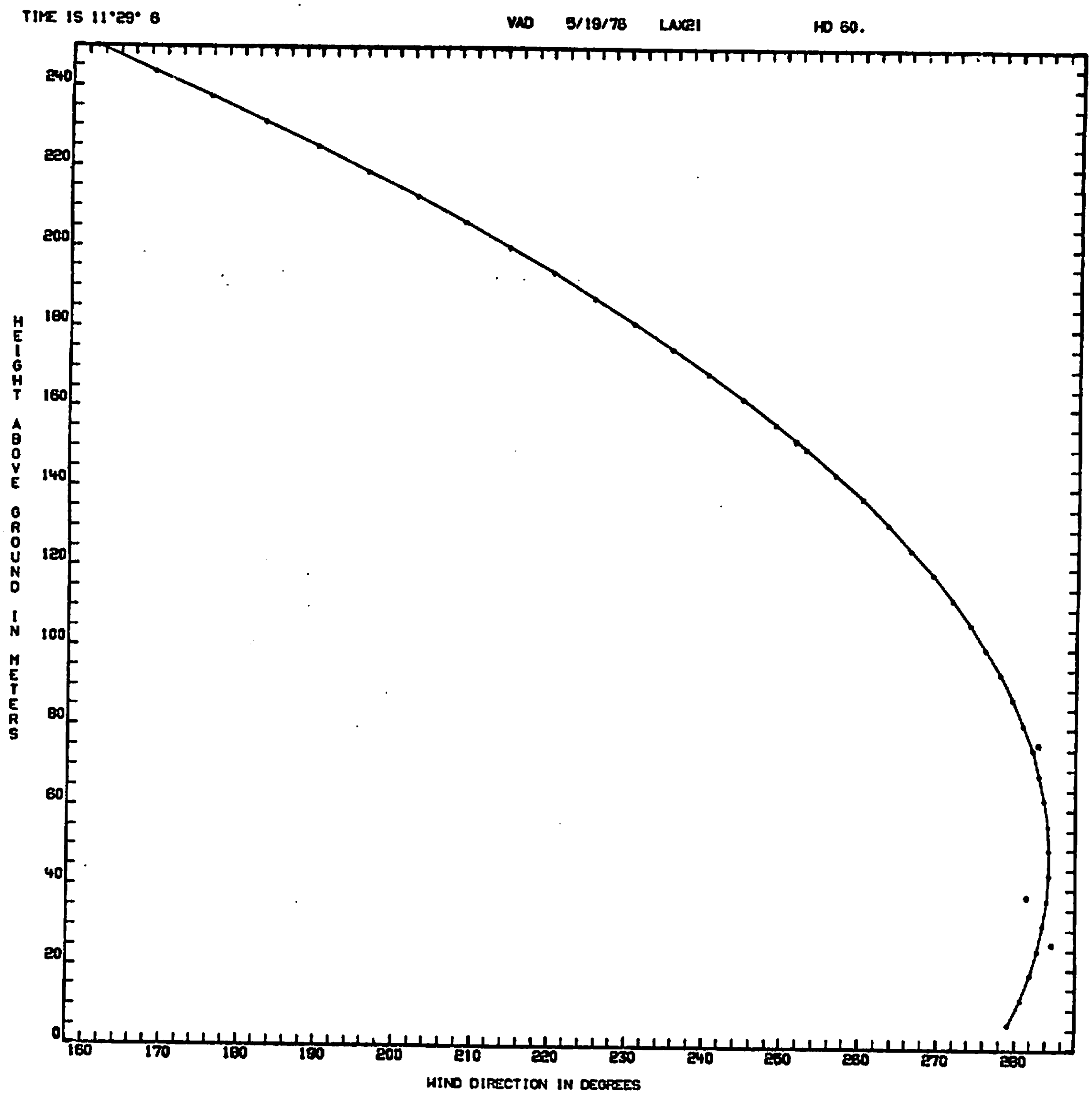

FIGURE B-1. (Continued)

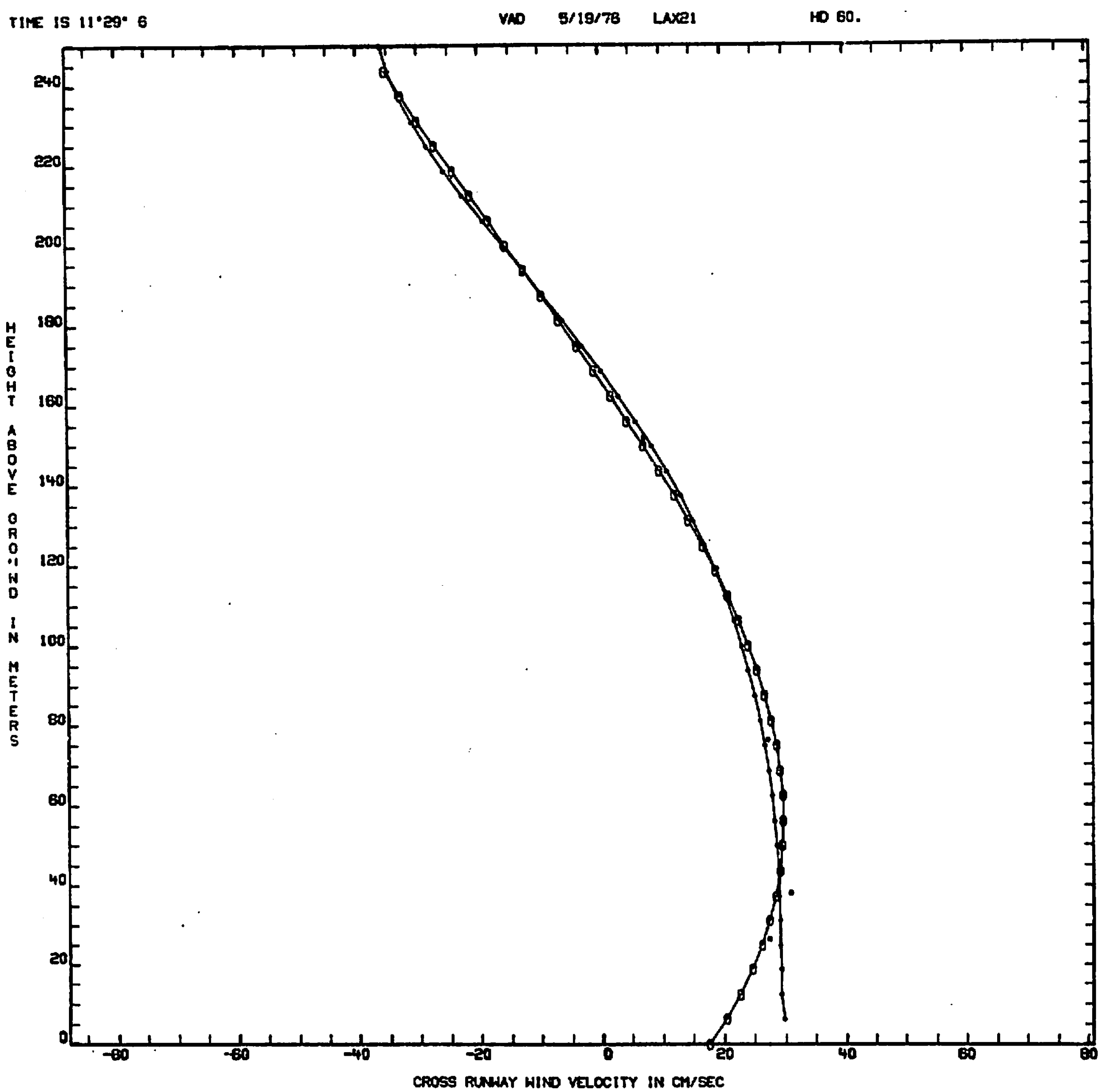

FIGURE B-1. (Continued)

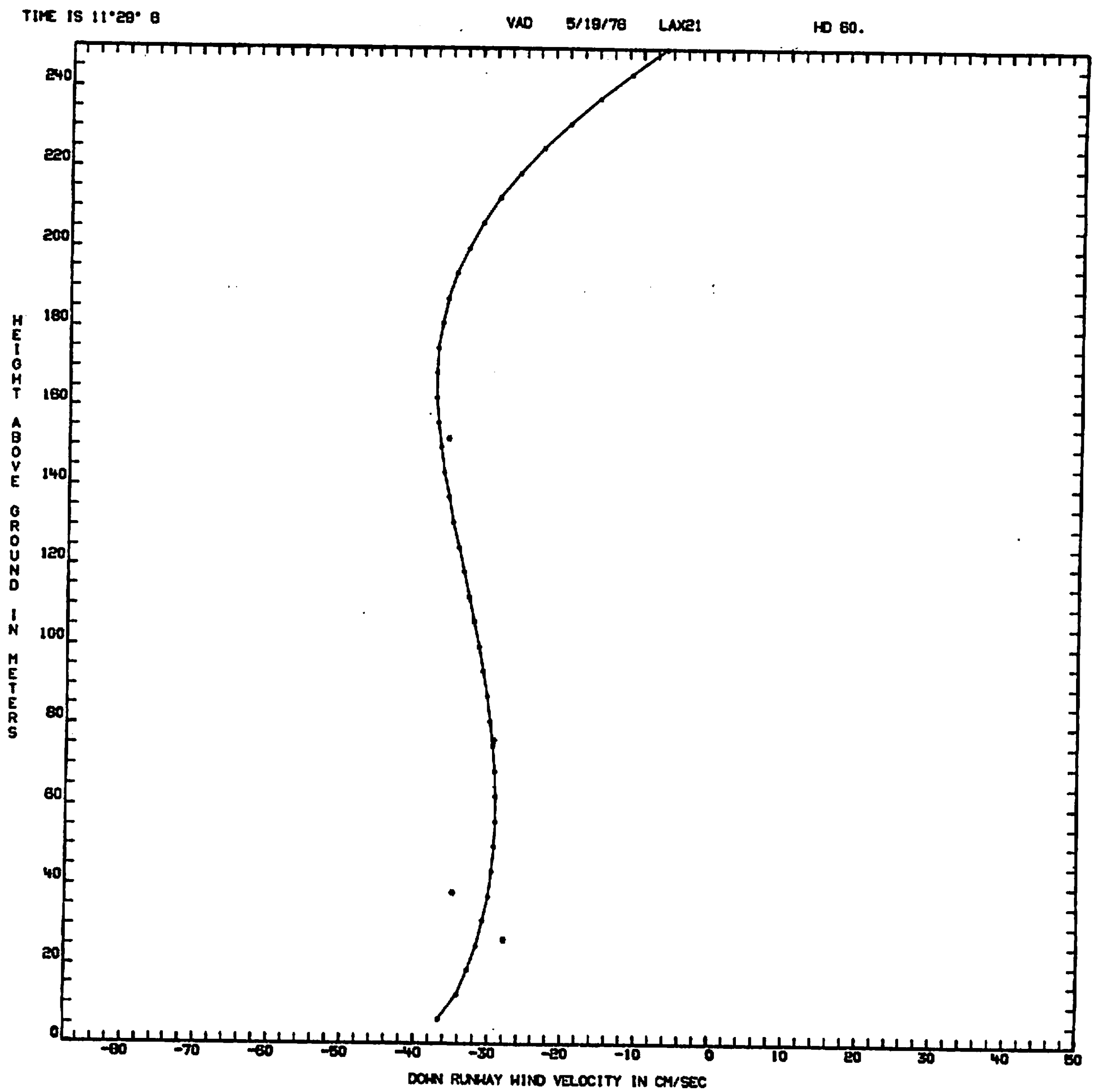

FIGURE B-1. (Continued)

Appendix C

VORTEX DESCENT DURING HEADWIND OR TAILWIND CONDITIONS

Takeoff wake vortex trajectory is sketched below,

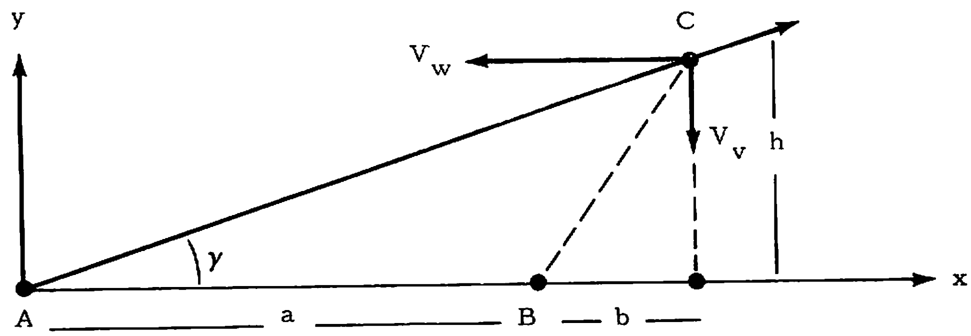

FIGURE C-1. GEOMETRY OF VORTEX DESCENT IN A HEADWIND

where

V_w = wind velocity,

V_v = vortex descent velocity, and

γ = takeoff flight path angle

Time required for vortex to descend from Point C to B is given by

$$t = \frac{h}{V_v} = \frac{b}{V_w} .$$

From flight path geometry,

$$\tan\gamma = h/(a + b) .$$

Therefore,

$$h = (a + b) \tan\gamma ,$$

$$t = \frac{(a + b) \tan\gamma}{V_v} = \frac{(a + t\,V_w)}{V_v} \tan\gamma ,$$

$$t = \frac{a}{V_v(1/\tan\gamma - V_w/V_v)} .$$

For the L-1011 wake vortex in Fig. 1, the predicted descent time from the takeoff glideslope to the landing glideslope over the middle marker in a 10-knot wind is given by

$$t = \frac{5700}{6.3\ (1/\tan 6.58^{\circ} - \frac{16.89}{6.3})} = 151 \text{ sec.}$$

Appendix D
WAKE VORTEX TRAJECTORIES

Sample wake vortex trajectories are presented.

P denotes port vortex,

S denotes starboard vortex, and

* denotes a vortex which cannot be identified as port or starboard by the computer algorithm.

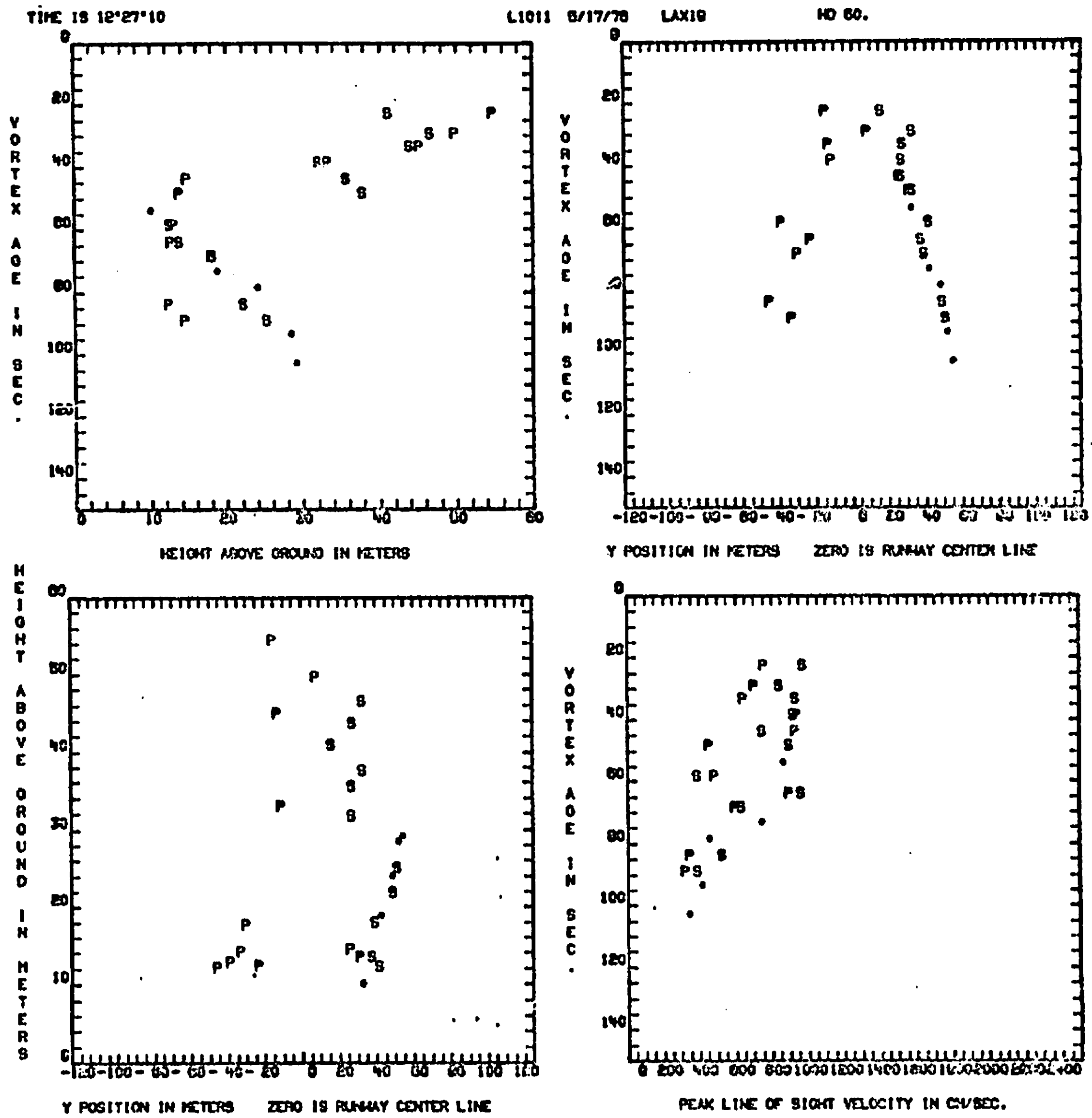

FIGURE D-1. SAMPLE WAKE VORTEX TRAJECTORIES

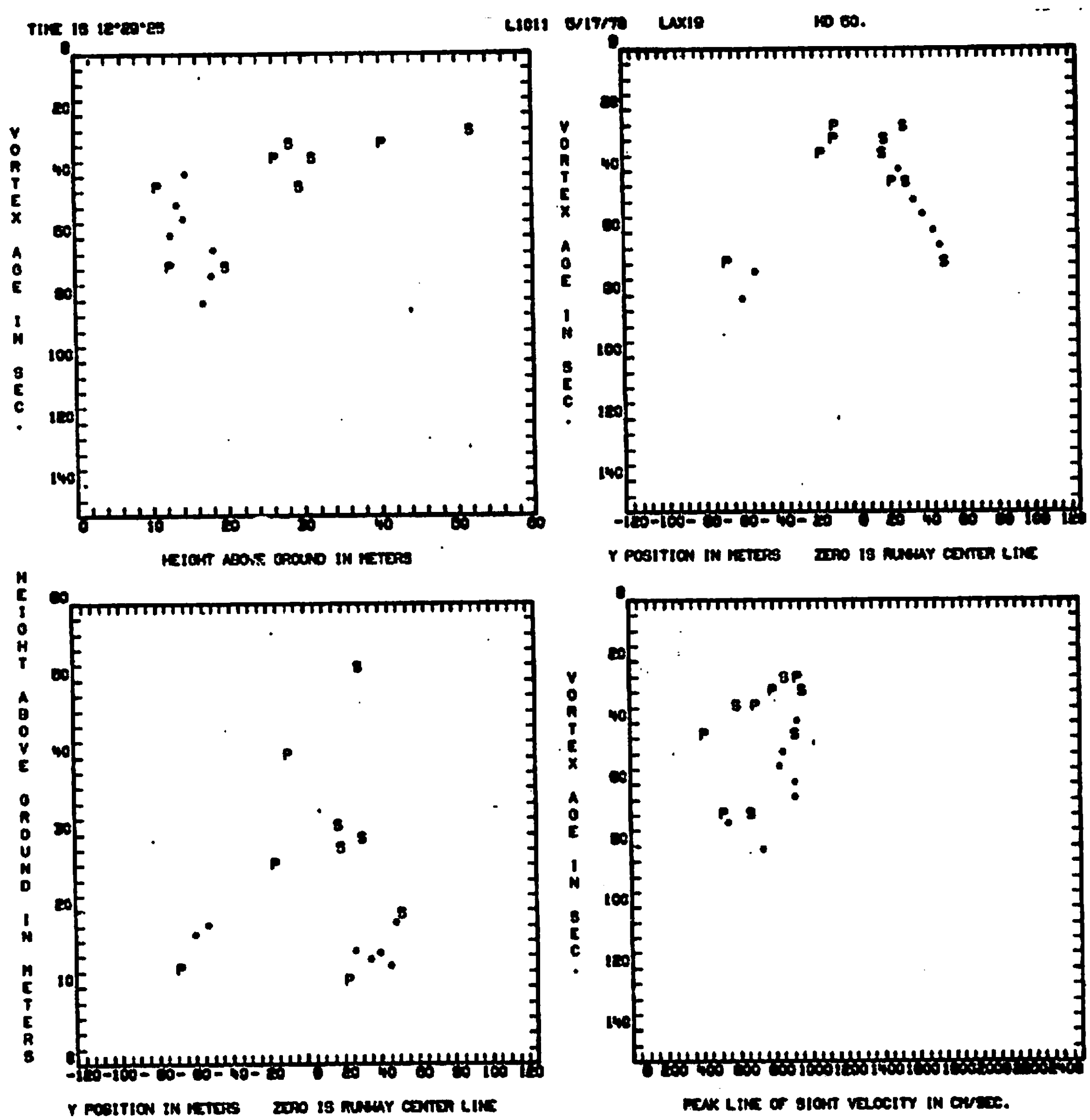

FIGURE D-1. (Continued)

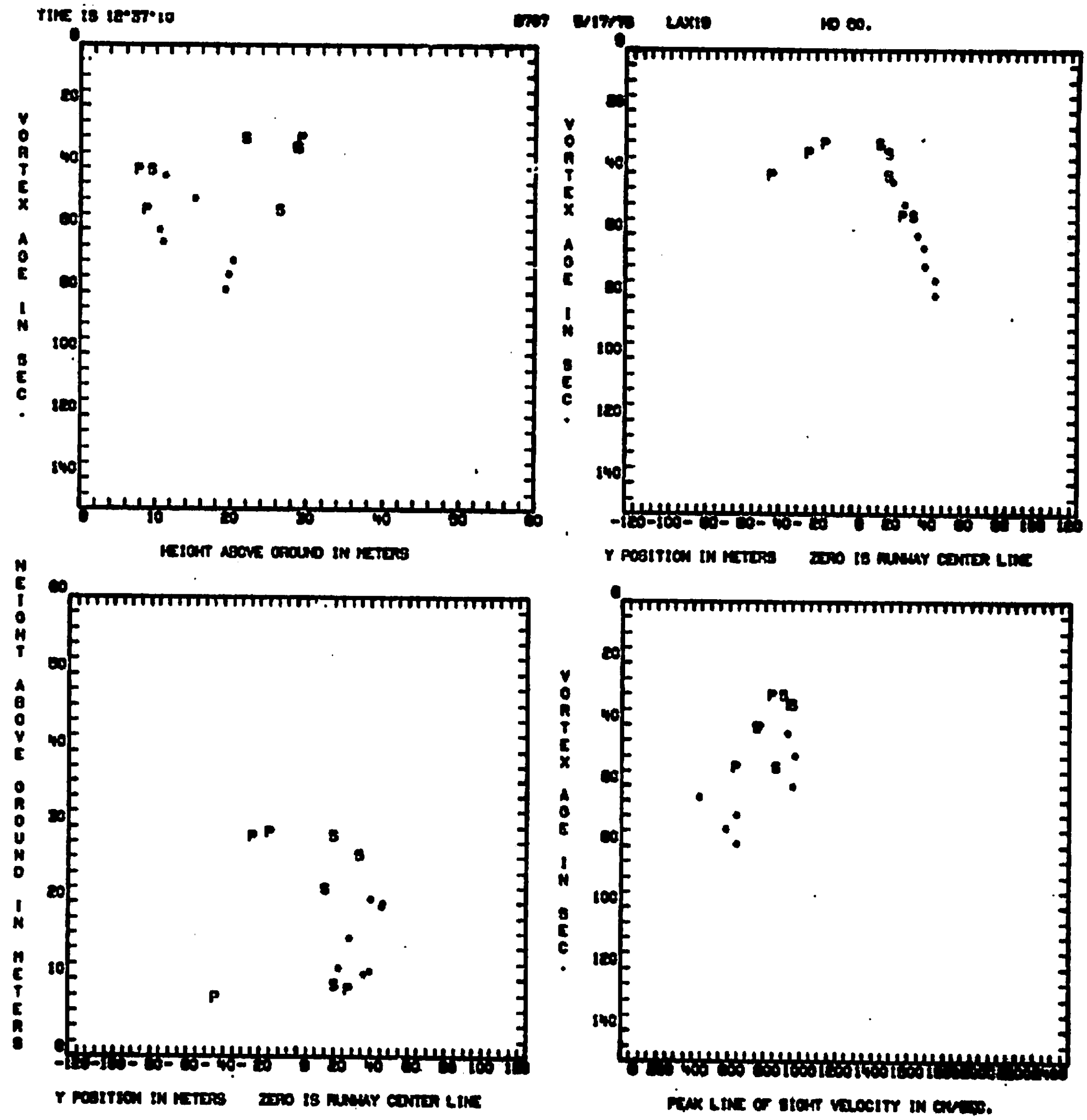

FIGURE D-1. (Continued)

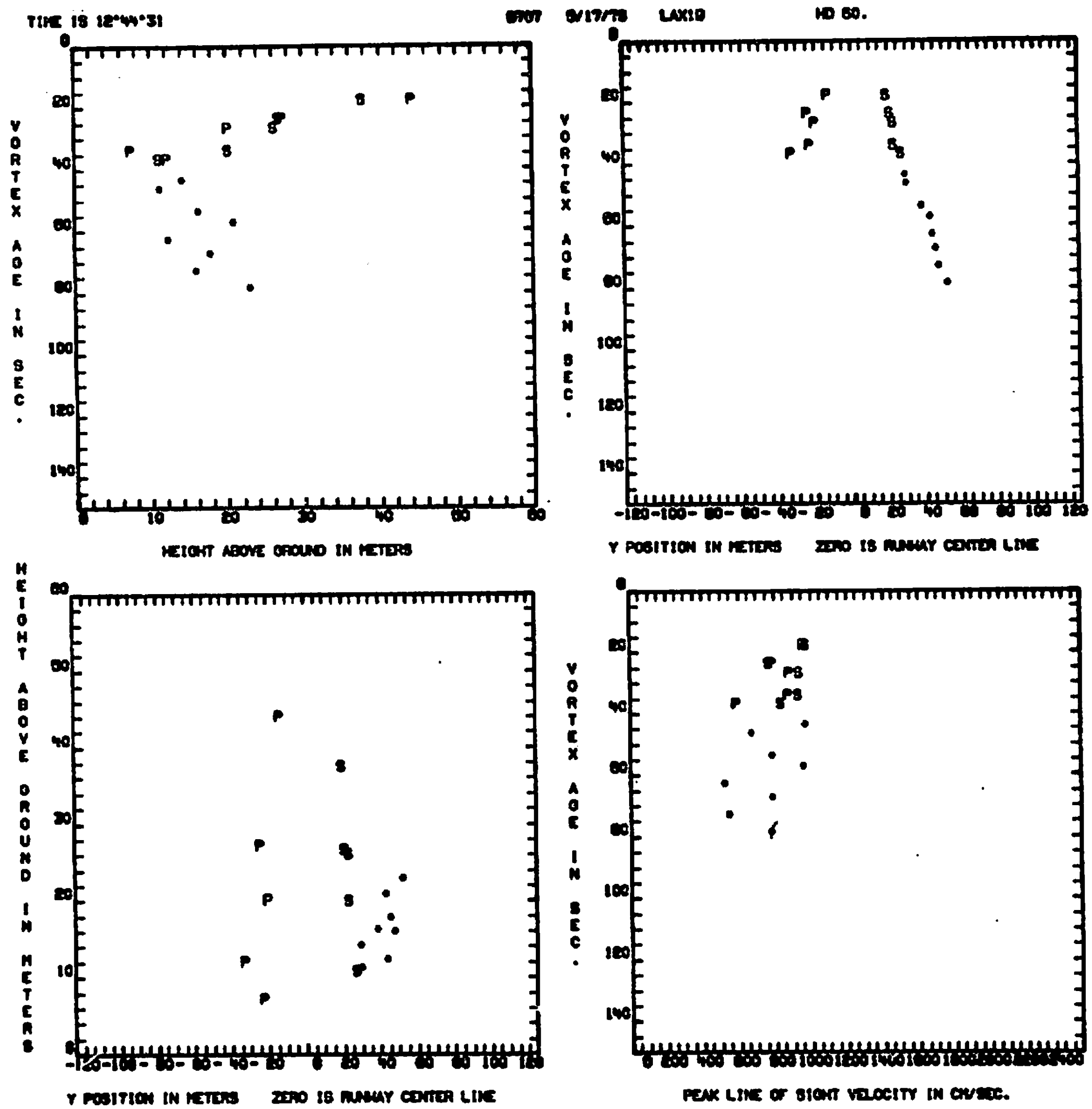

FIGURE D-1. (Concluded)

Appendix E
REPORT OF INVENTIONS

The objective of the work described in this document was the identification of the source(s) of wind anomalies previously reported by pilots at Los Angeles International Airport. The intent of the study was to use state-of-the-art technology to measure a specific phenomenon. Therefore, no innovation, discovery, improvement, or invention was made.

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